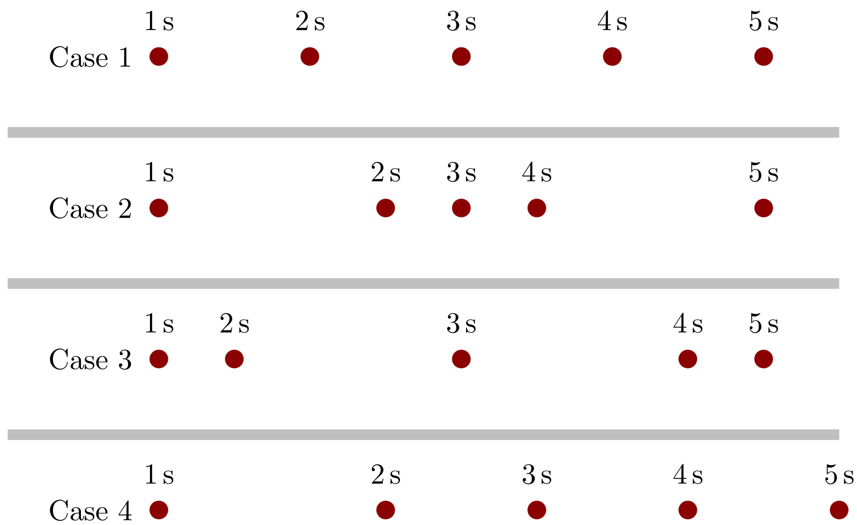
Phys 111: Exercises

One-Dimensional Kinematics

1 Motion diagrams: car slowing and accelerating

A car moves to the right. Earlier in its motion it slows down and later it speeds up. Which of the following (choose one) best represents its location as time passes? *(111F2023)*



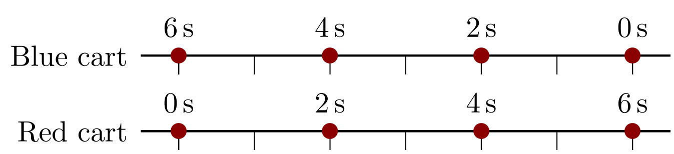
Briefly explain your choice.

2 Drone motion diagram

A drone (unmanned aircraft) hovers at one height above the ground. The drone is subsequently allowed to descend in a straight line toward the ground. It initially descends at an increasing rate, then at a steady rate and, a few feet before the ground, the descent rate decreases. Draw a motion diagram for the drone while it descends. *(111F2023)*

3 Motion diagrams: racing carts

Motion diagrams for two carts are as illustrated. *(111F2023)*

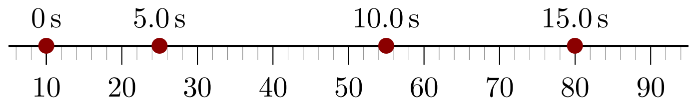


a) Is the speed of the red cart the same as or different to that of the blue cart? Explain your answer.

b) Is the velocity of the red cart the same as or different to that of the blue cart? Explain your answer.

4 Motion diagrams and average velocity

A car moves from left to right and its position, measured in meters, is recorded every 5.0 s. The resulting motion diagram is illustrated. *(111F2023)*



a) Determine the average velocity from 0 s to 5.0 s.

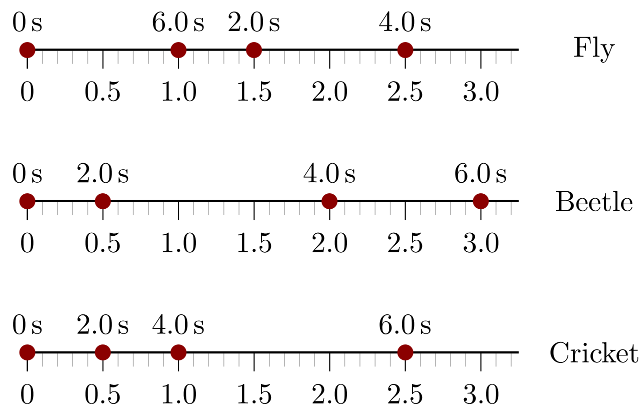
b) Determine the average velocity from 5.0 s to 10.0 s.

c) Determine the average velocity from 5.0 s to 15.0 s.

d) Determine the average velocity from 0 s to 15.0 s. Is this the average of the two velocities in the interval 0 s → 5.0 s and 5.0 s → 15.0 s?

5 Motion diagrams, speed and average velocity

Several insects move along a sraight line and their positions, measured in meters, are recorded every 2.0 s. The resulting motion diagrams are illustrated. *(111F2023)*



a) Rank the insects in order of average speed from 0.0 s to 6.0 s.

b) Rank the insects in order of average velocity from 0.0 s to 6.0 s.

6 Katie Ledecky splits

Katie Ledecky, one of the greatest female swimmers, won the women's 800 m freestyle race at the 2023 World Aquatics Championships. In the final, she covered the first 200 m in 1: 58.29 (means 1 min and 58.29 s), the second 200 m in 2: 03.63, the third 200 m in 2: 04.00 and the final 200 m in 2: 01.50. Determine her average speed for each 200 m section and also the entire race. Which section most resembled her speed for the entire race? *(111F2023)*

7 Bouncing hockey puck

A hockey puck can slide along a horizontal surface. Starting at an initial location, it slides right and takes 3.0 s to hit a board 18 m away. It bounces back to the left and reaches a final point 4.0 m from the board 2.0 s from the time it first hit the board. Determine the average velocity of the puck from the initial to final moments. *(111F2023)*

8 Red car, blue car, green car

Determine the average speed and the average velocity for cars moving in a straight line as follows:

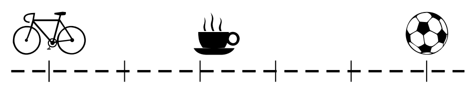
a) Red car moves right for 50 m in 10.0 s.

b) Blue car moves right for 16 m in 8.0 s and then continues right for 34 m in 2.0 s.

c) Red car moves right for 30 m in 5.0 s reverses and moves left for 20 m in 5.0 s. *(111F2023)*

9 Man versus dog

The following objects lie along a straight line: a bicycle, a coffee cup and a soccer ball. The distance from the coffee cup to the bicycle is 400 m and from the cup to the ball is 500 m. A man starts at the cup and travels in a straight line to the ball. This takes 200 s. A dog is initially at the cup and runs at constant speed to the bicycle, taking 50 s to do so. The dog immediately turns around and runs to ball; this takes the dog an additional 150 s. Consider the entire trip from the cup to the ball for each. Who has the larger average velocity for this entire trip? Explain your answer. *(111F2023)*



10 Displacement and average velocity

Various people move as described below over a total interval of 40 s. In each case determine the total displacement and the average velocity over the 40 s period. *(111F2023)*

a) Anna takes a trip in two stages. In the first stage, lasting 20 s, she moves 30 m to the right. In the second stage, lasting 20 s, she moves 10 m to the left.

b) Bill takes a trip in two stages. In the first stage, lasting 10 s, he moves 10 m to the left. In the second stage, lasting 30 s, he moves 30 m to the right.

c) Explain whether displacement and average velocity capture all the information about the motion of each. If not, how might one modify the description of the motion in terms of displacement and velocity to describe the motion more accurately?

11 Average velocity, speed for motion with changing directions

a) A person takes a trip, first walking 30 m to the right in 5.0 s and then returning to his starting point in another 10 s. Determine the average velocity of the person for the entire trip.

b) Anna takes a trip in two stages. First she moves 100 m right in 40 s. She briefly stops and then she moves 120 m to the left in another 60 s. Determine her average velocity for each stage of the trip and also for the entire trip.

c) Bill takes a trip in two stages. First he moves 200 m left in 100 s. He briefly stops and then he moves 150 m to the right in another 100 s. Determine his average velocity for each stage of the trip and also for the entire trip. *(111F2023)*

12 Average velocity and direction of motion

a) An object moves in such a way that during a certain period the average velocity of the object is negative. Is it possible that at the end of the period the object is to the right of the origin of the coordinate system/axis? Explain your answer.

b) An object moves in such a way that over a certain period the average velocity of the object is positive. Is it possible that at some point during the period the object moves to the left? Explain your answer. *(111F2023)*

13 Average velocity and displacement down a field

Three people, Alice, Bob and Charlie leave one end of a 100 m long field at the same instant and travel in the same direction toward the other end. *(111F2023)*

a) Alice travels at a constant speed of 8.0 m/s for half the distance and then at 4.0 m/s for the remaining half. Determine Alice's average velocity for the entire trip.

b) Bob travels at a constant speed of 10.0 m/s for half the distance and then at 2.0 m/s for the remaining half. Determine Bob's average velocity for the entire trip.

c) Charlie travels for half of the time at a constant speed of 8.0 m/s for the remaining half of the time at a constant speed of 4.0 m/s. Determine Charlie's average velocity for the entire trip.

d) Determine the order in which they arrive at the other end of the field.

14 El Capitan climb

The rock climbing route called "The Nose" ascends the El Capitan formation in Yosemite National Park. The elevation gain on the climb is 2900 ft and the quickest ascent took 1 hr, 58 min, 7 s. Determine the average speed for this ascent in m/s. *(111F2023)*

15 Average speed of the Moon

The Moon orbits the Earth in an ellipse with average radius 239,000 miles. It completes one orbit in 27 days, 7 hrs, 43 min, 11.5 s. Suppose that it orbits in a perfect circle with radius 239,000 miles. *(111F2023)*

a) Determine the average speed of the Moon in mph.

b) Determine the average speed of the Moon in m/s.

16 Running speed

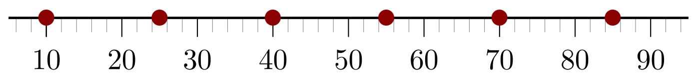
Estimate the speed with which you could run a distance of about 100 yards. Convert your answer to standard metric units. *(111F2023)*

17 Grass growing

Estimate the speed with typical lawn grass that one might find on campus grows. Express your answer in standard metric units. Describe all of the steps that give your estimate. *(111F2023)*

18 Motion diagrams and position vs. time graphs, 1

A car moves from left to right and its position, measured in meters, is recorded every 5.0 s. The resulting motion diagram is illustrated. *(111F2023)*

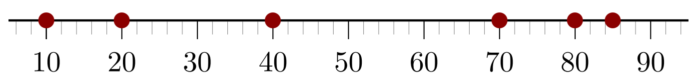


a) Produce a table of numerical data for position versus time for the car for the duration of the motion.

b) Produce a position versus time graph for the car for the duration of the motion. This graph must be drawn by hand using axes that are clearly labeled.

19 Motion diagrams and position vs. time graphs, 2

A car moves from left to right and its position, measured in meters, is recorded every 5.0 s. The resulting motion diagram is illustrated. *(111F2023)*



a) Produce a table of numerical data for position versus time for the car for the duration of the motion.

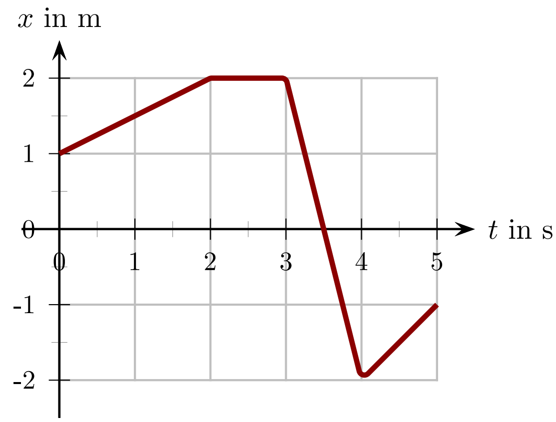
b) Produce a position versus time graph for the car for the duration of the motion. This graph must be drawn by hand using axes that are clearly labeled.

20 Hockey puck trip time

A hockey puck travels along a horizontal surface to the right for a distance of 12 m at speed 5.0 m/s. It hits a board and bounces to the left traveling a distance of 20 m at speed 4.0 m/s. Determine the total time for this trip. *(111F2023)*

21 Angry ant on a stick

An angry ant walks along a straight stick. The graph illustrates the ant's position vs. time. *(111F2023)*



a) Describe in words qualitatively how the ant moves during the period from 0 s to 5 s. Include as much detail without using any numbers.

b) During which period is the ant's speed largest? During which period is it smallest? Explain your answers.

22 Slug on a stick

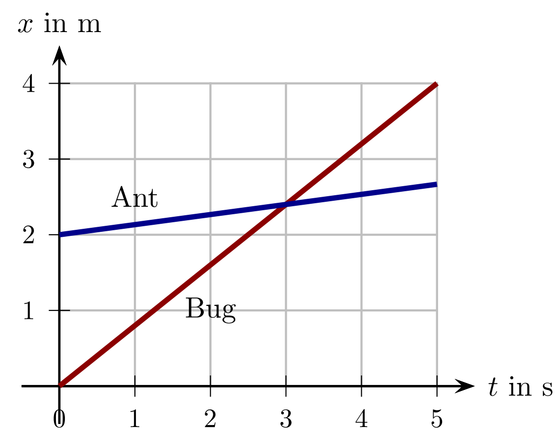
A slug crawls along a straight stick. The graph illustrates the slug's position vs. time. Answer the following, giving explanations for each answer. *(111F2023)*

a) Determine the velocity of the slug at 1.0 s.

b) Determine the velocity of the slug at 4.0 s.

23 Ant and bug on a stick

An ant and a bug walk along a straight stick. The graph illustrates their position vs. time. Answer the following, explaining each answer. *(111F2023)*



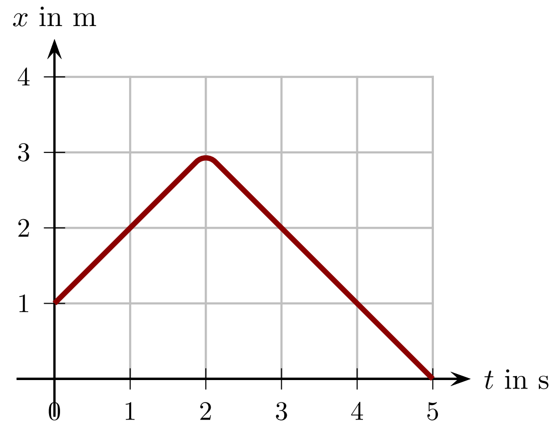
a) When and where, if ever, are the ant and the bug at the same location?

b) When, if ever, do the ant and the bug have the same speed?

c) When, if ever, does the ant move faster than the bug?

24 Ant on a stick

An ant walks along a straight stick. The graph illustrates the ant's position vs. time. Answer the following, giving explanations for each answer. *(111F2023)*



a) During which times is the ant moving right? During which times is it moving left?

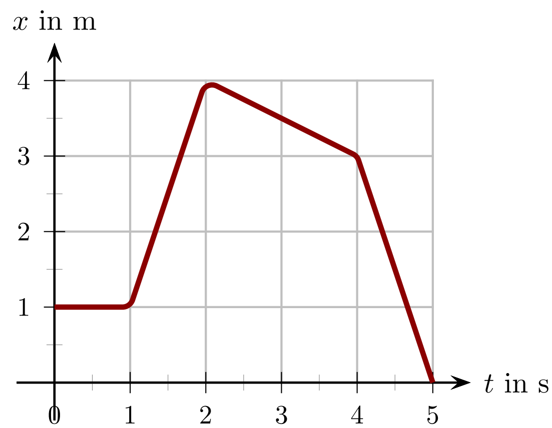
b) When, if ever, is the velocity of the ant 0 m/s?

c) How does the speed of the ant at 1.0 s compare to its speed at 4.0 s?

d) How does the velocity of the ant at 1.0 s compare to its velocity at 4.0 s?

25 Tick on a stick

A tick walks along a straight stick. The graph illustrates the tick's position vs. time. *(111F2023)*



a) Determine the velocity of the tick at 0.5 s.

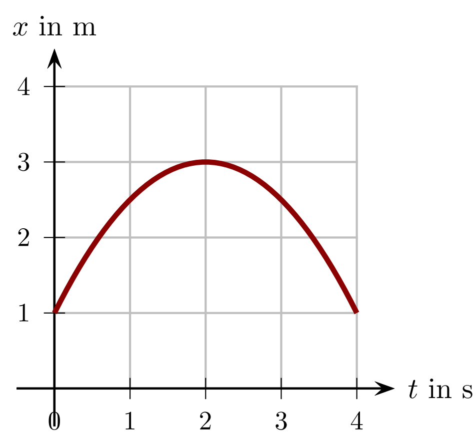
b) Determine the velocity of the tick at 1.5 s.

c) Determine the velocity of the tick at 3.0 s.

d) Determine the velocity of the tick at 4.5 s.

26 Bug on a stick

A bug walks along a straight stick. The graph illustrates the bug's position vs. time. In each of the following, explain your answers. *(111F2023)*



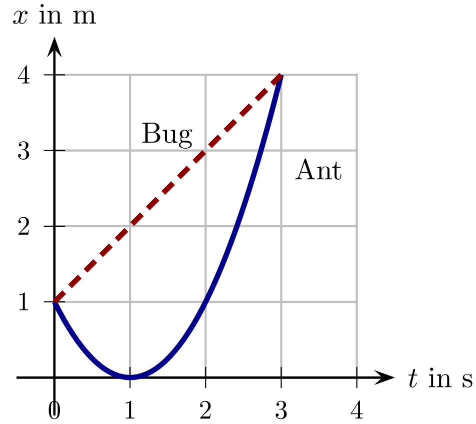
a) Does the bug ever return to the position that it occupied initially ($t = 0\,\text{s}$)? If so, when?

b) Does the bug ever reverse direction? If so when?

c) Does the bug ever have zero velocity? If so, when?

27 Ant and bug on a stick: speeds

An ant and a bug walk along straight sticks. The solid graph illustrates the ant's position vs. time. The dashed graph indicates the bug's position vs. time. Answer the following, giving explanations for each answer. *(111F2023)*



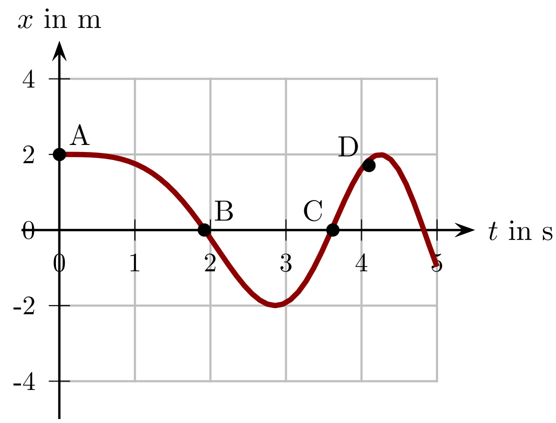
a) At what time(s) are the ant and bug at the same location?

b) Which is moving faster at 2 s?

c) Do the ant and bug ever have the same velocity? If so when?

28 Graceful ladybug on a stick

A ladybug insect walks gracefully back and forth along a straight stick. A graph of position vs. time for its motion is illustrated with several instants labeled A, B, C and D. Explain your answers for the following. *(111F2023)*



a) At which of these moments is the ladybug moving right?

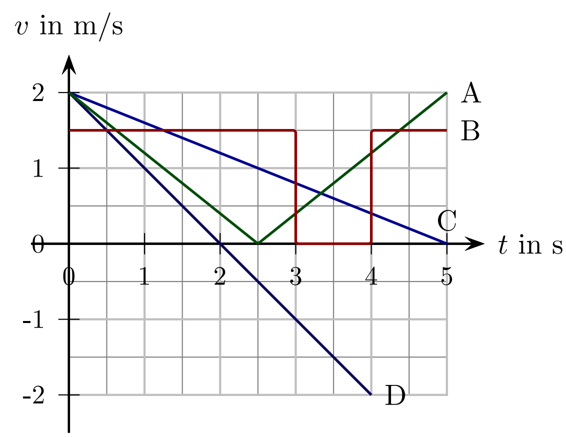
b) At which of these moments is the ladybug slowing down?

c) Rank the moments in order of increasing instantaneous speed.

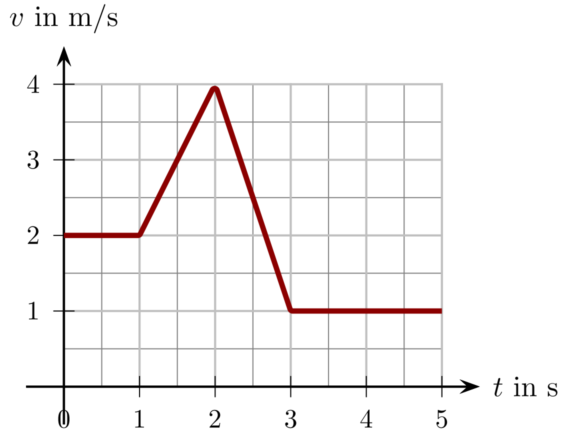
d) Sketch a graph of velocity versus time for the ladybug.

29 Bead sliding along a wire

A bead slides along a straight piece of wire. After an initial moment it slides right with decreasing speed, coming to a brief stop. Immediately after this it slides right with increasing speed. Taking right as positive, which of the following represents a graph of *velocity versus time* for the bead? Explain your choice. *(111F2023)*



30 Wandering ant



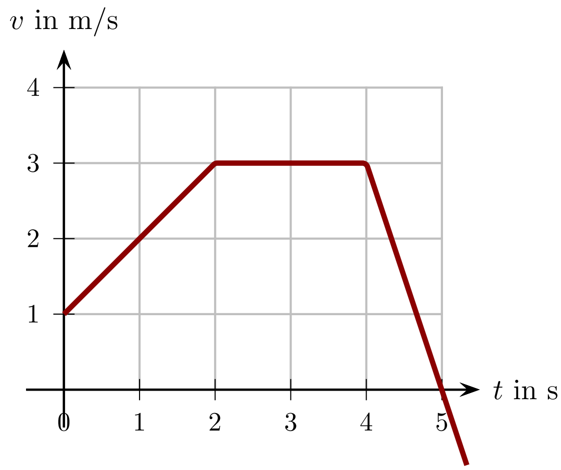
An ant walks along a straight stick. The graph illustrates the ant's velocity vs. time. Answer the following, giving explanations for each answer. *(111F2023)*

a) How does the magnitude of the ant's acceleration at 1.5 s compare (larger, smaller, same) to its acceleration at 2.5 s?

b) How does the magnitude of the ant's acceleration at 0.5 s compare (larger, smaller, same) to its acceleration at 2.5 s?

c) How does the magnitude of the ant's acceleration at 0.5 s compare (larger, smaller, same) to its acceleration at 4.0 s?

31 Accelerating bug on a stick



A bug walks along a straight stick. The graph illustrates the bug's velocity vs. time. At $t = 0\,\mathrm{s}$ the bug is at the $x = 2.0\,\mathrm{m}$ mark. *(111F2023)*

a) Determine the position, velocity and acceleration of the bug at 1.0 s.

b) Determine the position, velocity and acceleration of the bug at 3.0 s.

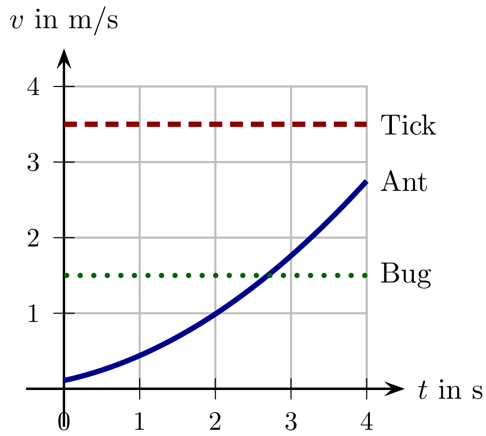
c) Determine the position, velocity and acceleration of the bug at 5.0 s.

32 Cyclist versus skateboarder

A skateboarder moves down a gentle slope. She passes a cyclist, who is at rest and at this moment the skater's speed is 4.0 m/s. At an instant 10 s later the skater's speed is 10.0 m/s and the cyclist's is 8.0 m/s. During this period, who has the greater acceleration? Explain your answer. *(111F2023)*

33 Insects on sticks

An ant, a tick and a bug walk along straight sticks. The solid graph illustrates the ant's velocity vs. time. The dashed graph indicates the tick's velocity vs. time. The dotted line indicates the bug's velocity versus time. *(111F2023)*



a) Which of the following is true during the period from 0s to 4s? Explain your answer.

   i) The acceleration of the ant is the same as that of the tick.
   ii) The acceleration of the tick is always larger than that of the ant.
   iii) The acceleration of the tick is always smaller than that of the ant.
   iv) The acceleration of the tick is sometimes smaller than that of the ant, sometimes larger.

b) Which of the following is true during the period from 0s to 4s? Explain your answer.

   i) The acceleration of the ant is the same as that of the bug.
   ii) The acceleration of the bug is always larger than that of the ant.
   iii) The acceleration of the bug is always smaller than that of the ant.
   iv) The acceleration of the bug is sometimes smaller than that of the ant, sometimes larger.

34 Acceleration sign

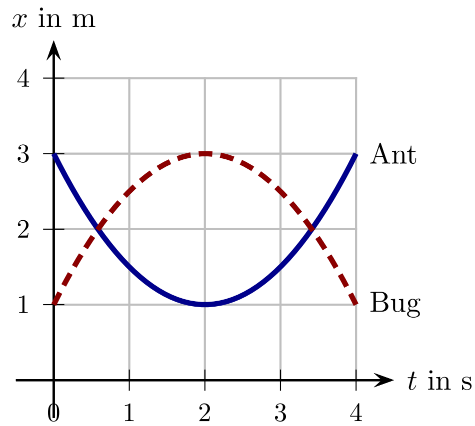
A bicycle can move east (positive) or west (negative). *(111F2023)*

a) If the bicycle moves east can the acceleration be negative? Explain your answer.

b) If the bicycle moves west can the acceleration be positive? Explain your answer.

35 Ant and bug on sticks

An ant and a bug walk along straight sticks. The solid graph illustrates the ant's position vs. time. The dashed graph indicates the bug's position vs. time. *(111F2023)*



a) For the bug and, separately, the ant, which of the following is true during the period from $0s$ to $4s$? Explain your answers.

   i) Velocity is zero at all times.
   ii) Velocity is positive at all times.
   iii) Velocity is negative at all times.
   iv) Velocity is first positive and later negative.
   v) Velocity is first negative and later positive.

b) For the bug and, separately, the ant, which of the following is true during the period from $0s$ to $4s$? Explain your answers.

   i) Acceleration is zero at all times.
   ii) Acceleration is positive at all times.
   iii) Acceleration is negative at all times.
   iv) Acceleration is first positive and later negative.
   v) Acceleration is first negative and later positive.

36 Moving man, 1

A man in an animation walks along a horizontal line. Positions are marked in meters along the line with positive numbers to the right of the origin and negative to the left. His positions and velocities are recorded at equally spaced intervals in time. The data is:

Time in s	Position in m	Velocity in m/s
0.0	-5.00	-4.00
2.0	-7.00	2.00
4.0	3.00	8.00

a) Determine the man's average acceleration from 0.0 s to 2.0 s.

b) Determine the man's average acceleration from 2.0 s to 4.0 s. *(111F2023)*

37 Person walking left and right

A person walks along a horizontal line. Positions are marked in meters along the line with positive numbers to the right of the origin and negative to the left. His velocity is recorded at equally spaced intervals in time. The data is:

Time in s	Velocity in m/s
10.00	−1.00
10.10	−0.80
10.20	−0.60
10.30	−0.40
10.40	−0.20
10.50	0.00
10.60	0.20
10.70	0.40
10.80	0.60
10.90	0.80

a) During which period is the person moving left? During which period is the person moving right?

b) Determine the person's acceleration while moving left.

c) Determine the person's acceleration while moving right.

d) Does the person's acceleration appear to change during the period from 10.10 s to 10.90 s?

e) At what moment does the person reverse direction? According to the data is the acceleration zero or not at this moment? *(111F2023)*

38 Bungee jumper

A bungee jumper falls downward stretching the cord, reaching a low point, after which the cord pulls him up again. His velocity is recorded at equally spaced intervals in time. The data is:

Time in s	Velocity in m/s
10.0	−20.0
10.5	−15.0
11.0	−10.0
11.5	−5.0
12.0	0.0
12.5	5.0
13.0	10.0
13.5	15.0
14.0	20.0

a) During which period is the man falling? When is he rising?

b) By how much does the man's velocity change per second? Is this change constant throughout the recorded motion?

c) Determine the man's acceleration while he is falling and also while he is rising. Are these accelerations the same or not?

d) What is the man's acceleration (according to the data) at his low point? *(111F2023)*

39 Moving man activity

Go to the moving man animation at:

http://phet.colorado.edu/en/simulation/moving-man

Run the moving man animation. Click on the charts tab. Set the position to 0.00 m, the velocity to $-5.00\,\mathrm{m/s}$ and the acceleration to $2.00\,\mathrm{m/s^2}$. Run the animation, stopping it just before the man hits the wall. The animation will have recorded the motion. Check the playback button at the bottom. You can slide the light blue bar left and right to get data for the motion. Gray zoom icons at the right will let you rescale the charts. *(111F2023)*

a) Consider the interval from 2.0 s to 3.0 s. Describe the motion verbally during this time.

b) How does the speed of the man at 2.0 s compare to that at 3.0 s? Explain your answer.

c) How does the velocity of the man at 2.0 s compare to that at 3.0 s? Explain your answer.

d) Will the average acceleration over the interval from 2.0 s to 3.0 s be positive, negative or zero? Explain your answer.

e) If the acceleration is not zero, does it vary during this interval? Explain your answer.

f) Determine the average acceleration over the interval from 2.0 s to 3.0 s.

40 Person moving with constant acceleration

A person is initially at rest and subsequently moves right with a constant acceleration. The person's reaches speed $6.0\,\mathrm{m/s}$ at a point $9.0\,\mathrm{m}$ to the right of the starting location. The aim of this exercise will be to determine the time taken to reach this point. A first step will be to determine the acceleration of the person. *(111F2023)*

a) Sketch the situation, illustrating the person at the two instants described above.

List all relevant variables for the two instants:

$t_{\mathrm{i}} =$	$t_{\mathrm{f}} =$
$x_{\mathrm{i}} =$	$x_{\mathrm{f}} =$
$v_{\mathrm{i}} =$	$v_{\mathrm{f}} =$

b) Determine the acceleration by selecting one of the kinematic equations, substituting and solving for a.

c) Using a different kinematic equation, find the time that it takes the person to reach speed $6.0\,\mathrm{m/s}$.

d) Suppose that you had tried to find the time taken to reach speed $6.0\,\mathrm{m/s}$ by using

$$v = \frac{\Delta x}{\Delta t} \Rightarrow 6.0\,\mathrm{m/s} = \frac{9.0\,\mathrm{m}}{\Delta t}.$$

What time does this give? Does it agree with the answer that you obtained to the previous part? Is it correct?

41 Avoid the wall!

A skateboarder slides toward a wall. Initially the skateboarder is 18 m left of the wall and moving with speed 6.0 m/s to the right. The aim of this exercise will be to determine the minimum acceleration to barely avoid hitting the wall. *(111F2023)*

a) Sketch the situation, illustrating the skateboarder at the initial instant and the instant just before reaching the wall.

   List all relevant variables for the two instants:

$$t_{\mathrm{i}} = \qquad\qquad t_{\mathrm{f}} =$$
$$x_{\mathrm{i}} = \qquad\qquad x_{\mathrm{f}} =$$
$$v_{\mathrm{i}} = \qquad\qquad v_{\mathrm{f}} =$$

b) Determine the acceleration by selecting one of the kinematic equations, substituting and solving for a.

c) Use one of the kinematic equations to determine the time that it takes for the skateboarder to reach the wall.

d) Would the equation

$$v = \frac{\Delta x}{\Delta t} \quad \Rightarrow \quad 6.0\,\mathrm{m/s} = \frac{18\,\mathrm{m}}{\Delta t}$$

   allow one to find the time taken to reach the wall correctly? Why or why not?

e) Set up the moving man animation at:

   http://phet.colorado.edu/en/simulation/moving-man

   and run this to check your prediction. In order to verify that you have done this, use the animation to provide the times at which the man is 10 m to the left of the wall.

42 Braking car, 1

A car travels to the right with speed 30.0 m/s (about 67 mph). The car brakes and slows to a stop with constant acceleration. It does this in a distance of 80.0 m (about 260 ft). The aim of this exercise is to find the time taken to do this. *(111F2023)*

a) Sketch the situation, illustrating the car at two key instants.

   List all relevant variables for the two instants:

b) Determine the acceleration using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for a. (is acceleration positive or negative?)

   Answer: $-5.63\,ms^2$

c) Using a different kinematic equation, find the time that it takes the car to stop. Write down the equation, substitute from your list of variables and solve for time.

   Answer: $5.33\,s$

43 Braking car, 2

A car travels to the right with speed 24.6 m/s (about 55 mph). The car brakes, coming to a stop in 50 m (about 165 ft). The acceleration during the braking process is constant. *(111F2023)*

a) Determine the acceleration of the car while it brakes.

b) Determine the time taken for the car to stop.

44 Accelerating aircraft

An aircraft accelerates from rest to a speed of 120.0 m/s. It does this with a constant acceleration of 4.00 m/s^2. The aim of this exercise is to find the distance traveled by the aircraft during this process. *(111F2023)*

a) Sketch the situation, illustrating the aircraft at two key instants. List all relevant variables for the two instants and list the acceleration.

b) Determine the distance traveled by the aircraft using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for the relevant variable.

   Answer: $1800\,m$

c) Using a different kinematic equation, find the time that it takes for the aircraft to reach this speed. Write down the equation, substitute from your list of variables and solve for time.

   Answer: $30\,s$

d) Would it have worked to use $v = \frac{\Delta x}{\Delta t} \Rightarrow 120.0\,\mathrm{m/s} = \frac{1800\,\mathrm{m}}{\Delta t}$?

45 Accelerating cart

A cart travels in one direction. At an initial instant it passes the 4.0 m mark while traveling to the right with speed 15 m/s. *(111F2023)*

a) Determine the location of the cart at an instant 6.0 s later if its acceleration is 3.0 m/s^2.

b) Determine the location of the cart at an instant 6.0 s later if its acceleration is -3.0 m/s^2.

46 Accelerating shrew

A shrew (a small mammal) travels in one direction. At an initial instant it travels to the right with speed 3.0 m/s. It subsequently moves with constant acceleration and after traveling an additional 2.0 m to the right it reaches a speed of 7.0 m/s. Determine the time taken to do this. *(111F2023)*

47 Moving sloth

A sloth (a tree-climbing mammal) travels along a straight branch. At an initial instant it travels to the right with speed $3.0\,\mathrm{m/s}$. It subsequently crawls with constant acceleration and after an additional $2.0\,\mathrm{s}$ has traveled an additional $4.0\,\mathrm{m}$ to the right. Determine its speed at the end of this period. *(111F2023)*

48 Reversing cart

At an initial instant a cart travels to the left with speed $12\,\mathrm{m/s}$. Subsequently the cart's acceleration is $4.0\,\mathrm{m/s^2}$. *(111F2023)*

a) How long does it take for the cart to reverse its direction of travel?

b) How far does the cart travel before it reverses its direction of travel?

49 Racing cyclists

Two cyclists can ride along a straight road. Juliette moves right with a constant speed of $20\,\mathrm{m/s}$. She passes Elisa, who is at rest. At the moment that Juliette passes, Elisa begins to move, accelerating at a constant rate of $2.0\,\mathrm{m/s^2}$. Elisa maintains this for $12.0\,\mathrm{s}$ and after that she moves with constant velocity. *(111F2023)*

a) Explain how you can be sure that Elisa eventually passes Juliette.

b) Determine the time (after Elisa starts to move) that it takes Elisa to catch up to Juliette.

c) Determine the distance traveled by each when Elisa catches up with Juliette.

50 Runway design, 1

The takeoff speed for an aircraft under certain conditions is $260\,\mathrm{km/h}$. During takeoff, one wants the acceleration to be as low as possible. *(111F2023)*

a) Suppose that the runway has length $1500\,\mathrm{m}$. Determine the aircraft's minimum acceleration so that it can take off on this runway.

b) Suppose that the acceleration is only $0.20g = 1.96\,\mathrm{m/s^2}$. Determine the minimum length of the runway so that the aircraft could take off successfully.

Note: It is useful to describe acceleration in terms of g as this is correlated to what humans can feel. An acceleration of g is what you feel when jumping off a diving board. An acceleration of around $6g$ will cause a person to blackout.

51 Aircraft takeoff acceleration

The takeoff speed for an aircraft under certain conditions is 260 km/h. A typical runway has length 3500 m. *(111F2023)*

a) Suppose that the aircraft starts at rest somewhere along the runway and uses 2/3 of the runway length to takeoff. Determine the acceleration of the aircraft, assuming that it is constant.

b) It is useful to describe acceleration in terms of g as this is correlated to what humans can feel. An acceleration of g is what you feel when jumping off a diving board. An acceleration of around $6g$ will cause a person to blackout. What factor of g is the aircraft's acceleration?

c) Determine the fraction of the runway that the aircraft would have to use so that the acceleration were g.

52 Jumping cat

A cat jumps, launching itself vertically. During it's subsequent motion up and down, air resistance is negligible. In the following let the upward direction be positive. *(111F2023)*

a) Which of the following is true in the period after the cat's feet have left the ground and before the cat reaches its highest point above the ground?

   i) Acceleration is zero at all times.
   ii) Acceleration is positive at all times.
   iii) Acceleration is negative at all times.

b) Which of the following is true in the period while the cat drops back to the ground?

   i) Acceleration is zero at all times.
   ii) Acceleration is positive at all times.
   iii) Acceleration is negative at all times.

c) Which of the following is true when the cat is at is highest point above the ground?

   i) Acceleration is zero at all times.
   ii) Acceleration is positive at all times.
   iii) Acceleration is negative at all times.

53 Ball launched vertically

A ball is launched vertically from Earth's surface with speed 10 m/s. The aim of the first part of this exercise is to determine the maximum height reached by the ball and time taken to reach the maximum height. *(111F2023)*

a) Sketch the situation, illustrating the ball at two key instants.
   List all relevant variables, including the acceleration, for the two instants:

b) Determine the maximum height reached by the ball by using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for the maximum height variable.
   Answer: $5.1\,m$

c) Determine the time taken to reach the maximum height by using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for the maximum height variable.
   Answer: $1.0\,s$

The second part of this exercise aims to find the speed of the ball just before returning to the ground using the fall from its maximum height.

d) Sketch the situation for the falling ball, illustrating the ball at two key instants.
   List all relevant variables, including the acceleration, for the two instants:

e) Determine the speed of the ball just before hitting the ground the ball by using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for the velocity variable.
   Answer: *velocity:* $-10\,m/s$, *speed:* $10\,m/s$.

54 Ball maximum height

A ball is launched vertically upward from Earth's surface with speed 25 m/s. *(111F2023)*

a) Determine the maximum height reached by the ball.

b) Determine the speed of the ball when it is 16 m above Earth's surface.

55 Parachuting package

A package is released from rest at a height of 100 m above Earth's surface. It falls freely until it is 40 m above Earth's surface. At that instant it deploys a parachute and after this is falls with a constant speed. The aim of this exercise is to determine the time taken to reach Earth.

To do this we will calculate the time taken for the free fall motion, Δt_A, and separately that time taken to fall with the parachute open, Δt_B.

The aim of the first part of this exercise is to determine Δt_A. *(111F2023)*

a) Sketch the situation, illustrating the ball at two key instants that will allow one to determine the time for the free fall portion of the motion.

   List all relevant variables for the two instants and the acceleration.

b) Determine Δt_A by using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for Δt_A.

   Answer: $3.5\,s$.

The second part of this exercise aims to find Δt_B.

c) Sketch the situation for the falling ball, illustrating the ball at two key instants that will allow one to determine the time for the parachuting portion of the motion.

   List all relevant variables for the two instants and the acceleration.

d) There is one quantity that one can obtain from the free fall part of the motion that will be needed to analyze the parachuting portion of the motion. Identify and compute this and insert it in to the list of variables from the previous part.

e) Now determine Δt_B by using one of the kinematic equations. Write down the equation, substitute from your list of variables and solve for Δt_B.

   Answer: $1.2\,s$.

f) Determine the total time taken to fall.

   Answer: $4.7\,s$.

56 Thrown rock

A rock is thrown vertically down from a bridge. It leaves the hand with speed 20 m/s and hits the water 15 m below. Determine its speed at the instant before it hits the water. *(111F2023)*

Answer: $26\,m/s$

57 Ball thrown from above the ground, 1

A ball is thrown vertically upwards, leaving the hand at a height of 1.2 m above the ground. It hits the ground 2.5 s after leaving the hand. *(111F2023)*

a) Determine the speed with which the ball left the hand.

b) Determine the maximum height above the ground reached by the ball.

58 Ball thrown from above the ground, 2

A ball is thrown vertically upwards, leaving the hand with speed 4.0 m/s at a height of 1.2 m above the ground. Determine the speed of the ball just before it hits the ground. *(111F2023)*

59 Diver

A diver stands on a diving board that is 10 m above the surface of the water. The diver launches herself vertically up, leaving the board with a speed of 5.0 m/s. *(111F2023)*

a) Determine the time taken for the diver to hit the water. ***Answer:*** $2.0\,s$

b) Determine the diver's speed when she hits the water. ***Answer:*** $15\,s$

60 Jumping flea

A flea is at rest on a bed and launches itself vertically. A child watching this thinks that the flea is airborne for a total time of about 2 s. Determine the maximum height above the bed that the flea would reach if this were true. Ignore air resistance. Is it plausible that the flea could have been airborne for that long? What might be a more realistic range of times? *(111F2023)*

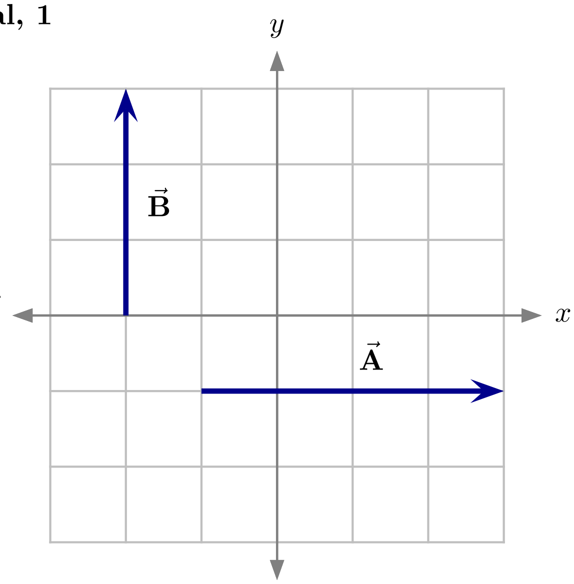
61 Penny and a well

A penny is held at rest at the top of a well. The penny is released, falls freely and takes 1.75 s to hit the water below. Determine the depth (distance from the top to the water) of the well. *(111F2023)*

Answer: $15\,m$

Vectors

62 Vector addition and subtraction: graphical, 1

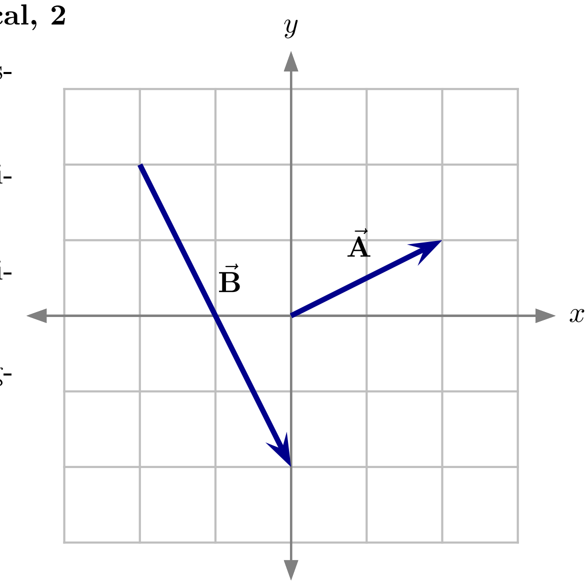


Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$, are illustrated. *(111F2023)*

a) Sketch $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

b) Let A be the magnitude of $\vec{\mathbf{A}}$, let B be the magnitude of $\vec{\mathbf{B}}$ and C be the magnitude of $\vec{\mathbf{C}}$. In this case, do these magnitudes satisfy $C = A + B$? Explain your answer.

63 Vector addition and subtraction: graphical, 2



Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$, are illustrated. *(111F2023)*

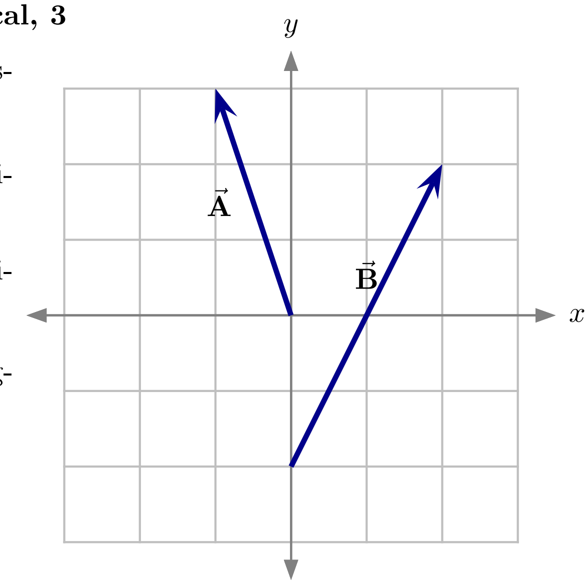
a) Sketch $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

b) Sketch $\vec{\mathbf{C}} = \vec{\mathbf{A}} - \vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

c) Sketch $\vec{\mathbf{C}} = 2\vec{\mathbf{A}} - \dfrac{1}{2}\vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

64 Vector addition and subtraction: graphical, 3

Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$, are illustrated. *(111F2023)*



a) Sketch $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

b) Sketch $\vec{\mathbf{C}} = \vec{\mathbf{A}} - \vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

c) Sketch $\vec{\mathbf{C}} = 2\vec{\mathbf{A}} - \frac{1}{2}\vec{\mathbf{B}}$. Determine the magnitude and direction of $\vec{\mathbf{C}}$.

65 Vector algebra: conceptual

Consider two vectors labeled $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$. *(111F2023)*

a) Suppose that $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are perpendicular. Explain whether it is possible that $\vec{\mathbf{A}} - \vec{\mathbf{B}} = 0$.

b) Suppose that the magnitudes satisfy $B = 2A$. Let $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. Explain whether it is possible that the magnitude of $\vec{\mathbf{C}}$ satisfies $C = A$. Explain whether it is possible that the magnitude of $\vec{\mathbf{C}}$ satisfies $C = 2A$.

66 Adding two vectors

Consider displacement vectors $\vec{\mathbf{A}}$, whose magnitude is 4.0 m, and $\vec{\mathbf{B}}$, whose magnitude is 3.0 m. Their directions are not specified. Let $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. *(111F2023)*

a) What is the maximum possible magnitude for $\vec{\mathbf{C}}$? How must the vectors be arranged to give this?

b) What is the minimum possible magnitude for $\vec{\mathbf{C}}$? How must the vectors be arranged to give this?

67 Vector components: conceptual

Consider a vector $\vec{\mathbf{A}}$ in two dimensions. *(111F2023)*

a) Is it possible that either A_x or A_y is larger than the magnitude, A? Explain your answer.

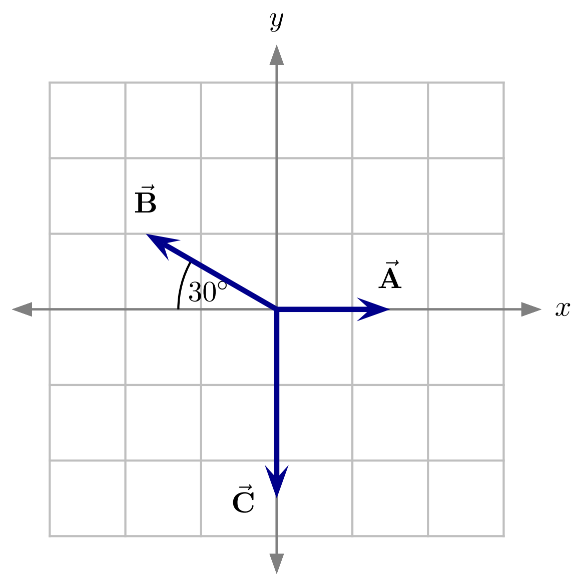
b) Is it possible that both components of $\vec{\mathbf{A}}$ can be non-zero and the magnitude of $\vec{\mathbf{A}}$ is zero? Explain your answer.

68 Vector components: algebraic, 1

Displacement vectors, $\vec{\mathbf{A}}, \vec{\mathbf{B}}$, and $\vec{\mathbf{C}}$ are illustrated. Their magnitudes are $A = 15\,\text{m}, B = 20\,\text{m}$ and $C = 25\,\text{m}$. *(111F2023)*

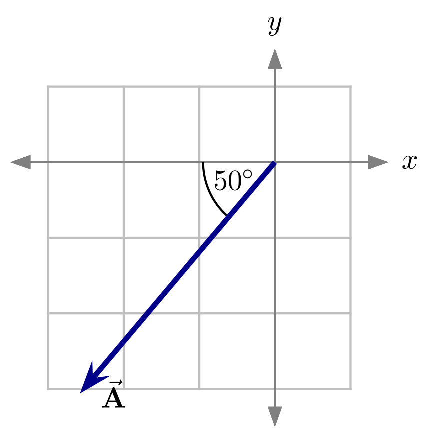
a) Determine the x and y components of each vector.

b) Determine the components of $\vec{\mathbf{D}} = \vec{\mathbf{A}} + \vec{\mathbf{B}} + \vec{\mathbf{C}}$.



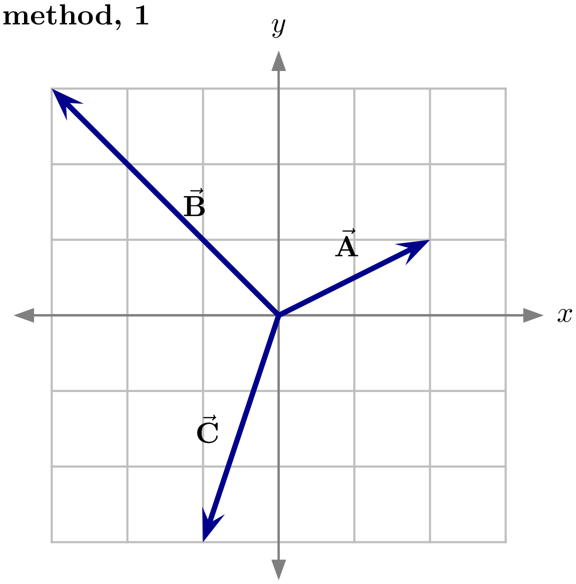
69 Vector components: algebraic, 2

Determine the components of $\vec{\mathbf{A}}$, whose magnitude is $20.0\,\text{m}$. *(111F2023)*



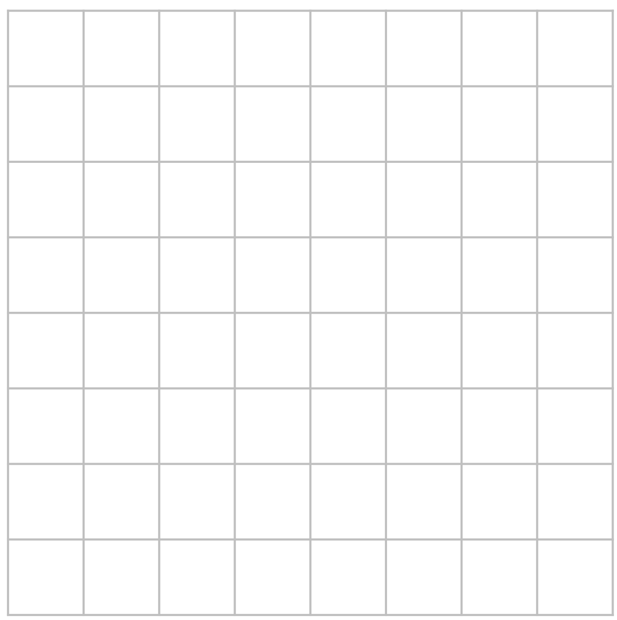
70 Vector addition: graphical and algebraic method, 1

Displacement vectors, $\vec{\mathbf{A}}, \vec{\mathbf{B}}$, and $\vec{\mathbf{C}}$ are illustrated. Let $\vec{\mathbf{D}} = \vec{\mathbf{A}} + \vec{\mathbf{B}} + \vec{\mathbf{C}}$. *(111F2023)*



a) Using the graph sheet below, determine $\vec{\mathbf{D}}$ graphically via the head–to–tail method. Use the result to determine the magnitude of $\vec{\mathbf{D}}$.

b) List the horizontal and vertical components of each of $\vec{\mathbf{A}}, \vec{\mathbf{B}}$, and $\vec{\mathbf{C}}$ and use these components to determine the components of $\vec{\mathbf{D}}$. Use the result to determine the magnitude of $\vec{\mathbf{D}}$.



71 Vector addition: algebraic method, 1

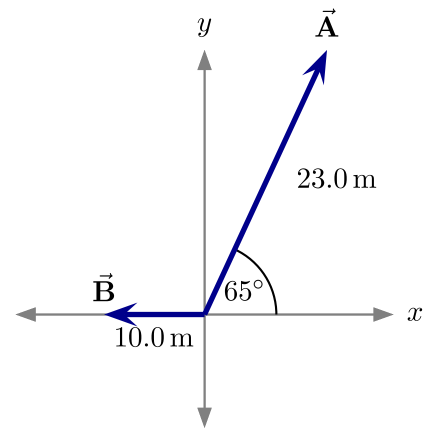
Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are illustrated. *(111F2023)*

a) Determine the components of $\vec{\mathbf{A}}$.

b) Determine the components of $\vec{\mathbf{B}}$.

c) Determine the components of $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$.

d) Determine the magnitude of $\vec{\mathbf{C}}$.



72 Vector addition: algebraic method, 2

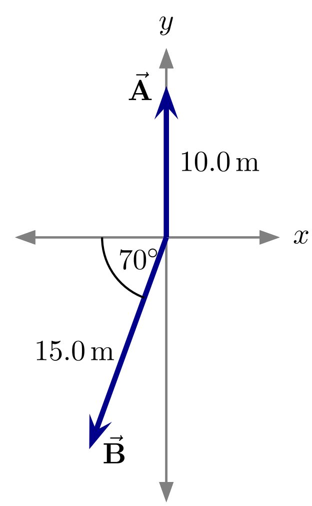
Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are illustrated. *(111F2023)*

a) Determine the components of $\vec{\mathbf{A}}$.

b) Determine the components of $\vec{\mathbf{B}}$.

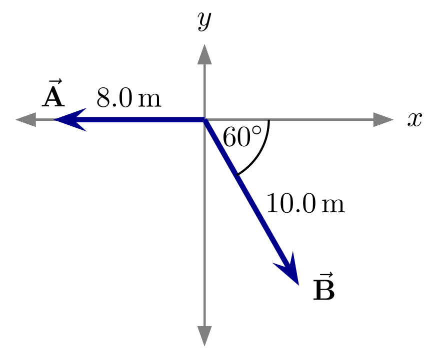
c) Determine the components of $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$.

d) Determine the magnitude of $\vec{\mathbf{C}}$.



73 Vector addition: algebraic method, 3

Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are illustrated. Determine the magnitude of $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. *(111F2023)*

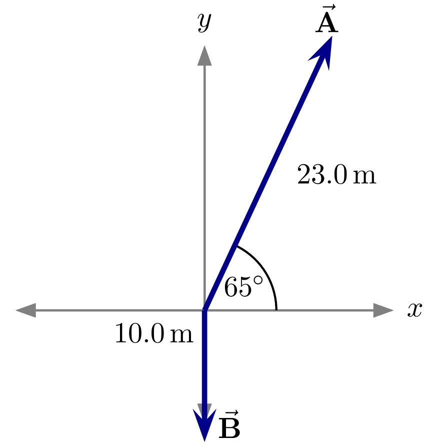


74 Vector addition: algebraic method, 4

Two displacement vectors, $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are illustrated. *(111F2023)*

a) Determine the components of $\vec{\mathbf{C}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$.

b) Determine the magnitude of $\vec{\mathbf{C}}$.



75 Vector algebra using components

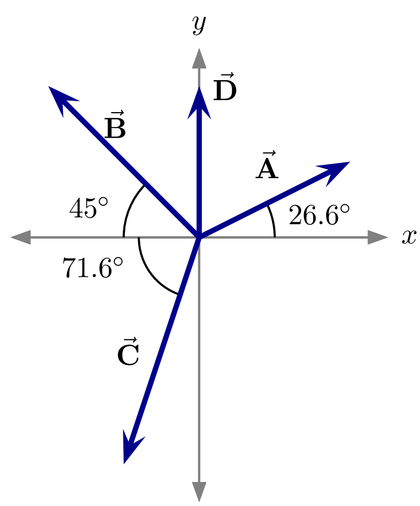
Displacement vectors, $\vec{\mathbf{A}}, \vec{\mathbf{B}}, \vec{\mathbf{C}}$, and $\vec{\mathbf{D}}$ are illustrated. Their magnitudes are $A = 2.0\,\mathrm{m}, B = 2.5\,\mathrm{m}, C = 3.0\,\mathrm{m}$ and $D = 1.5\,\mathrm{m}$. *(111F2023)*

a) Determine the x and y components for each vector.

b) Determine the x and y components for $\vec{\mathbf{E}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$. Determine the magnitude of $\vec{\mathbf{E}}$.

c) Determine the x and y components for $\vec{\mathbf{E}} = \vec{\mathbf{B}} + \vec{\mathbf{C}}$. Determine the magnitude of $\vec{\mathbf{E}}$.

d) Determine the x and y components for $\vec{\mathbf{E}} = \vec{\mathbf{B}} + \vec{\mathbf{D}}$. Determine the magnitude of $\vec{\mathbf{E}}$.



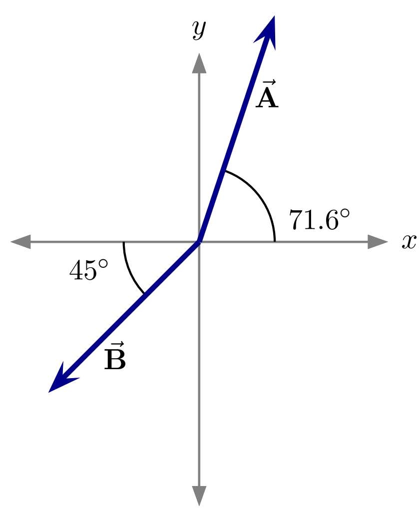
e) Determine the x and y components for $\vec{\mathbf{E}} = \vec{\mathbf{B}} + \vec{\mathbf{C}} + \vec{\mathbf{D}}$. Determine the magnitude of $\vec{\mathbf{E}}$.

76 Vector subtraction using components

Displacement vectors, $\vec{\mathbf{A}}, \vec{\mathbf{B}}$ are illustrated. Their magnitudes are $A = 3.16\,\mathrm{m}$ and $B = 2.83\,\mathrm{m}$. *(111F2023)*

a) Determine the components of $\vec{\mathbf{C}} = \vec{\mathbf{A}} - \vec{\mathbf{B}}$. Determine the magnitude of $\vec{\mathbf{C}}$.

b) Determine the components of $\vec{\mathbf{C}} = 4\vec{\mathbf{A}} - 3\vec{\mathbf{B}}$. Determine the magnitude of $\vec{\mathbf{C}}$.

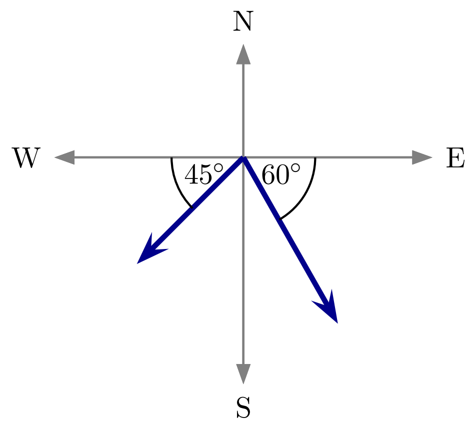


77 Marching soldier

A soldier marches around a playing field whose edges are along North-South (N-S) and East-West (E-W) lines. The soldier starts in the southwest corner, marches in a straight line in the direction 30° N of E for 40 m. He then marches straight south for 12 m. Finally he marches in a a straight line in the direction 50° N of W for 30 m. After this, how far is the soldier from his starting point? *(111F2023)*

78 Successive displacements

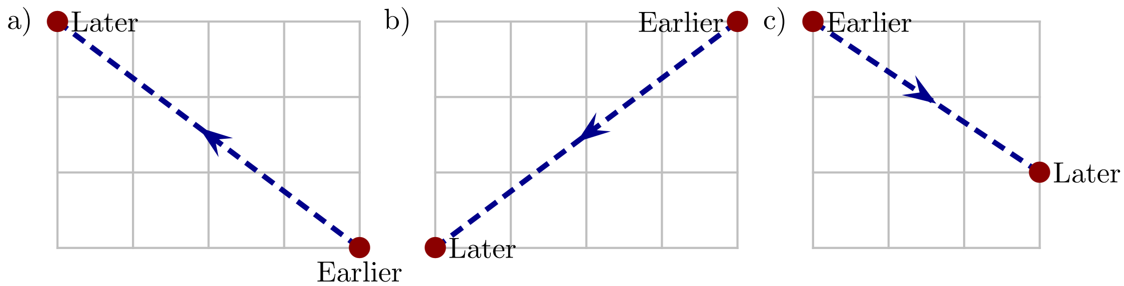
An insect crawls along a horizontal two dimensional surface in two straight stages. First the insect walks 8.0 cm at an angle of 45° south of west. Second, the insect walks 10.0 cm in a straight line at an angle 60° south of east. Determine an expression for the displacement of the insect and how far the insect ends up from its starting point. *(111F2023)*



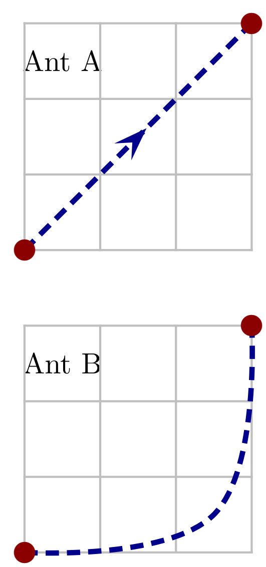
Two dimensional kinematics

79 Velocity vectors from motion

Particles move along the illustrated trajectories. Their locations are illustrated at instants 4.0 s apart. The grid units are meters. For each case determine the average velocity vector for the particle over the entire interval and express it in terms of the conventional unit vectors. *(111F2023)*



80 Ants on a table



Two ants move on a flat surface between two grains of sugar. Their trajectories are illustrated. The ants take the same time to move between the grains but follow different trajectories. Which of the following is true about the average velocities of the ants for the entire trip? Explain your answer. *(111F2023)*

i) The average velocities are the same.

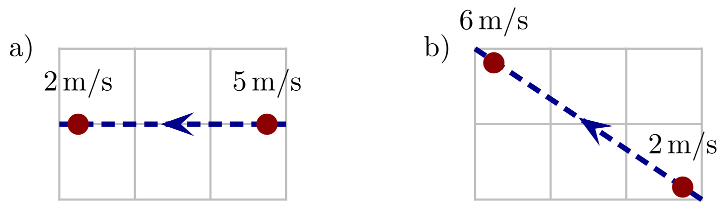
ii) The average velocity of ant A is smaller than that for ant B.

iii) The average velocity of ant A is larger than that for ant B.

iv) The average velocities are different but one cannot say which is larger.

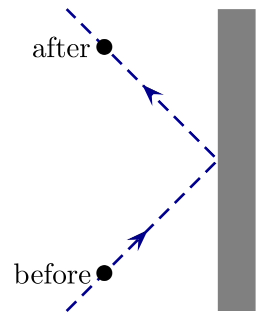
81 Acceleration vectors from motion

Two particles move along the illustrated trajectories. Their locations and speeds are illustrated at instants 0.25 s apart. For each case determine the acceleration vector for the particle. *(111F2023)*



82 Bouncing hockey puck

A hockey puck slides along a horizontal surface toward a board, hitting it at an angle and bouncing off with unchanged speed. The view from above is as illustrated. *(111F2023)*

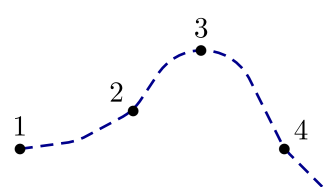


a) Draw the velocity vectors of the puck just before and just after hitting the board, use these to draw the vector $\Delta\vec{\mathbf{v}}$, and use the result to draw the direction of the acceleration vector.

b) If the puck traveled backwards along the same path (i.e. diagonally from top left to the board and then toward the bottom left), what would the direction of the acceleration vector be? Explain your answer.

83 Ants moving along a curved path

Various ants follow the same path on a horizontal surface, starting at point 1. The path is as illustrated. Ant A moves with a constant speed, ant B gradually speeds up and ant C gradually slows. *(111F2023)*

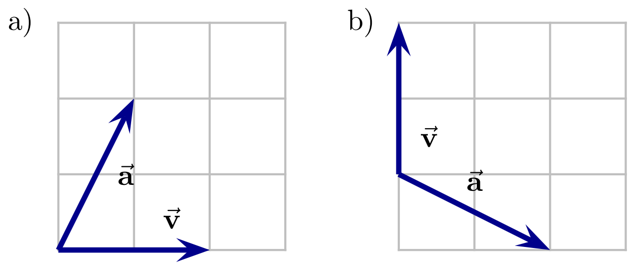


a) Draw the velocity vector at points 1, 2, 3 and 4.

b) Does any of the ants have zero acceleration at all times? Explain your answer.

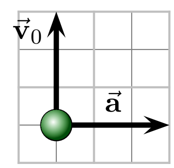
84 Velocity and acceleration vectors and motion

Position and acceleration vectors for two particles at one moment are illustrated. For each case, describe whether the particle is speeding up, slowing down or moving with constant velocity. Also describe how the direction of the particle's motion changes. Explain your answers. *(111F2023)*



85 Constant acceleration in two dimensions

A ball can slide along a horizontal surface. At an initial instant its velocity is $\vec{\mathbf{v}}_0$. At all later times it accelerates with a constant acceleration, $\vec{\mathbf{a}}$. The situation with the vectors drawn to scale as viewed from above is illustrated (for the velocity vector, the grid unit is the standard unit of velocity and for acceleration the grid unit is the standard unit of velocity). *(111F2023)*



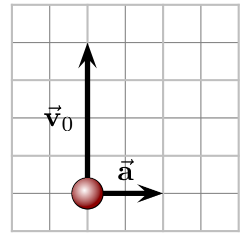
a) Draw, as accurately as possible, the velocity vector at an instant 1.0 s after the initial instant.

b) Let v_0 denoted the speed at the initial instant. Determine an expression for the speed, in terms of v_0, at an instant 1.0 s after the initial instant.

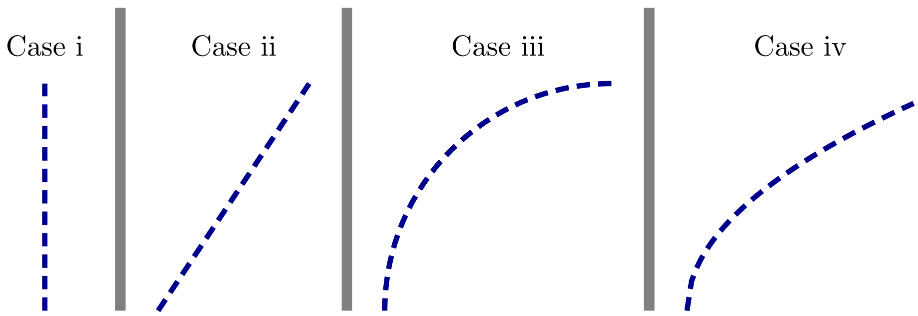
c) Determine the time for the speed v to be twice the speed at the initial moment.

86 Motion with constant acceleration

A ball can slide along a horizontal surface. At an initial instant its velocity, $\vec{\mathbf{v}}_0$, is as illustrated. At all later times it accelerates with a constant acceleration, $\vec{\mathbf{a}}$, as illustrated. *(111F2023)*



a) Draw, as accurately as possible, the velocity vector at an instant 0.5 s after the initial instant.
b) Draw, as accurately as possible, the velocity vector at an instant 1.0 s after the initial instant.
c) Which of the following best represents the trajectory of the particle? Explain your answer.



87 Dropping a coin on a ship

A person is on the deck of a ship. While the ship is at rest in a harbor, the person drops a coin from rest and the coin lands on the deck of the ship. The person marks the spot where the coin lands. Later the ship sails with constant speed in a straight line and the person returns to the same spot and drops the coin again. Does the coin land at the original mark, in front of it or behind it? Explain your answer. *(111F2023)*

88 Jumping monkey

A monkey jumps leaving the Earth at an angle of 45° from the surface. Which of the following is true when the monkey reaches the highest point along the trajectory? Explain your answer. *(111F2023)*

i) The acceleration of the monkey is zero.
ii) The acceleration of the monkey is horizontal in the forwards direction.
iii) The acceleration of the monkey is horizontal in the backwards direction.
iv) The acceleration of the monkey is vertical downward.
v) The acceleration of the monkey is vertical upward.

89 Red vs. blue ball

Two balls, one red and the other blue, are on a horizontal table. The are made to roll off the table. At the instants that they leave the speed of the blue ball is four times that of the red ball. Which of the following is true regarding the times taken to hit the floor on which the table stands? Explain your answer. *(111F2023)*

i) The time taken for blue ball is a quarter of that for the red ball.

ii) The time taken for blue ball is half that for the red ball.

iii) The time taken for blue ball is the same as that for the red ball.

iv) The time taken for blue ball is twice that for the red ball.

v) The time taken for blue ball is four times that for the red ball.

90 Balls launched off horizontal surfaces

Two balls, one red and the other blue, are on horizontal surfaces above a floor. They are each launched horizontally off the surface with the same speed. The height of the blue ball surface above the floor is nine times that of the red ball surface. Let t_{red} be the time between the moment that the red ball leaves the table until it hits the floor; similarly t_{blue} represents the same for the blue ball. Let Δx_{red} be the horizontal distance between the point where the red ball leaves the table and hits the ground. *(111F2023)*

a) Suppose that the balls are launched with the same speed. Which of the following is true? Explain your answer.

   i) $t_{\text{blue}} = \frac{1}{9}\, t_{\text{red}}$

   ii) $t_{\text{blue}} = \frac{1}{3}\, t_{\text{red}}$

   iii) $t_{\text{blue}} = \quad t_{\text{red}}$

   iv) $t_{\text{blue}} = 3\, t_{\text{red}}$

   v) $t_{\text{blue}} = 9\, t_{\text{red}}$

b) Suppose that the balls are launched with the same speed. Which of the following is true? Explain your answer.

   i) $\Delta x_{\text{blue}} = \frac{1}{9}\, \Delta x_{\text{red}}$

   ii) $\Delta x_{\text{blue}} = \frac{1}{3}\, \Delta x_{\text{red}}$

   iii) $\Delta x_{\text{blue}} = \quad \Delta x_{\text{red}}$

   iv) $\Delta x_{\text{blue}} = 3\, \Delta x_{\text{red}}$

   v) $\Delta x_{\text{blue}} = 9\, \Delta x_{\text{red}}$

c) Suppose that the blue ball is launched with a slower speed than the red ball. Describe how this would affect the answers of the previous questions.

91 Running off a roof

A person runs with speed 8.0 m/s off a flat roof that is 3.0 m above the ground. First suppose that the person travels horizontally at the moment that he leaves the roof. Determine how far horizontally from the edge of the roof the person will land. *(111F2023)*

a) Sketch the situation with the "earlier" instant being that at which the person leaves the roof and the "later" instant being the moment just before the person hits the ground.

List as many of the variables as possible. Use the format:

$$\begin{array}{ll} t_i = & t_f = \\ x_i = & x_f = \\ y_i = & y_f = \\ v_{ix} = & v_{fx} = \\ v_{iy} = & v_{fy} = \\ a_x = & a_y = \end{array}.$$

b) Sketch the velocity vector at the earlier moment and use this to determine the components of $\vec{\mathbf{v}}_i$. Enter these in the list above.

c) Identify the variable needed to answer the question of the problem. Select and write down a kinematic equation that contains this variable and attempt to solve it.

You should see to solve the variable describing the horizontal position, you first need the value for another, currently unknown variable. Which variable is this?

d) Use the vertical aspects of the object's motion to solve for this other unknown variable and use this result to answer the question of this problem.

Suppose that the person ran and jumped from the building at an angle of 30° above the horizontal. This will change how far the person travels. Before answering that question, we ask, what is the maximum height above the ground reached by the person for this running jump?

e) Sketch the velocity vector at the earlier moment and use this to determine the components of $\vec{\mathbf{v}}_0$. Reconstruct the list of variables for the problem.

f) Sketch the velocity vector at the instant when the person reaches his highest point. Use this to add additional information to the list of variables for the problem.

g) Use the kinematic equations to determine the maximum height that the person reaches.

h) Determine the speed of the person at the maximum height.

i) Determine how far horizontally from the edge of the roof the person will land.

92 Projectile motion range

A person runs with speed 8 m/s off a flat roof that is 3.0 m above the ground. The person can launch himself at various angles and the purpose of this exercise is to determine the speed with which the person hits the ground and where on the ground the person lands (for various angles of launch). First suppose that the person travels horizontally at the moment that he leaves the roof. It was found that the person lands 6.3 m from the base of the building. *(111F2023)*

a) Sketch the situation with the "earlier" instant being that at which the person leaves the roof and the "later" instant being the moment just before the person hits the ground. List as many of the variables as possible. Use the format

$$\begin{array}{ll} & t = \\ x_0 = & x = \\ y_0 = & y = \\ v_{0x} = & v_x = \\ v_{0y} = & v_y = \\ a_x = & a_y = \end{array} .$$

b) Draw the velocity vector at the earlier instant and use this to determine the components of $\vec{\mathbf{v}}_0$. Enter these in the list above.

c) Draw the velocity vector at the later instant. Describe whether the components are positive, negative or zero.

d) The speed of the object is the magnitude of the velocity vector. So to determine the speed, you will first need to determine the components of the velocity vector. Use the kinematic equations to determine the x and y components of the velocity at the later instant. You must start by writing the equation that you use, before substituting.

e) Sketch the velocity vector at the instant just before the person hits the ground and indicate the values of the x and y components on the sketch. Use this to determine the speed of the person just before hitting the ground.

Now suppose that the person travels with the same speed but launches himself at an angle of 45° from the roof.

f) Using the same "earlier" and later instants as before, list as many of the variables as possible.

g) Draw the velocity vector at the earlier moment and use this to determine the components of $\vec{\mathbf{v}}_0$.

h) Use the kinematic equations to determine the x and y components of the velocity at the later instant.

i) Sketch the velocity vector at the instant just before the person hits the ground and indicate the values of the x and y components on the sketch. Use this to determine the speed of the person just before hitting the ground.

j) Determine the time taken to hit the ground.

k) Determine how far the person lands from the building.

93 Aircraft dropping object

An aircraft flies horizontally with a constant speed of 600 km/h at a height of 1200 m above a flat surface. It drops an object from its underside; this object is supposed to hit a particular spot on the ground. How far (horizontally) from the spot must the aircraft be for the object to hit the spot? *(111F2023)*

94 Rifle shot

A rifle fires a bullet. At the moment that the bullet leaves the rifle it travels horizontally with speed 300 m/s. Determine how far the bullet will drop by the time that it reaches a vertical wall that is 100 m from the end of the rifle that is closest to the wall. *(111F2023)*

95 Ball thrown horizontally

A ball is thrown, leaving the hand horizontally at a height of 2.0 m above the ground. It lands a horizontal distance of 5.0 m from where it left the hand. *(111F2023)*

a) Determine the time from when the ball leaves the hand until it hits the ground.

b) Determine the speed with which the ball leaves the hand.

96 Jumping over a ditch

A dog attempts to jump over a ditch, which is 2.0 m wide. The dog launches itself from one edge of the ditch with speed 5.0 m/s at an angle of 30° from the horizontal. The aim of this exercise is to determine whether the dog will reach the other side of the ditch. First we will find out whether the dog reaches its maximum height before or after it is above the middle of the ditch. *(111F2023)*

a) Sketch the situation with the "earlier" instant being that at which the dog launches and the "later" instant being the moment when it reaches its highest point. List as many of the variables as possible. Use the format

$$\begin{aligned} t_i &= & t_f &= \\ x_i &= & x_f &= \\ y_i &= & y_f &= \\ v_{ix} &= & v_{fx} &= \\ v_{iy} &= & v_{fy} &= \\ a_x &= & a_y &= \end{aligned} .$$

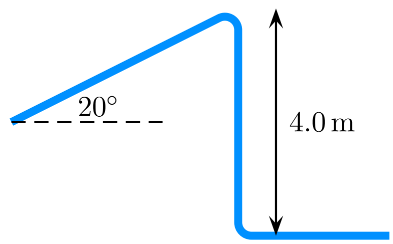
b) Draw the velocity vector at the earlier instant and use this to determine the components of $\vec{\mathbf{v}}_i$. Enter these in the list above.

c) Draw the velocity vector at the later instant. Describe whether the components are positive, negative or zero and enter as much information about these in the list above.

d) Determine the horizontal distance traveled by the dog by the time that it reaches its maximum height.

e) As the dog descends from its maximum height back to the ground, how much further does it travel? Does it reach the other side of the ditch?

97 Launching off a ski ramp, 1



A ski ramp is arranged as illustrated. A skier launches off the ramp with a speed of 15 m/s. Initially the aim of this exercise is to determine the maximum height reached by the skier and the velocity at this point. A later goal is to determine the distance at which the skier lands from the bottom of the ramp. *(111F2023)*

a) Sketch the situation with the "earlier" instant being that at which the skier launches and the "later" instant being the moment when she reaches its highest point. List as many of the variables as possible. Use the format

$$\begin{aligned} t_i &= & t_f &= \\ x_i &= & x_f &= \\ y_i &= & y_f &= \\ v_{ix} &= & v_{fx} &= \\ v_{iy} &= & v_{fy} &= \\ a_x &= & a_y &= \end{aligned}$$

b) Draw the velocity vector at the earlier instant and use this to determine the components of $\vec{\mathbf{v}}_i$. Enter these in the list above.

c) Draw the velocity vector at the later instant. Describe whether the components are positive, negative or zero and enter as much information about these in the list above.

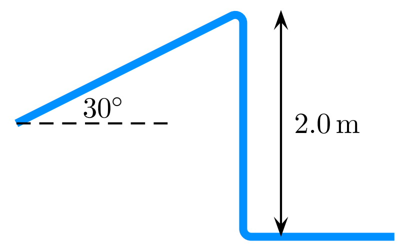
d) Determine the time taken to reach the maximum height and then the horizontal distance traveled by the skier to reach her maximum height. Determine the velocity at this point.

You will now consider the motion from the highest point back to the ground.

e) Repeat the problem set-up with the"earlier" instant being that at which the skier is at maximum height and the "later" instant being the moment *just before* she reaches hits the ground. Determine the time taken for this portion of the motion and use it to determine the horizontal distance from the base of the ramp to the skier's landing point.

98 Launching off a ski ramp, 2

A ski ramp is arranged as illustrated. A skier launches off the top of the ramp with a speed of 28 m/s. Determine the horizontal distance at which the skier lands from the bottom of the ramp. *(111F2023)*



99 Jumping grasshopper

A grasshopper jumps, leaving the ground at an angle of 70° from the horizontal. The grasshopper reaches a height of 0.60 m. *(111F2023)*

a) Determine the speed with which the grasshopper leaves the ground.

b) Determine how far the grasshopper lands from where it jumped.

100 Jumping lemur

A lemur (a type of primate) jumps, leaving the ground at an angle of 40° from the horizontal with speed 6.0 m/s. *(111F2023)*

a) Determine the maximum height reached by the lemur.

b) Determine the amount of time for which the lemur is airborne.

c) Determine the horizontal distance traveled by the lemur from the moment it leaves the ground until it returns to the ground.

101 Diver splashdown

A diver launches off a platform at an angle of 55° above the horizontal and with speed 8.0 m/s. The platform is 3.0 m above the surface of a pool. *(111F2023)*

a) Determine the diver's speed just before hitting the water.

b) Determine the time taken by the diver to hit the water.

102 Stone thrown from a bridge

A person stands on a bridge over a small lake. The person throws a stone with speed 18.0 m/s at an angle of 40° above the horizontal. The stone leaves the hand at a height 3.0 m above the surface of the water. *(111F2023)*

a) Determine the time taken for the stone to reach the highest point in its trajectory.

b) Determine the time taken for the stone to hit the water.

c) Determine the horizontal distance traveled by the stone between the throw and when it hits the water.

103 Cannonball range

A cannonball is fired from the ground (assume that the ball leaves from the ground level) and must hit a target on the ground a distance of 500 m away. Assume that the ground is horizontal and ignore air resistance. *(111F2023)*

a) Suppose that the cannonball leaves at an angle of 50° from the horizontal. Determine the speed with which it must be fired to hit the target.

b) Suppose that the cannonball is fired with speed 150 m/s. Determine the angle above the horizontal at which it must be fired so that it hits the target.

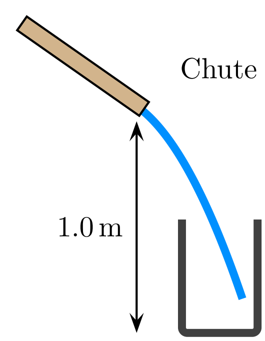
c) *(Challenging)* Determine the minimum speed with which the cannonball must be fired so that it can hit the target if the angle is adjusted correctly.

104 Angry tennis player

An angry tennis player hits a tennis ball into the air toward the fence that surrounds the court. The tennis player is a horizontal distance of 20 m from the fence, which is 10 m high. The tennis player hits the ball with speed 28 m/s at an angle of 70° above the horizontal from a height of 1.2 m above the ground. Does the ball reach the fence? Does it pass over the top of the fence? Explain your answer. *(111F2023)*

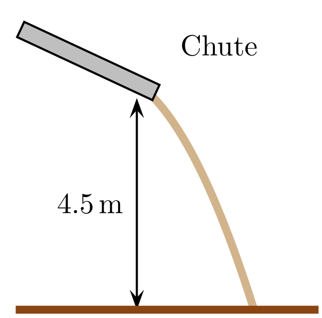
105 Water chute and bucket

Water slides down a chute that is at an angle of 35° above the horizontal. It leaves the end of the chute with speed 3.0 m/s. A bucket with sides 30 cm high and diameter 20 cm is placed beyond the chute so that it catches the water. Determine where the left edge of the bucket be should placed so that the water will land in the bucket. Provide the entire range of possible locations. *(111F2023)*



106 Grain chute

Grain pours off a chute that is at an angle of 25° above the horizontal. It leaves the end of the chute with speed 5.0 m/s. Determine how far it travels horizontally. *(111F2023)*



107 Rotating mountain bike wheel

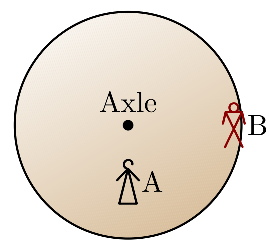
One standard mountain bike wheel has rims with diameter 29in. A cyclist rides the bike with a constant speed of 15 mph. Determine the speed and centripetal acceleration of a point on the rim in metric units. *(111F2023)*

108 Ball on a string

A ball swings with constant speed on the end of a 50 cm long string. Determine the period of orbit (time for one circle) such that the ball's acceleration is $2g$. *(111F2023)*

109 Rotating dolls

Two dolls sit in fixed places on a disk that rotates about its center. Doll A is halfway from the axle to the rim. Doll B is at the rim. The wheel rotates at a uniform constant rate. Let v_A be the speed of A, v_B be the speed of B, a_A the acceleration of A, etc. In each of the following, explain your answer. *(111F2023)*



a) Which of the following is true?

i) $v_A = \frac{1}{4} v_B$

ii) $v_A = \frac{1}{2} v_B$

iii) $v_A = v_B$

iv) $v_A = 2v_B$

v) $v_A = 4v_B$

b) Which of the following is true?

i) $a_A = \frac{1}{4} a_B$

ii) $a_A = \frac{1}{2} a_B$

iii) $a_A = a_B$

iv) $a_A = 2a_B$

v) $a_A = 4a_B$

110 Acceleration on Grand Mesa versus Grand Junction

Consider standing in two places: one in Grand Junction and the other on top of Grand Mesa. The altitude of Grand Junction is roughly 1380 m and Grand Mesa 3200 m. The aim of this exercise is to determine the difference in velocity and acceleration between the two locations. Grand Junction's location latitude is about 39° North. Note that all objects rotate about an axis through Earth's poles. *(111F2023)*

a) Determine the speed with which a person in Grand Junction moves as Earth (radius 6400 km at sea level) rotates.

b) Determine the speed with which a person on top of Grand Mesa moves.

c) Determine the acceleration of a person in Grand Junction.

d) Determine the acceleration of a person on the Grand Mesa. Are the accelerations noticeably different?

111 Acceleration on Earth's surface

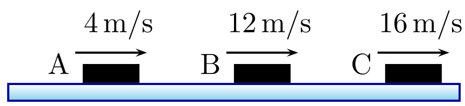
People stand on Earth's surface and are at rest *relative to Earth*. Earth has a radius of 6.4×10^3 km and spins about its poles at a rate of one revolution every 24 hrs. *(111F2023)*

a) Determine the acceleration of a person at Earth's equator.

b) Another person stands at a location much closer to the North pole. Is this person's acceleration the same as, larger than or smaller than that of a person at the equator? Explain your answer.

Dynamics

112 Hockey pucks sliding horizontally



Three identical hockey pucks slide horizontally across a frictionless sheet of ice and they maintain the indicated speeds during a particular period. Let F_A be the magnitude of the force acting on A during this period, F_B be the magnitude of the force acting on B, etc, ... Which of the following is true? Explain your answer. *(111F2023)*

i) $F_B = 2F_A$ and $F_C = 4F_A$

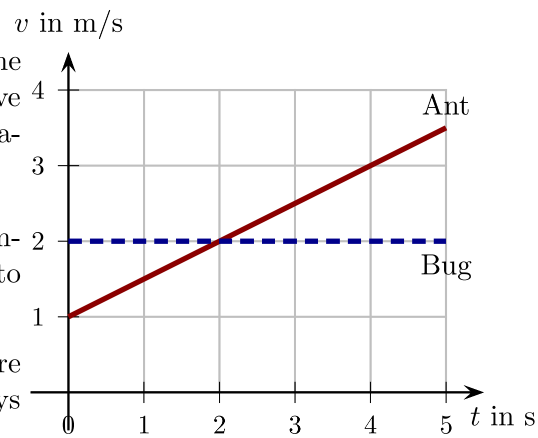
ii) $F_A = 2F_B$ and $F_A = 4F_C$

iii) $F_A = F_B = F_C \neq 0$

iv) $F_A = F_B = F_C = 0$

113 Forces on an ant and a bug

An ant and a bug walk along straight wires. The graph illustrates their velocities vs. time. They have the same mass. Answer the following, giving explanations for each answer. *(111F2023)*



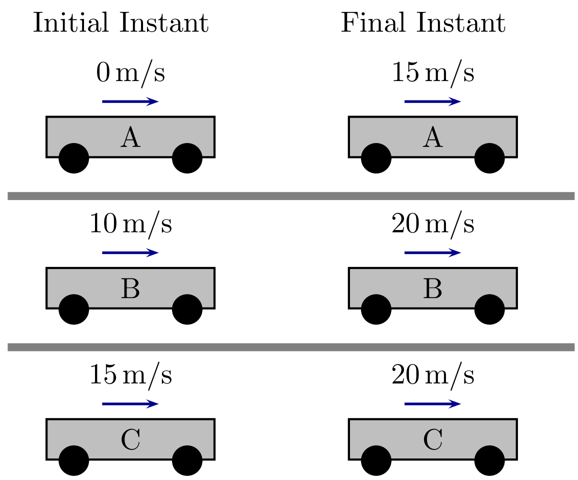
a) How does the net force on the ant at 2.0 s compare (same, larger, four times as large,etc,) to the net force on the ant at 4.0 s?

b) How does the net force on the ant compare (same, always larger, sometimes larger, always smaller,...) to the net force on the bug?

c) Is the net force exerted on the ant ever the same as that exerted on the bug? If so, explain when.

114 Moving carts

Three identical carts move horizontally along tracks. Their speeds at two instants 5.0 s apart are indicated. Let F_A be the magnitude of the net force acting on A during this interval, F_B be the magnitude of the net force acting on B, etc, ... Which of the following is true? Explain your answer. *(111F2023)*



i) $F_A > F_B > F_C$.

ii) $F_B = F_C > F_A$.

iii) $F_B = F_C < F_A$.

iv) $F_A = F_B = F_C \neq 0$

115 Riding a bicycle

Suppose that you ride a bicycle at constant speed in straight lines across various surfaces. In each of the following, explain your answers. *(111F2023)*

a) If you ride at a constant speed along a flat horizontal surface, which of the following is true?

   i) The net force on the bicycle is zero.
   ii) The net force on the bicycle is in the direction of motion.
   iii) The net force on the bicycle is opposite to the direction of motion.
   iv) Whether the net force is zero or not depends on the speed.

b) If you ride at a constant speed along a slanted flat uphill surface, which of the following is true?

   i) The net force on the bicycle is zero.
   ii) The net force on the bicycle is in the direction of motion.
   iii) The net force on the bicycle is opposite to the direction of motion.
   iv) Whether the net force is zero or not depends on the speed.

116 Pushing carts

Zog and Geraldine (his wife) each push a cart along a horizontal surface where friction is negligible. Both carts are initially at rest. Zog takes the cart with mass 25 kg and exerts a force of 400 N on it for a period of 4.0 s and he then collapses and stops pushing. Geraldine has to push a cart of mass 50 kg and she is also able to exert a force of 400 N on it. Geraldine claims that it is possible for the speed of her cart to eventually reach the speed of Zog's cart. Is this true? Explain your answer. *(111F2023)*

117 Forces on a cart sliding horizontally

A cart can slide horizontally left or right. *(111F2023)*

a) Suppose that the cart slides to the left with increasing speed. Which of the following is true about the net force, $\vec{\mathbf{F}}_{\text{net}}$, acting on the cart? Explain your choice.

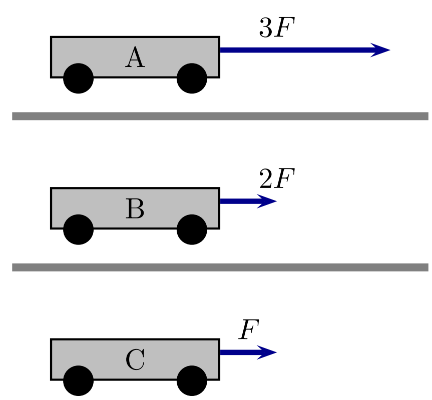
  i) $\vec{\mathbf{F}}_{\text{net}} = 0$
  ii) $\vec{\mathbf{F}}_{\text{net}} \neq 0$ and points right.
  iii) $\vec{\mathbf{F}}_{\text{net}} \neq 0$ and points left.

b) Suppose that the cart slides to the left with decreasing speed. Which of the following is true about the net force acting on the cart? Explain your choice.

  i) $\vec{\mathbf{F}}_{\text{net}} = 0$
  ii) $\vec{\mathbf{F}}_{\text{net}} \neq 0$ and points right.
  iii) $\vec{\mathbf{F}}_{\text{net}} \neq 0$ and points left.

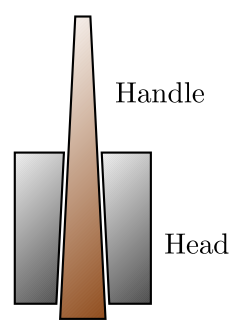
118 Moving carts

Consider three carts with different masses. Different forces act on each cart and each is expressed as a multiple of some basic force, F. The mass of cart A is 8 times the mass of cart C. The mass of cart B is 3 times the mass of cart C. Rank the carts in order of increasing acceleration. Explain your answer. *(111F2023)*



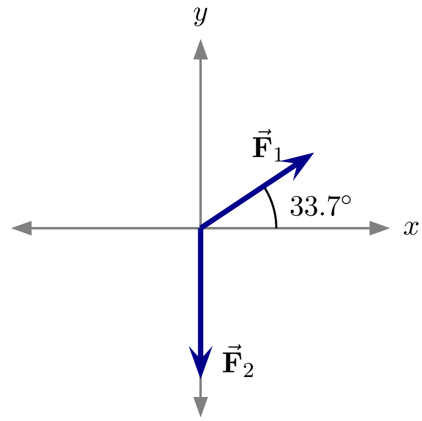
119 Pickax

A pickax consists of a tapered wooden handle and a metal head that slides over the wooden handle. An exaggerated simplified cross section view is illustrated. The head sometimes works loose. One way to secure it is to hold the handle vertical with the head at the bottom and then drop the handle. Use Newton's laws to explain why even letting the handle hit the ground gently is likely to secure the head more tightly than hitting the head from above. *(111F2023)*



120 Net force vector: two forces

Two forces, $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$ act on an object and are as illustrated. Their magnitudes are $F_1 = 400\,\mathrm{N}$ and $F_2 = 500\,\mathrm{N}$. *(111F2023)*

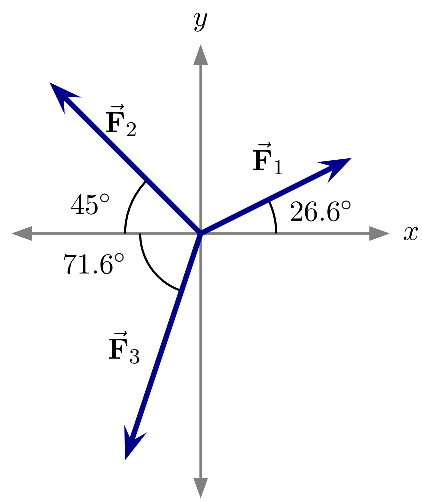


a) Determine the x and y components of the net force.

b) Determine the magnitude of the net force acting on the object.

121 Net force vector: three forces

Three forces, $\vec{\mathbf{F}}_1, \vec{\mathbf{F}}_2$ and $\vec{\mathbf{F}}_3$ act on an object and are as illustrated. Their magnitudes are $F_1 = 40\,\mathrm{N}, F_2 = 25\,\mathrm{N}$ and $F_3 = 15\,\mathrm{N}$. *(111F2023)*



a) Determine the x and y components of the net force.

b) Determine the magnitude of the net force acting on the object.

122 Force, acceleration and velocity

The exercise will investigate the assertion:

"The larger the force on an object, the larger the object's velocity."

Consider two carts, labeled A and B, each with mass 3.0 kg that can slide left or right. The net force on cart A is 12.0 N to the right and the net force on cart B is 6.0 N to the right. It would appear that the velocity of A is twice the velocity of B. Consider the situation where the velocity of each cart at 0.0 s is exactly 0.0 m/s and that the forces act on the carts at all later times. Explain your answers in the following. *(111F2023)*

a) Determine the velocity of each cart at 1.0 s, 2.0 s, 3.0 s, 4.0 s and 5.0 s.

b) Is the "velocity of A twice the velocity of B?"

c) Is the "velocity of A at 2.0 s twice the velocity of B at 4.0 s?" Does this suggest a need to be specific with statements about velocity?

Now consider a different situation where the velocity of A at 0.0 s is exactly −8.0 m/s and the velocity of B is 0 m/s.

d) Determine the velocity of each cart at 1.0 s, 2.0 s, 3.0 s, 4.0 s and 5.0 s.

e) Is the "velocity of A twice the velocity of B?"

f) Is the "velocity of A at 3.0 s twice the velocity of B at 3.0 s?"

g) Is the statement: "The larger the force on an object, the larger the object's velocity" true or not in general?

123 Force on an accelerating box

A 50 kg box is initially at rest on a horizontal sheet of ice. Subsequently someone pulls on the box with a constant horizontal force. The box moves 15 m during the first 10 s while the force is applied. Determine the magnitude of the force. *(111F2023)*

124 Moving a sleepy dog

A sleepy 30 kg dog lies on a horizontal surface. The dog is initially at rest. Subsequently a child pushes horizontally on the dog with a 150 N force. There is no friction between the dog and the surface and forces in the vertical direction are irrelevant to its motion. *(111F2023)*

a) Determine how far the dog moves after the child has pushed for 3.0 s.

b) Determine the speed of the dog after the child has pushed for 3.0 s.

c) If the child continues pushing for twice as long will the speed be twice as much? Will the distance traveled be twice as much? Explain your answers.

125 Citrus fruit microjets

Citrus fruit emit aromatic oils when the peel is disrupted. This can occur in the form of microscopic scale jets of fluid, that had been stored in small glands within the fruit's peel. Recent studies have shown that the jets emitted from lemons leave with speed about $7.0\,\mathrm{m/s}$. The aim of this problem is to estimate the force exerted on the jet emitted from a single gland. The volume of a typical gland in a lemon is $6.0 \times 10^{-10}\,\mathrm{m}^3$. Assuming the fluid has a similar density to water, this would imply that the fluid has mass $6.0 \times 10^{-7}\,\mathrm{kg}$. *(111F2023)*

a) Suppose that this entire fluid was accelerated from rest to $7.0\,\mathrm{m/s}$ across a distance equal to the radius of a sphere with the volume of the gland. Show that the radius is $5.2 \times 10^{-4}\,\mathrm{m}$. Determine the acceleration of the fluid.

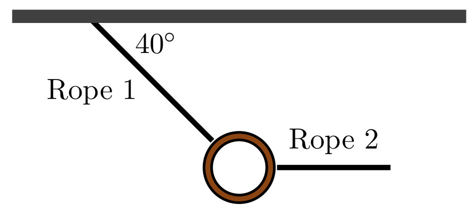
b) Determine the net force on the fluid. How does this compare to the gravitational force on the fluid? Does gravity matter in this case?

Detailed analyses of this are much more sophisticated and eventually consider pressure within the glands. More details can be found in Smith, et.al. PNAS, **115** (26), E5887–E5895 (2018).

126 Pushing a curling stone across a frozen ice sheet

A $20\,\mathrm{kg}$ curling (a type of sport) stone lies at rest on a horizontal sheet of ice. The stone is pushed by a player in a straight line with a constant horizontal force for a distance of $3.0\,\mathrm{m}$ and is then released. It travels in a straight line for a further distance of $42\,\mathrm{m}$ in $20\,\mathrm{s}$. There is no spin on the stone. Determine the magnitude of the force exerted by the player on the stone. *(111F2023)*

127 Suspended ring in equilibrium, 1



A 2.50 kg ring is suspended from the ceiling and is held at rest by two ropes as illustrated. Rope 2 pulls horizontally. The aim of this exercise is to use Newton's 2nd Law to determine the tension in each rope. One piece of background information that you will need to answer this is that the magnitude of the gravitational force on an object of mass m is $w = mg$. *(111F2023)*

a) Draw a free body diagram for the ring. Label the tension forces $\vec{\mathbf{T}}_1$ and $\vec{\mathbf{T}}_2$.

b) Write Newton's 2nd Law in its component form, i.e. write

$$F_{\text{net } x} = \Sigma F_{ix} = ma_x \quad (1)$$
$$F_{\text{net } y} = \Sigma F_{iy} = ma_y \quad (2)$$

Insert as much information as possible about the acceleration. You will return to these equations shortly; they will generate the algebra that eventually gives you the tensions.

c) These equations require all components of all forces, including the two unknown tension forces. In order to manage these, you should express the components of each tension force in terms of its magnitude. When doing this denote the magnitude of the tension in rope 1 by T_1 and for rope 2, by T_2.

d) List as much information as possible about each component for each force; each could be a number or an algebraic expression. Use one of the two formats below.

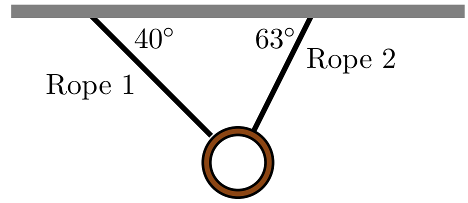
$$\begin{aligned} w_x &= \cdots \\ w_y &= \cdots \\ T_{1x} &= \cdots \\ T_{1y} &= \cdots \\ &\vdots \end{aligned}$$

Force	x comp	y comp
$\vec{\mathbf{w}}$		
$\vec{\mathbf{T}}_1$		
$\vdots$		

e) Use Eq. (1) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (2). You should get two expressions that contain the two unknowns T_1 and T_2. Solve them for the unknowns.

f) If you had one rope that is rated to break when the tension exceeds 30 N and another rated to break when the tension exceeds 40 N, which one would you use to suspend the object as illustrated above?

128 Suspended ring in equilibrium, 2



A 2.50 kg ring is suspended from the ceiling and by two ropes as illustrated. The aim of this exercise is to use Newton's 2nd Law to determine the tension in each rope. *(111F2023)*

a) Draw a free body diagram for the ring. Label the tension forces $\vec{\mathbf{T}}_1$ and $\vec{\mathbf{T}}_2$.

b) Write Newton's 2nd Law in its component form, i.e. write

$$F_{\text{net }x} = \Sigma F_{ix} = m a_x \quad (3)$$
$$F_{\text{net }y} = \Sigma F_{iy} = m a_y \quad (4)$$

Insert as much information as possible about the acceleration. You will return to these equations shortly; they will generate the algebra that eventually gives you the tensions.

c) These equations require all components of all forces, including the two unknown tension forces. In order to manage these, you should express the components of each tension force in terms of its magnitude. When doing this denote the magnitude of the tension in rope 1 by T_1 and for rope 2, by T_2.

d) List as much information as possible about each component for each force; each could be a number or an algebraic expression. Use one of the two formats below.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$T_{1x} = \cdots$$
$$T_{1y} = \cdots$$
$$\vdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{T}}_1$		
$\vdots$		

e) Use Eq. (3) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (4). You should get two expressions that contain the two unknowns T_1 and T_2. Solve them for the unknowns.

129 Suspended ball

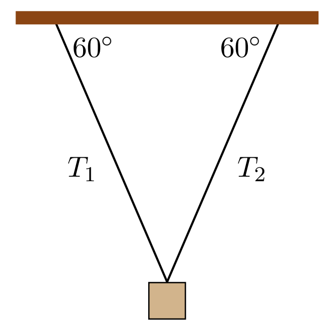
A 6.0 kg ball is suspended from the ceiling. A person pushes horizontally on the ball so that the ball is at rest with the rope at an angle of 70° from the horizontal. Determine the force exerted by the person. *(111F2023)*

130 Object suspended at rest

A 0.20 kg block is suspended by two ropes as illustrated. The tension in the left rope is T_1 and in the right rope it is T_2. *(111F2023)*

a) Is T_1 the same as or different to T_2? Explain your answer.

b) Determine the magnitude of the tension in each rope.



131 Stretched clothesline

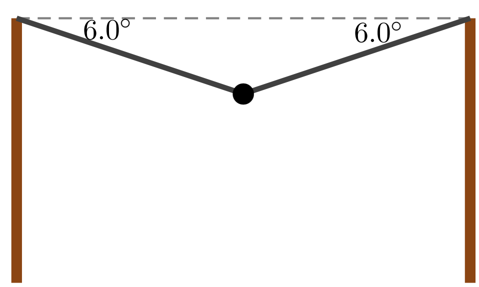
A clothesline (rope) initially droops approximately horizontally between two poles. A hanger is suspended at rest from the midpoint of the clothesline. *(111F2023)*

a) Is it possible to stretch the clothes line so that it is perfectly horizontally while the hanger is suspended? Explain your answer using Newton's laws.

b) The hanger is removed. Is it possible to stretch the clothes line so that it is perfectly horizontally? Explain your answer using Newton's laws.

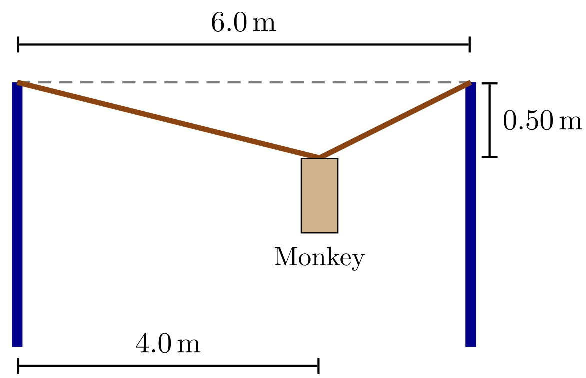
132 Slackline

A 75.0 kg person is at the midpoint of a slackline (cord stretched between two supports). The angle between the slackline and the horizontal is 6.0°. Determine the tension in the slackline. *(111F2023)*

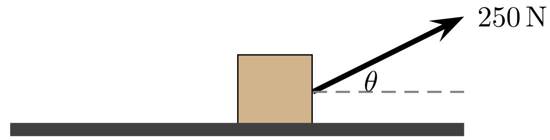


133 Dangling monkey

A 15.0 kg monkey hangs from a rope stretched between the tops of two equally tall supports in the illustrated configuration. Determine the tension in the rope left of the monkey and the tension in the rope right of the monkey. *(111F2023)*



134 Pulling a box



A 20.0 kg box can move along a frictionless horizontal surface. A person pulls on the box with the indicated force. Initially assume that the force pulls horizontally; later we will consider a general angle. *(111F2023)*

a) Draw a free body diagram for the box.

b) Write Newton's Second Law in its component form, i.e. write

$$F_{\text{net }x} = \Sigma F_x = \cdots$$
$$F_{\text{net }y} = \Sigma F_y = \cdots$$

Insert as much information as possible about the components of acceleration at this stage. You will return to these equations soon; they will generate the algebra that eventually gives you the acceleration and the normal force.

c) List all the components of all the forces, using one of the two formats below.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$F_{\text{person }x} = \cdots$$
$$F_{\text{person }y} = \cdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{n}}$		
$\vec{\mathbf{F}}_{\text{person}}$		

Use these to determine expressions for the components of the net force.

d) Use Newton's second law in component form to relate the acceleration components to the forces.

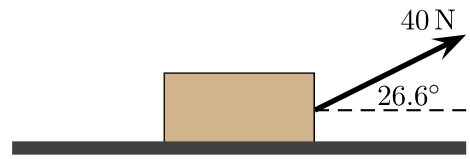
e) Determine the normal force on the box.

f) Determine the acceleration of the box.

g) Now suppose that $\theta = 25°$ and repeat the entire exercise to determine the normal force and the acceleration.

135 Dynamics of a single object

A 5.0 kg box can move along a frictionless horizontal surface. A person exerts a force at the illustrated angle. The aim of this exercise is to use Newton's laws to determine the acceleration of the box and the normal force exerted by the surface (provided that the box stays on the surface). *(111F2023)*



The *entire collection* of these steps is called "applying Newton's laws of mechanics to determine the acceleration of the block."

a) Draw a free body diagram for the block.

b) Write Newton's Second Law in its component form, i.e. write

$$F_{\text{net }x} = \Sigma F_x = \cdots \quad (5)$$
$$F_{\text{net }y} = \Sigma F_y = \cdots \quad (6)$$

Insert as much information as possible about the components of acceleration at this stage. You will return to these equations shortly; they will generate the algebra that eventually gives you the acceleration and the normal force.

c) Determine the magnitude of the gravitational force. Let n be the *magnitude* of the normal force. Do you think that $n = mg$?

d) List all the components of all the forces, using one of the two formats below.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{n}}$		
$\vdots$		

e) Use Eq. (5) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (6). Solve these for the acceleration and the magnitude of the normal force. Is $n = mg$?

f) Suppose that rather than pull up, the person pushed down on the box at the same angle from the left and with the same force. Would the acceleration and normal forces differ from the case where the person pulled up?

g) You may have noticed that the acceleration does not depend on the normal force. This is only true if there is no friction. It turns out that when friction is present, the magnitude of friction force increases as the normal force increases. Knowing this, would pulling up or pushing down give a larger acceleration?

136 Multiple forces and motion

A 20.0 kg box can move along a frictionless horizontal surface. Three people pull horizontally on the box with the indicated forces. *(111F2023)*

a) Draw a free body diagram for the box.

b) Write Newton's Second Law in its component form, i.e. write

$$F_{\text{net } x} = \Sigma F_x = \cdots$$
$$F_{\text{net } y} = \Sigma F_y = \cdots$$

Insert as much information as possible about the components of acceleration at this stage. You will return to these equations soon; they will generate the algebra that eventually gives you the acceleration and the normal force.

c) List all the components of all the forces, using one of the two formats below.

$$F_{1x} = \cdots$$
$$F_{1y} = \cdots$$
$$F_{2x} = \cdots$$
$$F_{2y} = \cdots$$
$$F_{3x} = \cdots$$
$$F_{3y} = \cdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_1$		
$\vec{\mathbf{F}}_2$		
$\vec{\mathbf{F}}_3$		

Use these to determine the components of the net force.

d) Use Newton's second law, which you wrote earlier, to determine the components of the acceleration of the box.

e) If the box were moving right while these forces act would it slow down or speed up?

f) If the box were moving left while these forces act would it slow down or speed up?

137 Lowering a box with ropes

Two ropes are attached to the top of a 75 kg box. They both pull vertically up with the same tension. The box moves downwards with constant downward acceleration of $2.5\,\mathrm{m/s^2}$. Determine the tension in each rope. *(111F2023)*

138 Lowering a bunch of bananas

A bunch of bananas has mass 40 kg. Starting from rest, they are lowered from a ship by a rope through a distance of 12.0 m. The rope pulls vertically upward with tension 305 N and there is an upward air resistance force of 60 N. Determine the time taken to lower the bananas. *(111F2023)*

139 Box on the floor of an elevator

A 20 kg box sits on the floor of an elevator. *(111F2023)*

a) During an initial 1.5 s period the elevator moves upward with a speed that increases steadily from 0 m/s to 7.5 m/s. Determine the normal force exerted by the floor on the box during this period.

b) During an later 2.5 s period the elevator moves upward with a speed that decreases steadily from 7.5 m/s to 0 m/s. Determine the normal force exerted by the floor on the box during this period.

140 Alice in an elevator

Alice, with mass 58 kg stands in an elevator, which moves vertically. The elevator accelerates (at a constant rate) from rest to speed of 4.0 m/s during a period of 1.5 s. It then moves with a constant velocity for a period of 10.0 s. Finally it slows to a stop at a constant rate during a period of 2.0 s. *(111F2023)*

a) Determine the total distance traveled by Alice during the entire journey.

b) Determine the normal force exerted by the elevator floor on Alice during each of the three stages of motion.

141 Free fall in an elevator

A phone with mass m sits on the floor of an elevator, which is initially at rest. The elevator cable snaps and the elevator and phone then undergo free fall (i.e. both move downward with an acceleration g). While they do this which is true of the magnitude of the normal force, n, acting on the phone? Explain your choice. *(111F2023)*

i) $n = 0$.

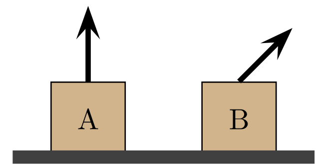
ii) $mg > n > 0$.

iii) $n = mg$.

iv) $n > mg$

142 Normal forces

Two identical boxes are at rest on a rough horizontal surface. A person pulls on each with the same force but in different directions on the boxes. On box A it pulls vertically and on box B it pulls at an angle of 45° from the vertical. Which of the following is true regarding the normal force exerted on A and that exerted on B? Explain your choice. *(111F2023)*



i) $n_A = n_B$.
ii) $n_A < n_B$.
iii) $n_A > n_B$.

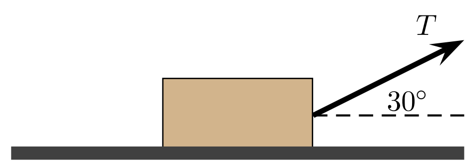
143 Sledding dog

A 37.0 kg dog sits on a 3.0 kg sled that can slide along a horizontal frictionless sheet of ice. At one instant the dog and sled are moving right with speed 6.0 m/s. For the next 4.0 s a person exerts a constant 80 N force on the dog/sled in the same direction as they move. *(111F2023)*

a) Determine the velocity of the dog/sled at the end of the 4.0 s period.
b) Determine the distance traveled by the dog/sled during the 4.0 s period.

144 Accelerating box

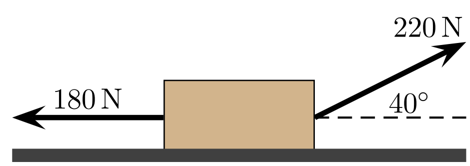
A rope pulls on a 30 kg box which slides across a frictionless horizontal surface. The box moves along the surface to the right with acceleration $3.5\,\text{m/s}^2$. *(111F2023)*



a) Determine the tension in the rope.
b) Determine the normal force exerted by the floor on the box.

145 Multiple forces and motion

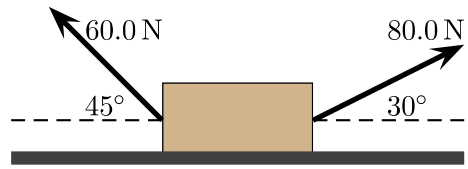
The illustrated forces act on an 80.0 kg box that slides along a frictionless horizontal surface. *(111F2023)*



a) Determine the acceleration of the box.
b) Suppose that at one moment the box was moving left. Will it slow down, speed up or move with constant velocity in the next moments? Explain your answer.
c) Suppose that at one moment the box was moving right. Will it slow down, speed up or move with constant velocity in the next moments? Explain your answer.

146 Multiple forces on a single object

A 25.0 kg crate can move along a frictionless horizontal surface. Two people exert forces on the crate as illustrated. *(111F2023)*



a) Determine the acceleration of the crate.

b) Determine the normal force on the crate.

147 Sledding down a slope

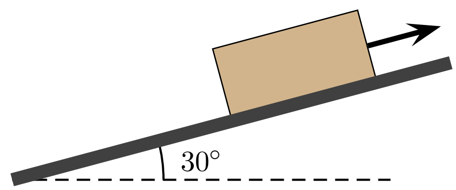
A sled and person, with combined mass 100 kg slide down a flat frictionless surface that is angled at 20° above the horizontal. *(111F2023)*

a) Determine the acceleration of the sled and person.

b) Determine the normal force on the sled and person.

148 Object pulled along a ramp

A 4.0 kg box can move along a frictionless ramp angled 30° from the horizontal. A person pulls on a rope which exerts a force of 15 N up the ramp parallel to its surface. The object of this exercise is to determine the acceleration of the box. *(111F2023)*



a) Draw a free body diagram for the box.

b) Describe the x and y axes that you will use.

c) Write Newton's Second Law in vector form and also in its component form, i.e. write

$$F_{\text{net }x} = \Sigma F_x = \cdots \quad (7)$$

$$F_{\text{net }y} = \Sigma F_y = \cdots \quad (8)$$

Insert as much information as possible about the components of acceleration at this stage. The resulting equations will generate much of the algebra that follows.

d) Determine the magnitude of the gravitational force.

e) List all the components of all the forces, using one of the two formats below.

$F_{gx} = \cdots$
$F_{gy} = \cdots$
$n_x = \cdots$
$n_y = \cdots$
$\vdots$

Force	x comp	y comp
$\vec{\mathbf{F}}_\text{g}$		
$\vec{\mathbf{n}}$		
$\vdots$		

f) Use Eq. (7) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (8).Use the resulting equations to determine the acceleration of the box.

g) Is it possible to say with certainty whether the box is moving up the ramp or down the ramp? Is either direction possible in this situation? If only one direction is possible, which is it?

h) Suppose that the box is initially at rest. With the indicated applied force, how long will it take for the box to slide a distance of 2.0 m along the ramp?

149 Bathroom scale in a train

A bathroom scale reads the normal force that it exerts on the object on the scale. Suppose that a bathroom scale is fixed to the floor of a train and a person stands on the scale. The train travels at a constant speed along horizontal sections of track and then up and down inclined sections (the slopes of the inclined sections are the same). In the following explain your answers. *(111F2023)*

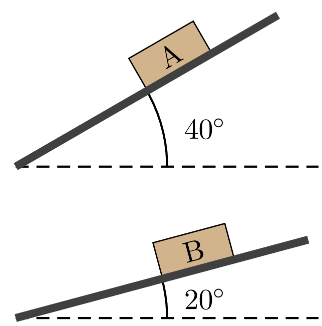
a) Is the reading on the scale when traveling up the inclined section the same as, smaller than or larger than when traveling along the horizontal section?

b) Is the reading on the scale when traveling down the inclined section the same as, smaller than or larger than when traveling up the inclined section?

c) Would the reading on the scale while the train travels up the inclined section depend on the speed with which it travels?

150 Blocks on ramps

Two blocks with the same mass are at rest on the illustrated inclined surfaces. Which of the following is true about the magnitudes of the normal forces that act on the blocks? Explain your answer. *(111F2023)*



i) $n_{\mathrm{A}} > n_{\mathrm{B}}$.

ii) $n_{\mathrm{A}} = n_{\mathrm{B}}$.

iii) $\frac{1}{2}\, n_{\mathrm{B}} < n_{\mathrm{A}} < n_{\mathrm{B}}$.

iv) $n_{\mathrm{A}} = \frac{1}{2}\, n_{\mathrm{B}}$.

v) $n_{\mathrm{A}} < \frac{1}{2}\, n_{\mathrm{B}}$.

151 Different boxes on the same ramp

Two boxes, one red (mass 3.0 kg) and the other blue (mass 6.0 kg) are each on frictionless ramps inclined at an angle of 10° from the horizontal. They are released from rest. Let a_{red} be the acceleration of the red box and a_{blue} that of the blue box. Which of the following is true? Explain your answer. *(111F2023)*

i) $a_{\mathrm{blue}} = \frac{1}{2}\, a_{\mathrm{red}}$

ii) $a_{\mathrm{blue}} = a_{\mathrm{red}}$

iii) $a_{\mathrm{blue}} = 2a_{\mathrm{red}}$

iv) $a_{\mathrm{blue}} > 2a_{\mathrm{red}}$

152 Snowboarder sliding up a ramp

An 80 kg snowboarder slides along a horizontal surface with a speed of 25 m/s and approaches a surface inclined at 10° above the horizontal. Both surfaces are frictionless and you can ignore air resistance. *(111F2023)*

a) Determine the acceleration of the snowboarder along the inclined surface.

b) Determine how far along the inclined surface the snowboarder slides before stopping.

c) Determine the maximum vertical height ascended by the snowboarder along the ramp.

153 Towing a car up a ramp, 1

A rope pulls a 2200 kg car up an icy ramp which is tilted at angle 10° above the horizontal. The tension in the rope is 4500 N. Determine the acceleration of the car, ignoring friction and air resistance. *(111F2023)*

154 Towing a car up a ramp, 2

A rope pulls a 2500 kg car up an icy ramp which is tilted at angle 15° above the horizontal. The rope pulls with a constant force. The car is at rest at the bottom of the ramp and while the rope pulls it travels a distance 54 m along the ramp in 6.0 s. Determine the tension in the rope. Ignore friction and air resistance. *(111F2023)*

155 Sledding on a slope

A person in a sled is at rest at the top of a slope that is angled 15° above the horizontal. The length of the slope is an 800 m (about 0.5 mi). The combined mass of the person and sled is 90 kg. They are released from the top of the slope and slide straight down without pushing. While this happens the air exerts a constant force of 150 N exactly opposite to the direction in which they move. Ignore friction between the sled and the slope. *(111F2023)*

a) Determine the acceleration of the person and sled. *You must solve this by starting with a FBD, using Newton's second law, finding components,. . . . Simply looking up a formula is not adequate.*

b) Determine the time taken for the person and sled to reach the bottom of the slope.

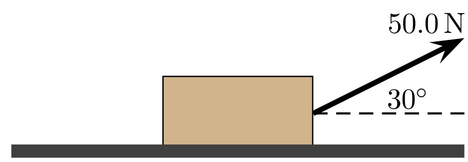
c) Determine the speed of the person and sled at the bottom of the slope.

156 Dragging a box horizontally

A 25 kg box can move along a rough horizontal surface. The coefficient of static friction between the box and surface is 0.30. A rope pulls horizontally on the box. Determine the minimum force needed to move the box from rest. *(111F2023)*

157 Dynamics of a single object with friction

A 15.0 kg box moves rightward along a horizontal surface. A rope pulls with a force at the illustrated angle. The coefficient of kinetic friction is 0.250. The primary aim of this exercise will be to determine the acceleration of the box. *(111F2023)*



a) Draw a free body diagram for the block.

b) Write Newton's Second Law in its component form, i.e. write

$$F_{\text{net }x} = \Sigma F_x = \cdots \qquad (9)$$
$$F_{\text{net }y} = \Sigma F_y = \cdots \qquad (10)$$

Insert as much information as possible about the components of acceleration at this stage. Can you describe in words what these equations are telling you to do?

c) Determine the magnitude of the gravitational force. Let n be the *magnitude* of the normal force. Using this write an expression for the magnitude of the friction force. Do you know the exact number for the friction force at this point?

d) List all the components of all the forces, using one of the two formats below.

$$w_x = \cdots$$
$$w_y = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

Force	x comp	y comp
$\vec{\mathbf{w}}$		
$\vec{\mathbf{n}}$		
$\vdots$		

e) Use Eq. (9) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (10). Does either give the acceleration immediately? Can one of then at least give the normal force immediately?

f) Determine the normal force and use this result to find the acceleration.

g) What tension would be required for the box to have acceleration $4.00\,\text{m/s}^2$ to the right?

158 Pushing a box at constant speed

A 10 kg box can move along a rough horizontal surface. You discover that when you push horizontally with a force of 50 N that the box moves with constant speed. Which of the following is true about the magnitude of the friction force? Explain your answer. *(111F2023)*

i) $f = 10\,\text{N}$

ii) $f = 50\,\text{N}$

iii) $f = 98\,\text{N}$

iv) f is more than 50 N but less than 98 N.

v) f is more than 98 N.

159 Pushing crates along a rough surface

Two people, Jordi and Agnes, each push horizontally on identical crates, which move at constant speeds along the same rough horizontal surface. Jordi pushes his crate faster than Agnes pushes her crate. Which of the following is true? Explain your answer. *(111F2023)*

i) Jordi exerts a larger force than Agnes.

ii) Jordi exerts a smaller force than Agnes.

iii) Jordi exerts the same force as Agnes.

160 Crate in a truck

A crate lies on the flat, horizontal bed of a truck. The truck moves along a horizontal surface. In the following the truck moves so that the crate does not slip along the bed of the truck. *(111F2023)*

a) Is there a friction force between the crate and the truck when they both move north at the same constant speed along a straight horizontal road? Explain your answer.

b) Suppose that the truck speeds up while heading North. In which direction does the friction force point when it does this? Explain your answer.

c) Suppose that the truck slows down while heading North. In which direction does the friction force point when it does this? Explain your answer.

Explain your answers. *Hint: Consider applying Newton's second law to the crate.*

161 Braking car

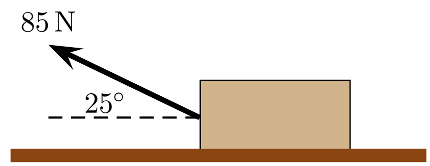
A 2000 kg car moves along a horizontal concrete road with speed 24 m/s. At one moment the driver applies the brakes sharply and the tires slide without rotating across the concrete surface. The coefficient of static friction in this case is 0.90 and the coefficient of kinetic friction is 0.60. Air resistance provides a 3500 N force acting opposite to the car's motion. *(111F2023)*

a) Determine the acceleration of the car.

b) Determine the distance which the car travels while the brakes are applied and it skids.

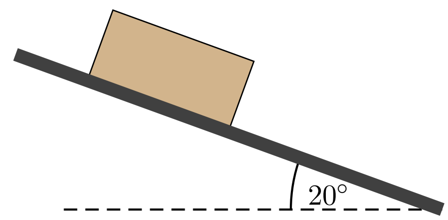
162 Sliding oak box

A person tries to control a 16 kg wooden (oak) box that slides down a ramp by pulling on a rope attached to the box. The box speeds up as it slides down the ramp and then moves right along a horizontal wooden (oak) surface. At this stage the rope is at an angle of 25° above the horizontal and the tension in the rope is 85 N. The coefficient of kinetic friction between two oak surfaces is 0.32. Determine the acceleration of the oak box as it slides along the horizontal surface. *(111F2023)*



163 Speed at the bottom of a rough ramp

A 10 kg box can move along a 4.0 m long rough ramp angled 20° from the horizontal. The coefficient of kinetic friction between the box and the ramp is 0.25 and the coefficient of static friction is 0.30. The box is released from rest at the top of the ramp and moves down the ramp. The aim of this exercise is to determine the speed of the box at the bottom of the ramp. *(111F2023)*



a) Draw a free body diagram for the box.

b) Describe your choice of x and y axes.

c) Write Newton's Second Law in vector form and also in its component form, i.e. write

$$F_{\text{net }x} = \Sigma F_x = \cdots \quad (11)$$
$$F_{\text{net }y} = \Sigma F_y = \cdots \quad (12)$$

where x and y refer to your specially chosen axes. Insert as much information as possible about the components of acceleration at this stage. The resulting equations will generate much of the algebra that follows.

d) Determine expressions for the *magnitudes* of the gravitational and the friction forces.

e) List all the components of all the forces, using one of the two formats below.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{n}}$		
$\vdots$		

f) Use Eq. (11) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (12). Use the resulting equations to find the acceleration of the box.

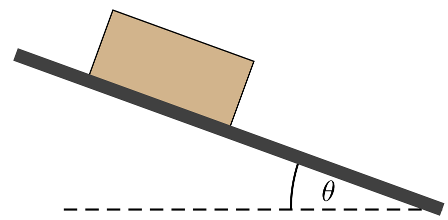
g) Determine the speed of the box when it reaches the bottom of the ramp.

h) Do these results depend on the mass of the box?

i) What would be the minimum force, pushing parallel to the ramp, required to keep the box at rest?

164 Perfect friction on a rough ramp

A box can move along a rough ramp which makes an angle θ from the horizontal and which has length L. The box is launched with speed v from the top of the ramp. The aim of this exercise is to determine the coefficient of friction needed to bring the box to a stop at the bottom of the ramp. *(111F2023)*



a) The first part of the solution uses kinematics to assess the acceleration of the box. Using kinematics, and eventually dynamics, is greatly simplified by choosing an appropriate "x" and a "y" axis. These do not have to be along the usual vertical and horizontal directions. Regardless of the axes that you choose, the usual general kinematics and dynamics equations will be valid. Describe the "x" and "y" axes that you will use.

b) Determine an expression for the magnitude of the acceleration of the box, a, in terms of variables relevant to this problem, such as L, θ, v, and possibly the mass of the box, m.

c) Draw a free body diagram for the box.

d) Write Newton's Second Law in vector form and also in its component form, i.e. write

$$F_{\text{net } x} = \Sigma F_{ix} = \cdots \tag{13}$$

$$F_{\text{net } y} = \Sigma F_{iy} = \cdots \tag{14}$$

where x and y refer to your specially chosen axes. Insert as much information as possible about the components of acceleration at this stage. The resulting equations will generate much of the algebra that follows.

e) Determine expressions for the *magnitudes* of the gravitational and the friction forces.

f) List all the components of all the forces, using one of the two formats below.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

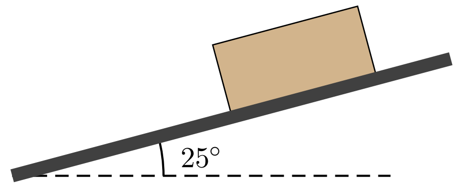
Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{n}}$		
$\vdots$		

g) Use Eq. (13) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (14). Use the resulting equations to find an expression for the coefficient of kinetic friction. Does the result depend on the mass of the box?

h) Suppose that the ramp is a roof whose length is 5.0 m and which is angled at 15° from the horizontal. If the box is pushed with speed 4.0 m/s, determine the coefficient of friction needed to stop the box at the bottom of the roof.

165 Crate sliding along a rough ramp

A 15 kg crate can slide up or down a ramp at angle 25° from the horizontal. The coefficient of kinetic friction between the crate and the ramp is 0.30. *(111F2023)*

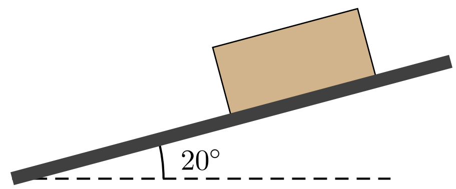


a) Determine the crate's acceleration if it slides up the ramp.

b) Determine the crate's acceleration if it slides down the ramp.

166 Crate pushed up a rough ramp

A 12 kg crate can slide up or down a ramp at angle 20° from the horizontal. The coefficient of kinetic friction between the crate and the ramp is 0.40. A hand pushes with a 120 N force parallel to the ramp in the uphill direction. Determine the crate's acceleration if it slides up the ramp. *(111F2023)*



167 Box on a ramp

A 100 kg box is at rest on a ramp that is inclined at angle 25° from the horizontal. *(111F2023)*

a) Determine the friction force on the box.

b) Determine the minimum coefficient of static friction between the box and ramp that allows the box to stay at rest.

168 Brick on a slope

A 1.50 kg brick is at rest on an inclined surface. The angle between the surface and the horizontal is 10°. *(111F2023)*

a) Determine the friction force that the surface exerts on the brick.

b) Determine the minimum coefficient of static friction between these surfaces that allows for the brick to stay at rest.

169 Car on a slope

A car with mass 1500 kg is at rest on an incline. The coefficient of static friction between dry asphalt and rubber here is 0.90 and the coefficient of static friction between wet asphalt and rubber is 0.40. *(111F2023)*

a) Determine the maximum angle of the incline so that the car will stay at rest when the surface is dry.

b) Determine the maximum angle of the incline so that the car will stay at rest when the surface is wet.

170 Launching a box up a ramp

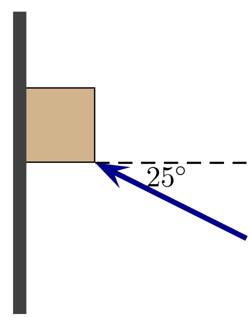
A ramp with length 2.0 m is inclined at an angle of 15° above the horizontal. A tiny box with mass 0.25 kg is launched with a very brief kick imparting speed 2.75 m/s at the base of the ramp. The coefficient of kinetic friction between the box and slope is 0.20. *(111F2023)*

a) Determine the acceleration of the box as it slides up the ramp.

b) Determine whether the box reaches the other end of the ramp or not.

171 Book held against a wall

A 10.0 kg book lies against a vertical wall and a hand pushes on it as illustrated. The coefficient of static friction between the book and wall is 0.30. The coefficient of kinetic friction between the book and wall is 0.20. *(111F2023)*



a) Determine the minimum force needed so that the book stays at rest on the wall.

b) Determine the magnitude of the force exerted by the hand so that the book slides down the wall with constant speed.

172 Ice skaters

Two ice skaters, Alice with mass 55 kg and Bob with mass 85 kg, are initially at rest on a frictionless horizontal surface. Bob gently pushes on Alice and while he does this she has a constant acceleration of $0.020\,\mathrm{m/s^2}$. *(131Sp2023)*

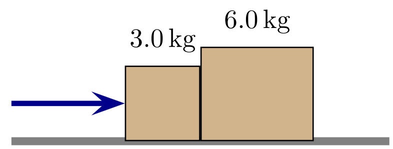
a) Determine the force exerted by Bob on Alice while she accelerates.

b) Determine the force exerted by Alice on Bob while Alice accelerates.

c) Determine the acceleration of Bob during the period while he is pushing on Alice.

173 Pushing crates in contact

Two crates can move along a horizontal surface. There is no friction between either crate and the surface. The crates maintain contact with each other. A hand pushes on the crate at the left. *(111F2023)*



a) Which of the following is true? Explain your answer.

   i) The force exerted by the smaller crate on the larger crate is less than the force exerted by the hand.

   ii) The force exerted by the smaller crate on the larger crate is more than the force exerted by the hand.

   iii) The force exerted by the smaller crate on the larger crate is the same as the force exerted by the hand.

b) The positions of the two crates are interchanged so that the larger crate is to the left of the smaller crate. Which of the following is true? Explain your answer.

   i) The force exerted by the larger crate on the smaller crate is less than the force exerted by the hand.

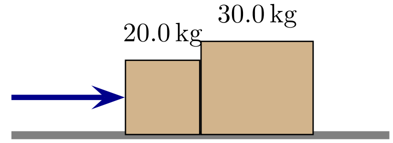
   ii) The force exerted by the larger crate on the smaller crate is more than the force exerted by the hand.

   iii) The force exerted by the larger crate on the smaller crate is the same as the force exerted by the hand.

c) For either of these arrangements, the crates could either be moving left or else right. Does the direction of motion affect the answers to the previous questions? Explain your answer.

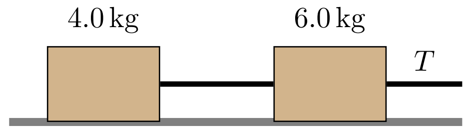
174 Pushing boxes in contact

Two boxes can move along a frictionless horizontal surface. The boxes maintain contact with each other. A person pushes with a 100 N force on the box at the left. Determine the force that the box at the left exerts on the box at the right. *(111F2023)*



175 Dragging connected crates

Two different crates can move along a horizontal surface. There is no friction between either crate and the surface. The crates are connected by a rope. A hand pulls on the other rope with tension T. *(111F2023)*



a) Which of the following is true? Explain your answer.

   i) The tension in the connecting rope is the same as T.

   ii) The tension in the connecting rope is more than T.

   iii) The tension in the connecting rope is less than T.

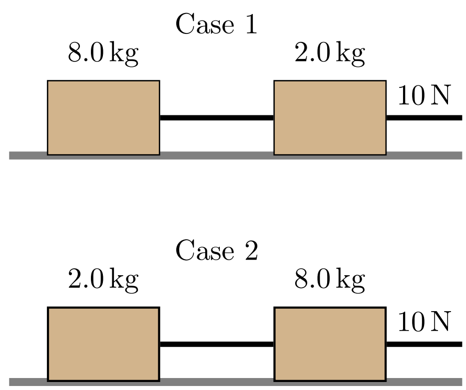
b) Which of the following is true? Explain your answer.

   i) The tension in the connecting rope depends on whether the heavier crate is to the left.

   ii) The tension in the connecting rope does not depend on whether the heavier crate is to the left.

176 Connected objects: tension and acceleration

Two objects on a frictionless horizontal surface are connected by a massless rope. They are connected in different orders and pulled by another massless rope. *(111F2023)*



a) Let a_1 be the acceleration for case 1 and a_2 the acceleration for case 2. Which of the following is true? Explain your choice.

   i) $a_1 = a_2$

   ii) $a_1 > a_2$

   iii) $a_1 < a_2$

b) Let T_1 be the tension in the rope connecting the blocks for case 1 and T_2 that for case 2. Which of the following is true? Explain your choice.

   i) $T_1 = T_2 = 10\,\mathrm{N}$

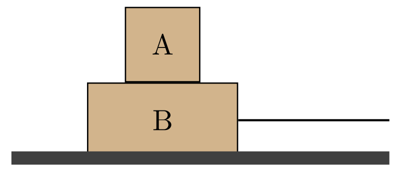
   ii) $T_1 < T_2 < 10\,\mathrm{N}$

   iii) $T_2 < T_1 < 10\,\mathrm{N}$

   iv) $T_1 = T_2 < 10\,\mathrm{N}$

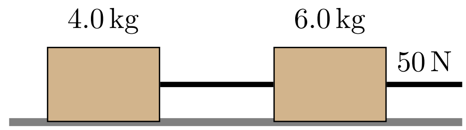
177 Slipping stacked objects

Two boxes are stacked and move along a frictionless horizontal surface as illustrated. Block A has mass 2.0 kg and block B has mass 3.0 kg. A rope is attached to block B and pulls horizontally with a 50 N force. The coefficient of friction between block A and block B is 0.25. Determine the acceleration of each block, assuming that they both move right and that B moves faster than A. *(111F2023)*



178 Connected objects: tension and acceleration

Two boxes can move along a horizontal surface. There is no friction between either box and the surface. The boxes are connected by a rope. A hand pulls on the other rope with force 50 N. *(111F2023)*

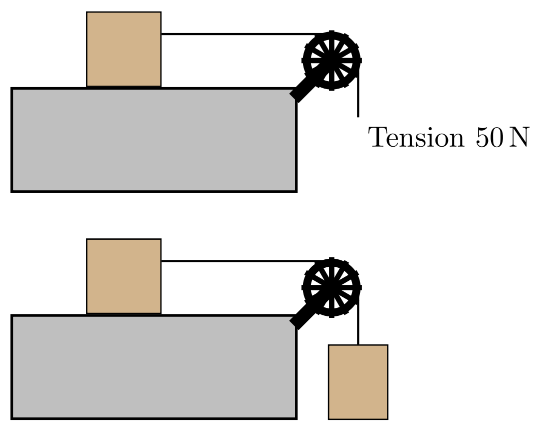


a) Determine the acceleration of each box.

b) Determine the tension in the rope connecting the boxes.

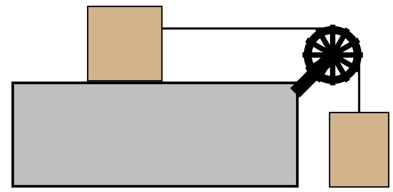
179 Connected objects: block dragged along a surface

A block on a surface can be dragged along a frictionless surface by a connecting rope in two ways. Either a person exerts a force on the rope or else a suspended block exerts a force on the rope. Suppose that the person exerts a 50 N tension force on the rope and that the weight (gravitational force on) of the suspended block is exactly 50 N. In which case is the acceleration of the block on the horizontal surface largest? Explain your answer. *(111F2023)*



180 Level/suspended blocks without friction

Two blocks are connected by a string, which runs over a massless pulley. A 10 kg block is suspended and a 5.0 kg block can slide along a frictionless horizontal surface. The string connected to the block on the surface runs horizontally. The blocks held at rest and then released. They move, constantly speeding up. Which of the following is true regarding the tension in the connecting string, T, while they move? Explain your choice. *(111F2023)*



i) $T = 0$.

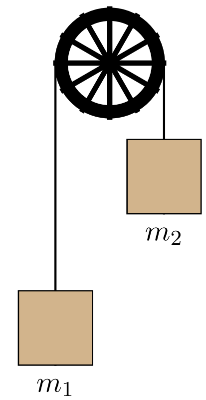
ii) $98\,\mathrm{N} > T > 0$.

iii) $T = 98\,\mathrm{N}$.

iv) $T > 98\,\mathrm{N}$

181 Atwood's machine

Two blocks, with masses indicated, are connected by a string which runs over a massless pulley. The aim of this exercise is to determine the acceleration of the blocks. *(111F2023)*



a) Draw a free body diagram for the *block on the left.*

b) Write Newton's Second Law in component form for the *block on the left,* i.e. write

$$F_{\text{net }x} = \Sigma F_x = \cdots \tag{15}$$
$$F_{\text{net }y} = \Sigma F_y = \cdots \tag{16}$$

Insert as much information as possible about the components of acceleration at this stage. The resulting equations will generate much of the algebra that follows.

c) List all the components of all the forces for the block on the left.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

Force	x comp	y comp
$\vec{\mathbf{F}}_g$		
$\vec{\mathbf{n}}$		
$\vdots$		

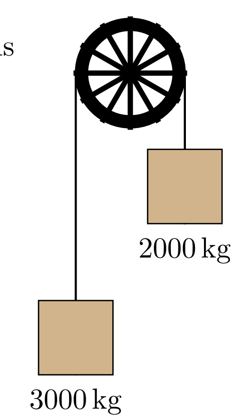
d) Use Eqs. (15) and (16) and the components to obtain an equation relating the tension in the rope and the acceleration of the block on the left. Can you solve this for acceleration at this stage?

e) Repeat parts a) to d) for the *block on the right.* Be careful about the acceleration!

f) Combine the equations for the two objects to obtain the acceleration and the tension in the rope.

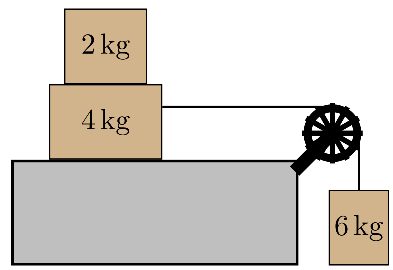
182 Counterbalanced elevator

A 3000 kg elevator is connected to a 2000 kg block by a rope that runs over a pulley. Determine the acceleration of the elevator. *(111F2023)*



183 Stacked objects on a surface connected to a suspended object

Various boxes are arranged as illustrated. The 4 kg block lies on a table with a horizontal surface. *(111F2023)*



a) Suppose that all the blocks are at rest. Is there a friction force between the 4 kg block and the table? If so, in which direction? Explain your answer.

b) Suppose that all the blocks are at rest. Is there a friction force between the 2 kg block and the 4 kg block? If so, in which direction? Explain your answer.

c) Suppose that the block on the table accelerates to the right and the 2 kg block does not slip relative to the 4 kg block. Is there a friction force between the 2 kg block and the 4 kg block? If so, in which direction? Explain your answer.

184 Merry-go-round

A merry-go-round is a large flat disk that spins around a vertical axis through its center. A child is at the edge of a merry-go-round with radius 3.0 m. The merry-go-round spins so that the child's acceleration is $1.5g$. Determine the period and frequency of orbit for this to occur. *(111F2023)*

185 Vinyl turntable

A turntable that plays vinyl records rotates at 33 rpm. The radius if the turntable is 0.15 m. *(111F2023)*

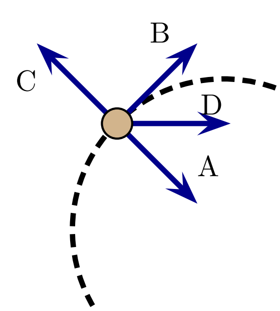
a) Determine the frequency of the turntable.

b) Determine the period of the turntable.

c) Determine the speed of a point on the edge of the turntable.

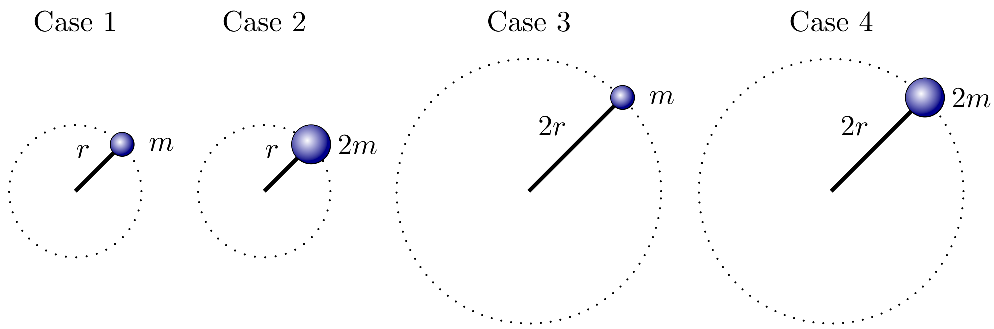
186 Bug walking in a circle

A bug walks at a constant speed in a circular path on a horizontal surface. Which vector best illustrates the net force on the bug at the illustrated moment? Explain your choice. *(111F2023)*



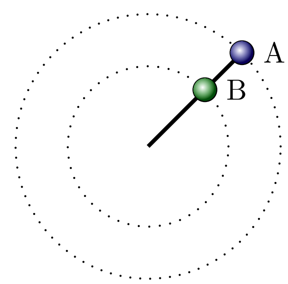
187 Balls swinging on the end of strings

Various balls at the end of strings swing in circles, with the same speed, on a horizontal frictionless surface. The diagram illustrates this as viewed from above. Rank the cases in order of increasing tension in the string. Explain your answer. *(111F2023)*



188 Connected balls swinging in horizontal circles, 1

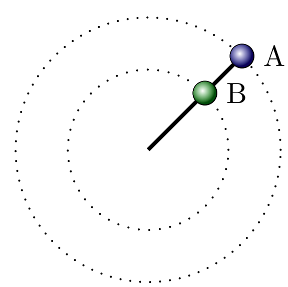
Two balls are connected by strings. They are on a horizontal frictionless surface and swing in horizontal circles about a central point; both strings point radially outward from the center as the balls move. The diagram illustrates this as viewed from above. *(111F2023)*



a) Draw a free body diagram, as viewed from the side, for ball B at the moment when the balls are at the leftmost location of their motion.
b) Draw the direction of the net force on the ball B at the moment when the balls are at the leftmost location of their motion.
c) How does the tension in the inner string compare (larger, smaller, same) to that in the string connecting the two balls? Explain your answer.

189 Connected balls swinging in horizontal circles, 2

Two balls are connected by strings. They are on a horizontal frictionless surface and swing in horizontal circles about a central point; both strings point radially outward from the center as the balls move. The diagram illustrates this as viewed from above. *(111F2023)*



a) Suppose that A has a larger mass than B. Is the tension in the inner string the same as, larger than or equal to the tension in the outer string? Explain your answer.
b) Suppose that A has a smaller mass than B. Is the tension in the inner string the same as, larger than or equal to the tension in the outer string? Explain your answer.

c) Now consider two particular balls, one with mass 3.0 kg and the other with mass 5.0 kg. They swing in circles as illustrated in one of the following two arrangements: i) the 3.0 kg is further out and the 5.0 kg is closer in, or ii) the 5.0 kg is further out and the 3.0 kg is closer in. In each case they swing with the same angular velocity. Which arrangement (larger mass on the outside, smaller mass on the outside) results in a larger tension in the outer string? Explain your answer.

190 Merry-go-round dynamics

A 50 kg child sits at the edge of a merry-go-round with radius 2.5 m. The merry-go-round rotates with frequency 15 revolutions per minute. *(111F2023)*

a) Determine the direction of the friction force on the child.

b) Determine the magnitude of the friction force on the child.

191 Child swinging on ice

A parent and child are each on a horizontal sheet of ice. The parent is fixed to the ice and swings the child, who is connected by a horizontal rope to the parent. The child slides without any friction with constant velocity. Determine an expression for the tension in the rope in terms of the mass of the child, the length of the rope and the angular velocity of the child. *(111F2023)*

192 Particle accelerator

The Large Hadron Collider (LHC) accelerates subatomic particles and then lets them collide with a target. During this trip the particles move through a circular tunnel with radius 2.80 km. One type of particle use in the LHC is a proton. Suppose that a proton travels this circle at 10% of the speed of light. Determine the net force on the proton. *Note: to be strictly correct this needs to include the effects of special relativity. The approach here will give an approximate force. (111F2023)*

193 Rotating Earth

Earth rotates, completing one rotation in a day (86400 s). Suppose that you stand on a scale at sea level at Earth's equator; the scale measures the normal force that it exerts and converts it into a reading in kilograms by dividing by $9.81\,\mathrm{m/s^2}$. In the following ignore air resistance. *(111F2023)*

a) Explain why the force measured by the scale will not equal the gravitational force exerted by Earth.

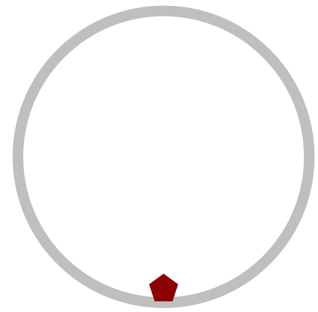
b) Assuming that your mass is 70.0 kg, determine the normal force and the scale reading.

c) Suppose that Earth's rotation were to speed up. How will this affect the scale reading?

d) If Earth were able to speed up, determine the time for one rotation such that the scale would read zero. How many hours would it take Earth to complete one rotation? What would happen to you if you were standing on the scale and Earth continued to speed up beyond this threshold?

194 Animals in a space station

A particular space station is essentially a giant circular hoop with radius 600 m. People and objects reside on the inside of the hoop. The hoop rotates at a constant rate. *(111F2023)*



a) Consider 30 kg dog on the inside of the space station. The dog is fixed at one point on the floor. Determine the speed of the space station so that the dog feels a normal force the same as it would at rest on Earth.
b) Determine the time taken for the space station of the previous part to complete one orbit.
c) A 4.0 kg rabbit also sits on the floor of the space station. It would also like to feel the same normal force as it does on Earth. Would the time taken for the space station to complete one orbit have to change to do this¿ Explain your answer.

195 Car turning

A 3000 kg car travels along a flat (horizontal) road. The road curves with a radius of 350 m. The maximum speed with which the car can do the turn is 18 m/s. *(111F2023)*

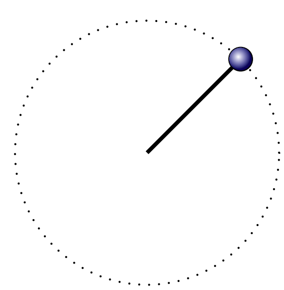
a) Determine the net force on the car. What force provides the net force?
b) Determine the (minimum) coefficient of static friction that allows the car to follow this curve at the given speed.

196 Coin on a turntable

A coin with mass m sits on a horizontal turntable with radius R. The distance from the turntable axle to the coin is d. The coefficient of static friction between the coin an the turntable is μ_s and the coefficient of kinetic friction is μ_k. The turntable is initially at rest and slowly speeds up. Determine an expression for the maximum angular velocity of the turntable so that the coin does not slip. *(111F2023)*

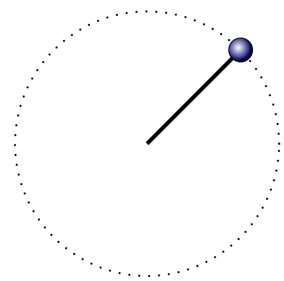
197 Ball swinging in a vertical circle, 1

A 0.80 kg ball swings with in a vertical circle at the end of a 0.50 m long string. The speed of the ball at the highest point in the circle is 3.0 m/s. Determine the tension in the string at this moment. *(111F2023)*



198 Ball swinging in a vertical circle, 2

A 0.20 kg ball swings with in a vertical circle at the end of a 0.50 m long string. *(111F2023)*



a) Draw a free body diagram for the ball at the highest point of the circle. Draw a free body diagram at the lowest point.

b) Suppose that the speed of the ball is constant throughout its motion. How does net force at the highest point of the circle compare (larger, smaller, same) to that at the lowest point of the circle? Use you answer to compare (larger, smaller, same) the tension in the string at the lowest point of the circle to the tension at the highest point of the circle.

c) Suppose that the string will break if the tension in it exceeds 5.0 N. Use Newton's second law to analyze the situation where the tension is largest (i.e. highest or lowest point) and determine the maximum speed with which the ball can move so that the string does not break.

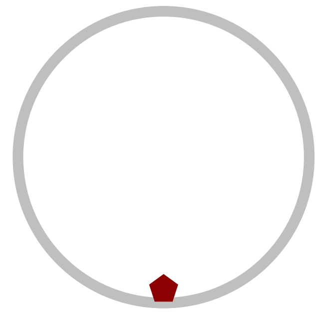
d) In general the speed of the ball can vary as it swings. As the speed decreases does the tension at the top of the circle increase, decrease or stay constant? Determine the minimum speed so that the tension is not zero. Describe what happens if the speed drops beneath this.

199 Monkey on a rope

A monkey with mass m_{monkey} swings from a rope. Is the tension in the rope at the bottom of the swing larger than, smaller than or the same as $m_{\text{monkey}}g$? Explain your answer. *(111F2023)*

200 Sliding inside a hoop

A small 0.10 kg object slides around the inside a frictionless vertical hoop with radius 0.25 m. *(111F2023)*



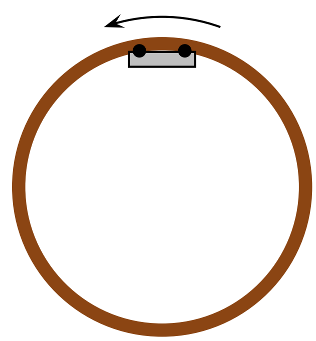
a) The speed of the object at the top of the hoop is 2.0 m/s. Determine the normal force exerted by the hoop on the object at the top of the loop.
b) The object reaches the bottom of the hoop with speed 3.71 m/s. Determine the normal force exerted by the hoop on the object at the bottom of the loop.
c) Determine the minimum speed at the top of the loop so that the object stays on the inside surface of the loop.

201 Loop-the-loop

A 50 g ball slides, without rolling, inside a vertically oriented circular loop with radius 80 cm. In two different situations, the ball is set into motion so that its speed is i) 4.0 m/s and the top of the loop and ii) 4.0 m/s and the bottom of the loop. Determine the normal force exerted by the loop on the ball in each case. *(111F2023)*

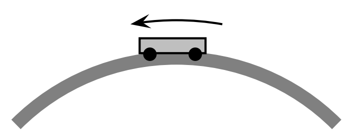
202 Roller coaster inside a circular loop

Two identical roller coasters cars, A and B, each move along a track that makes a vertically oriented circle with radius R. Each passes along the inside of the track at the top and is in contact with the track at this point. The speed of A is larger than the speed of B. Determine whether the normal force on A is the same as, smaller than or larger than the normal force on B. *(111F2023)*



203 Cart sliding over a hill

A 30 kg cart slides over a hill, which has a circular cross-section of radius 12 m. The speed of teh cart at the highest point is 4.0 m/s. Determine the normal force exerted by the hill on the cart. *(111F2023)*



Gravitation

204 Ordinary objects and gravitational forces

A 100 kg person stands near a 4000 kg elephant. Their centers of mass are 1.8 m apart. Determine the gravitational force exerted by the person on the elephant. *(111F2023)*

205 Scale of gravitational forces

Celestial objects are much larger than a typical 90 kg person and may be expected to exert much larger gravitational forces than the person. Suppose that this person stands 0.50 m away from a 20 kg dog. *(111F2023)*

a) Determine the ratio of the gravitational force exerted by Earth's Moon on the dog to the gravitational force exerted by the person on the dog.

b) Determine the ratio of the gravitational force exerted by Jupiter on the dog to the gravitational force exerted by the person on the dog. The nearest approach of Jupiter is about 6.3×10^{11} m. Are either of the forces exerted by celestial objects very much bigger?

206 Planet mass and free fall acceleration.

The radius of Earth can be obtained by geometrical measurements and is, on average 6.371×10^6 m. The acceleration due to Earth's gravity at the surface is $9.80\,\mathrm{m/s^2}$. *(111F2023)*

a) Determine the mass of Earth and compare your result to one that you could look up.

b) Grand Junction is located approximately 1400 m above sea level. Determine the free fall acceleration due to Earth's gravity at Grand Junction. Does this differ much from the acceleration at sea-level?

207 Moons of a planet

A planet has two moons. Moon B has twice the mass of Moon A. Moon B has an orbit with twice the radius of the orbit of Moon A. *(111F2023)*

a) Let F_A be the force exerted by the planet on Moon A and F_B be the force exerted by the planet on Moon B. Which of the following is true? Explain your answer.

  i) $F_B = 4F_A$
  ii) $F_B = 2F_A$
  iii) $F_B = F_A$
  iv) $F_B = \frac{1}{2} F_A$
  v) $F_B = \frac{1}{4} F_A$

b) Let a_A be the acceleration of Moon A and a_B be the acceleration of Moon B. Which of the following is true? Explain your answer.

  i) $a_B = 4a_A$
  ii) $a_B = 2a_A$
  iii) $a_B = a_A$
  iv) $a_B = \frac{1}{2} a_A$
  v) $a_B = \frac{1}{4} a_A$

208 Newton's cannonball

Newton's cannonball was a thought experiment in which a cannonball is fired from the top of a mountain and eventually orbits Earth. Suppose that a cannonball with mass m is fired horizontally from a mountain with altitude h above sea level, which is distance R_E from Earth's center. *(111F2023)*

a) **Starting with and using** Newton's Second Law, determine an expression for the cannonball's launch velocity, v so that it follows a circular orbit at height h above Earth's sea level.

b) Determine the speed with which the cannonball should be launched from the altitude of $8000\,\mathrm{m}$ above sea level to orbit as described above.

209 Newton's cannonball in a low orbit

Consider Newton's cannonball fired such that it orbits $3000\,\mathrm{m}$ (roughly the altitude of the Grand Mesa) above Earth's surface. Determine the speed of the cannonball. Ignore air resistance and any obstacles. *(111F2023)*

210 Mars 2020 spacecraft touchdown

The Mars 2020 spacecraft landed on Mars in February 2021. The components that landed had mass $3,649\,\text{kg}$. Assume that just before it landed on Mars, it fired its thrusters (engines) so that it descended at constant speed. Determine the force exerted by the thrusters. *(111F2023)*

211 Mars' orbit

Mars orbits the Sun in an approximately circular orbit with radius $2.28 \times 10^{11}\,\text{m}$. The period of orbit is $1.88\,\text{years}$ and Mars' mass is $6.42 \times 10^{23}\,\text{kg}$. *(111F2023)*

a) **Starting with and using Newton's Second Law** determine an expression for the mass of the Sun in terms of the period and radius of orbit of any planet that moves in a circular orbit around the Sun.

b) Use the result of the previous part to determine the mass of the Sun.

212 Orbiting satellite

A satellite orbits a planet with mass M_p in a circular orbit with radius r. The satellite's speed is constant. *(111F2023)*

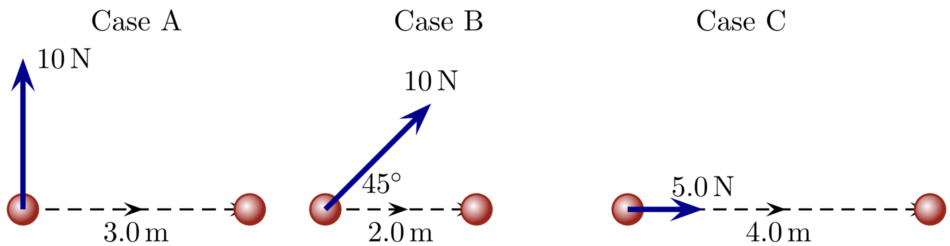
a) **Starting with and using** Newton's Second Law, derive an expression for the satellite's speed in terms of M_p and r.

b) Determine the speed of a satellite in a uniform circular orbit $60000\,\text{m}$ above the surface of the dwarf planet Ceres (mass $9.4 \times 10^{20}\,\text{kg}$ and radius $4.7 \times 10^{5}\,\text{m}$).

Work and Energy

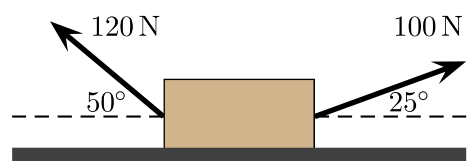
213 Ranking works

Three identical balls move under various forces as illustrated (there are other hidden forces present in each case). Rank these cases in order of increasing work done by the illustrated force. *(111F2023)*



214 Work done on a crate

A 20 kg crate moves along a horizontal frictionless surface. One person pulls up on the crate from the right and another pulls up on the left as illustrated. The crate is initially at rest and subsequently slides right for 5.0 m. *(111F2023)*

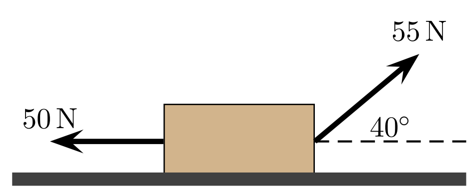


a) Determine the work done by each of the following forces: gravity, normal force, and the forces exerted by the two people.

b) Determine the net work done on the crate.

215 Tugging on a box

A 6.0 kg box moves 8.0 m to the right along a horizontal frictionless surface. Alice pulls left on the crate with a 50 N force as illustrated. Bob pulls right with a 55 N force, angled as illustrated. *(111F2023)*



a) Determine the work done by Alice on the box.

b) Determine the work done by Bob on the box.

c) Determine the net work done on the box.

216 Raising an elevator

An elevator is raised by a cable and slows to a stop. *(111F2023)*

a) While the elevator slows is the work done by the tension in the cable positive, negative or zero? Explain your answer.

b) While the elevator slows is the magnitude of the work done by tension larger than, smaller than or the same as the magnitude of the work done by gravity? Explain your answer.

217 Object sliding down a ramp

A $4.0\,\mathrm{kg}$ box slides down a ramp that makes and angle of 20° from the horizontal. The length of the ramp is $3.0\,\mathrm{m}$. *(111F2023)*

a) Determine the work done by gravity as the box slides all the way down the ramp from the top to the bottom.

b) Determine the work done by the normal force as the box slides all the way down the ramp from the top to the bottom.

218 Cart sliding up and down a ramp

A cart approaches a ramp. The cart slides up the ramp, reverses direction and then slides down. *(111F2023)*

a) Consider the segment of the motion where the cart slides up the ramp. Is the work done by gravity positive, negative or zero? Explain your answer.

b) Consider the segment of the motion where the cart slides down the ramp. Is the work done by gravity positive, negative or zero? Explain your answer.

219 Barge in a canal

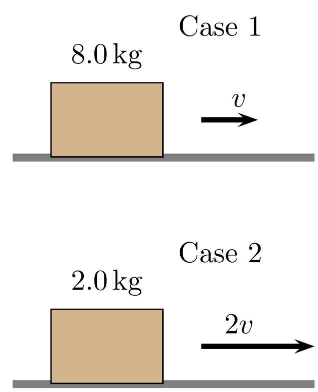
A barge can move along a straight canal. The barge is pulled by a donkey that walks along the bank of the canal. A rope connects the donkey to the barge. The donkey pulls the barge in a straight line for a distance of $750\,\mathrm{m}$. *(111F2023)*

a) Suppose that the rope makes an angle of 15° from the forwards direction of the barge's motion and the the donkey exerts a constant force of $275\,\mathrm{N}$ on the barge. Determine the work done by the donkey.

b) Now suppose that the rope length is changed and the result is that the rope makes an angle of 8.0° from the forwards direction of the barge's motion. Determine the force that must be exerted by the donkey so that it does the same work as it had done previously.

220 Kinetic energy

Two boxes on move on a frictionless horizontal surface. The speed of the box in case 2 is twice the speed of the box in case 1. Let K_1 be the kinetic energy of the block in Case 1 and K_2 be the kinetic energy of the block in Case 2. Which of the following is true? Explain your answer. *(111F2023)*



i) $K_1 = \frac{1}{4} K_2$

ii) $K_1 = \frac{1}{2} K_2$

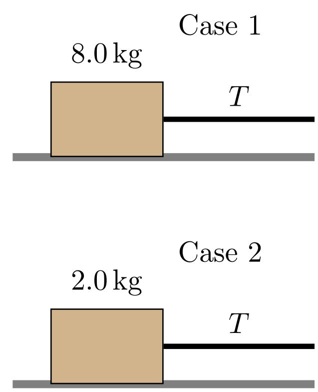
iii) $K_1 = K_2$

iv) $K_1 = 2K_2$

v) $K_1 = 4K_2$

221 Pulling a box: energy and speed

Two boxes on a frictionless horizontal surface are initially at rest. Both are pulled by a rope with the same tension for the same distance. *(111F2023)*



a) Let K_1 be the kinetic energy of the block in Case 1 after it has been pulled through distance d. Let K_2 be the kinetic energy of the block in Case 2 after it has been pulled through distance d. Which of the following is true? Explain your answer.

  i) $K_1 = \frac{1}{4} K_2$

  ii) $K_1 = \frac{1}{2} K_2$

  iii) $K_1 = K_2$

  iv) $K_1 = 2K_2$

  v) $K_1 = 4K_2$

b) Let v_1 be the speed of the block in Case 1 after it has been pulled through distance d. Let v_2 be the speed of the block in Case 2 after it has been pulled through distance d. Which of the following is true? Explain your answer.

  i) $v_1 = \frac{1}{4} v2$

  ii) $v_1 = \frac{1}{2} v_2$

  iii) $v_1 = v_2$

  iv) $v_1 = 2v_2$

  v) $v_1 = 4v_2$

222 Molecular kinetic energy

The average kinetic energy of molecules in a gas only depends on the temperature of the gas *(side note: this is about translational kinetic energy only)*. Consider a gas of helium molecules (each helium molecule consists of just one helium atom) and a gas of neon molecules (each neon molecule consists of one neon atom). Suppose that these gases are both at the same temperature. For these gases, how does the typical speed of the helium molecules compare (same, smaller, larger, ...) to that of the neon molecules. *(111F2023)*

223 Energy, distance and speed

A rock is initially at rest on a horizontal sheet of ice. Alice pushes the rock with a constant horizontal force. The rock moves in a straight line, first passing Bob who is 5.0 m from the initial location and then Carol, who is 5.0 m from Bob. *(111F2023)*

a) Let ΔK_1 be the change in the rock's kinetic energy from its initial location until it reaches Bob. Let ΔK_2 be the change in the rock's kinetic energy from the moment it passes Bob until it reaches Carol. Which of the following is true? Explain your answer.

   i) $\Delta K_2 < \Delta K_1$

   ii) $\Delta K_2 = \Delta K_1$

   iii) $\Delta K_2 > \Delta K_1$

b) Let v_1 be the rock's speed as it reaches Bob. Let v_2 be the rock's speed as it reaches Carol. Which of the following is true? Explain your answer.

   i) $v_2 = v_1$

   ii) $\sqrt{2}v_1 > v_2 > v_1$

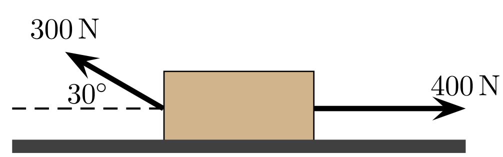
   iii) $v_2 = \sqrt{2}v_1$

   iv) $v_2 = 2v_1$

   v) $v_2 > 2v_1$

224 Work and motion

A 60 kg crate moves along a horizontal frictionless surface. Alice pulls up and left on the crate with a 300 N force as illustrated. Bob pulls right with a 400 N force. The crate is initially at rest and moves 5 m to the right while they pull on it. *(111F2023)*



a) Determine the work done by Alice on the crate.

b) Determine the work done by Bob on the crate.

c) Determine the net work done on the crate.

d) Determine the speed of the crate at moment that it reaches 5.0 m from its starting point.

225 Crate sliding down a frictionless ramp

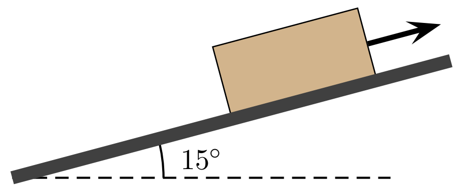
A 6.00 kg crate is at rest at the top of a frictionless ramp that is inclined at 25° from the horizontal. The length of the ramp is 3.00 m. Use work and energy to answer the following questions. *(111F2023)*

a) The crate is released. Determine the net work done on the crate as it moves from the top to the bottom of the ramp.

b) Use the net work to determine the speed of the block as it reaches the bottom of the ramp.

226 Box lowered down a frictionless ramp

A 5.00 kg box is at rest at the top of a frictionless ramp that is inclined at 15° from the horizontal. The length of the ramp is 8.00 m. A rope pulls on the crate with a 9.00 N force parallel to and up the ramp. *(111F2023)*



a) Determine the work done by gravity on the box from the top to bottom of the ramp.

b) Determine the work done by the rope on the box from the top to bottom of the ramp.

c) Determine the speed of the box at the bottom of the ramp.

227 Crate lowered down a frictionless ramp

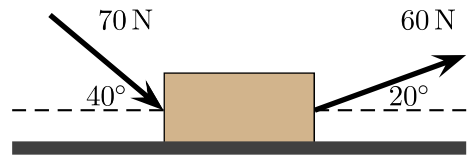
A 20.0 kg crate is at rest at the top of a frictionless ramp that is inclined at 30° from the horizontal. The length of the ramp is 5.00 m. A rope pulls on the crate with a 70.0 N force parallel to and up the ramp. Use work and energy to determine the speed of the crate when it reaches the bottom of the ramp. *(111F2023)*

228 Box pushed up a frictionless ramp

A 20.0 kg box is at rest at the bottom of a frictionless 3.50 m long ramp that is inclined at 15° from the horizontal. A person pushes horizontally on the box with a 60.0 N force. Determine the speed of the crate when it reaches the top of the ramp using energy. *(111F2023)*

229 Pushing a crate across a rough floor

A 10 kg crate can move across a rough horizontal floor. One person pulls up on the crate from the right and another pushes down as illustrated. The crate is initially at rest and subsequently slides right for 5.0 m. The coefficient of kinetic friction between the crate and floor is 0.20. *(111F2023)*



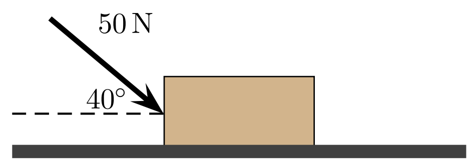
a) Determine the friction force on the crate.

b) Determine the work done by each of the following forces: gravity, normal force, friction force and the forces exerted by the two people.

c) Determine the speed of the crate at the moment that it has moved 5.0 m from its original location.

230 Pushing a crate at a constant speed along a rough floor

A worker pushes a crate a distance of 6.0 m along a rough horizontal surface. The crate moves with a constant speed. *Use work* to determine the frictional force acting on the cart. *(111F2023)*



231 Sliding hockey puck

A 0.150 kg hockey puck slides along a horizontal surface. Initially the surface is frictionless and the puck slides with speed 18 m/s. The puck then hits a rough section of floor which provides a constant friction force. The puck stops a distance of 2.5 m after hitting the rough section. *(111F2023)*

a) Determine the net work done on the puck as it moves across the rough section. *Hint: consider kinetic energy.*

b) Use the net work to determine the magnitude of the friction force acting on the puck.

c) Determine the coefficient of kinetic friction between the puck and the floor.

232 Cannonball energy

Two identical cannonballs are fired from the ground with the same speed. Cannonball Y is fired vertically upward while cannonball Z is fired at an angle of 60° above the horizontal. Consider the highest points reach by the cannonballs. *(131Sp2023)*

a) Explain which cannonball has the largest kinetic energy at its highest point.

b) Explain which cannonball has the largest gravitational potential energy at its highest point. Use this to determine which cannonball reaches a higher point.

233 Rocks launched from bridges

Two rocks are launched from a bridge across a river. The point of launch is 4.0 m above the water in the river. In the following ignore air resistance and assume that there are no obstacles between the rocks and the river. *(111F2023)*

a) Suppose that the two balls are identical. One is launched horizontally and the other is launched at an angle of 45° above the horizontal. Consider the speeds of each ball as they pass a point 3.0 m above the river. Which ball is travelling with a faster speed? Explain your answer.

b) Conside the same situation but where the balls have different masses. The lighter ball is launched horizontally. Which ball is travelling with a faster speed? Explain your answer.

234 Energy and projectiles

A 15 kg cannonball is fired, leaving the ground with speed 30 m/s. We aim to determine the speed of the cannonball when it reaches a height of 25 m above the ground. *(111F2023)*

a) Sketch the situation showing the trajectory of the cannonball. Indicate an "initial" and a "final" moment.

b) Determine the total energy at the moment that the cannonball is launched.

c) Determine the total energy when the cannonball is 25 m above the ground.

d) Determine the kinetic energy of the cannonball when it is 25 m above the ground.

e) Determine the speed of the cannonball when it is 25 m above the ground.

235 Work done by a string

A ball swings in a circle at the end of a string. Which of the following is true? Explain your answer. *(111F2023)*

i) The string does positive work on the ball whenever the ball speeds up and negative work on the ball whenever it slows down.

ii) The string does positive work on the ball regardless of its speed.

iii) The string does negative work on the ball regardless of its speed.

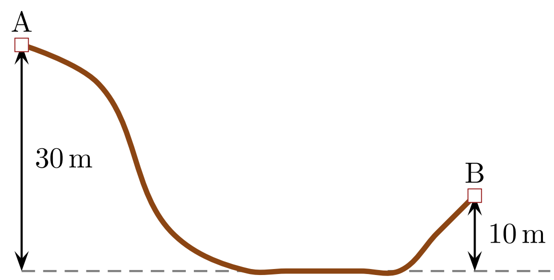
iv) The string does zero work on the ball regardless of its speed.

236 Cart and ramp

A 20 kg cart is launched with speed 4.0 m/s at the base of a frictionless ramp. Determine the maximum vertical height that the cart ascends as it moves up the ramp. *(111F2023)*

237 Ski jump

A 70 kg skier starts at rest at point A on the illustrated slope and then slides down, approaching launch point B. Ignore friction and air resistance. *(111F2023)*



a) Determine the total energy of the skier at A.

b) Determine the total energy of the skier at point B.

c) Determine the speed of the skier at point B.

d) Determine the maximum speed of the skier between points A and B.

238 Sledding

King Zog, with mass 160 kg, and Queen Geraldine, with mass 80 kg, sled down an icy hill. They start from rest at the same point above the bottom of the hill. Ignore friction and air resistance. Which of the following is true regarding their speeds at the bottom of the hill? Explain your answer. *(111F2023)*

i) Same speeds.

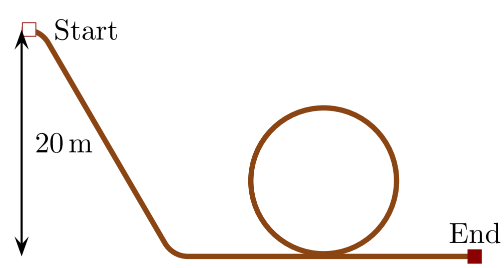
ii) Geraldine's speed is twice that of Zog.

iii) Geraldine's speed is four times that of Zog.

iv) Zog's speed is larger than Geraldine's speed.

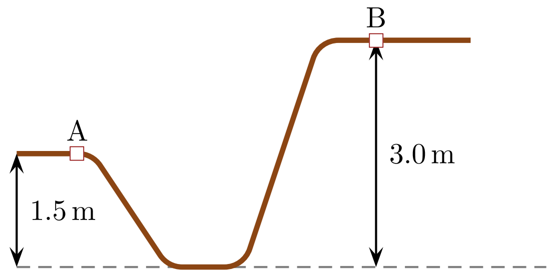
239 Loop-the-loop rollercoaster

A 100 kg rollercoaster starts from rest at the top of the illustrated track. The rollercoaster completes the loop. Determine speed of the rollercoaster at the end of the track. Ignore friction and air resistance. *(111F2023)*



240 Skate park, 1

A skater approaches point A with speed 10 m/s. The skater slides along the illustrated track. Ignore friction and air resistance. *(111F2023)*



a) Suppose that the mass of the skater is 60 kg. Determine the speed of the skater at point B.

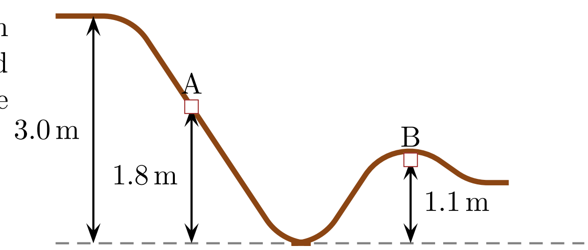
b) Determine the maximum speed of the 60 kg skater along the track.

c) Determine the minimum speed that the 60 kg skater should have at A so that she reaches B.

d) Would any of your results to the previous parts be different if the mass of the skater were different? Explain your answer.

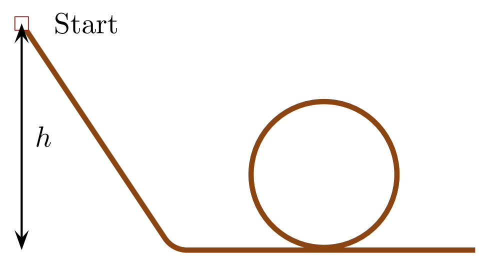
241 Skate park, 2

A 60 kg skater moves down a ramp at point A with speed 3.0 m/s. The skater slides along the illustrated track. Ignore friction and air resistance. Determine the speed of the skater at point B. *(111F2023)*



242 Completing the loop

A cart slides down a frictionless track toward a circular loop with radius R. The cart is released from rest. *(111F2023)*

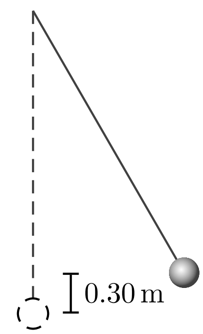


a) Determine an expression for the minimum speed for the cart at the top of the loop such that it completes the loop.

b) Determine an expression for the minimum height at which the cart should be released so that it completes the loop.

243 Pendulum

A pendulum consists of a ball that swings from a string. A 1.4 m long pendulum is raised so that it is released from rest 0.30 m above its lowest point. Determine the maximum speed of the pendulum. *(111F2023)*



244 Swinging monkey

A monkey grabs a 3.0 m rope and swings in a circular arc. The monkey reaches a maximum speed of 4.0 m/s. Determine the maximum angle (from the vertical) reached by the monkey as it swings. *(111F2023)*

245 Tarzan

Tarzan, with mass 80 kg, grabs a 5.0 m rope and swings in a circular arc. As Tarzan begins to swing the rope is at an angle of 35° from the vertical. Determine Tarzan's maximum speed. *(111F2023)*

246 Spring forces

A 5.0 kg bag is suspended by a spring from the ceiling of an elevator. The spring constant is 4000 N/m. *(111F2023)*

a) The elevator and spring move up with a constant speed of 0.50 m/s. Determine the amount by which the spring is stretched.

b) The elevator and bag accelerate upwards with an acceleration of 3.0 m/s^2. Determine the amount by which the spring is stretched.

247 Monkey on a vertical spring

A monkey hangs from a spring which is attached to the ceiling of a building. The spring hangs vertically and the monkey bounces up and down without touching the floor. *(111F2023)*

a) As the monkey ascends toward and nears its highest point, the spring is compressed. Which of the following is true while this happens?

   i) The spring does positive work, gravity does positive work.
   ii) The spring does positive work, gravity does negative work.
   iii) The spring does negative work, gravity does positive work.
   iv) The spring does negative work, gravity does negative work.

b) As the monkey begins to descend away its highest point, the spring is still compressed. Which of the following is true while this happens?

   i) The spring does positive work, gravity does positive work.
   ii) The spring does positive work, gravity does negative work.
   iii) The spring does negative work, gravity does positive work.
   iv) The spring does negative work, gravity does negative work.

248 Oscillating block

A 6.0 kg block can slide along a frictionless table. It is attached to a spring with spring constant 30 N/m. The block is pulled 0.20 m from the spring's equilibrium position. The block oscillates. *(111F2023)*

a) Describe whether you can use constant acceleration kinematics to predict the block's speed as it passes the equilibrium point.

b) Determine the speed of the box as it passes the equilibrium point.

249 Work done by a spring

A 20 kg box on a rough horizontal floor is pushed against a spring with constant 800 N/m. The spring is compressed by 0.10 m. The coefficient of kinetic friction between the box and floor is 0.15. The box departs from the spring when the spring reaches its equilibrium state. *(111F2023)*

a) Determine the work done by the friction force on the box from the point of release until the box departs.

b) Determine the work done by spring on the box from the point of release until the box departs.

c) Determine the speed of the box at the point of departure.

d) Is the acceleration of the box constant during this process? Could you use constant acceleration kinematics and Newton's second law to determine the speed of the box at the point of departure.

250 Spring bumper

Two walruses (named X and Y), with the same masses, slide along horizontal sheets of ice. Each collides with a horizontal spring mounted to a wall; the springs are identical. Prior to hitting the spring, walrus X moved with speed twice that of walrus Y. The springs compress, bringing each walrus to a stop. Which of the following is true regarding the distances by which the springs compress? Explain your answer. *(111F2023)*

i) Springs compress by the same distance.
ii) X compresses spring by twice as much Y.
iii) X compresses spring by four times as much Y.
iv) X compresses spring by half as much Y.
v) X compresses spring by a quarter of what Y compresses.

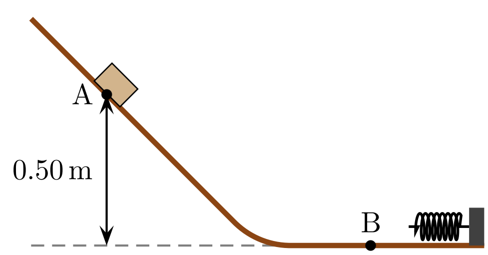
251 Bungee jumper

A 100 kg person is attached to a bungee cord and, starting at rest, jumps off a bridge that is 120 m above a river. The bungee cord behaves like a spring and the length of the cord when it is unstretched is 100 m. The spring constant of the cord needs to be such that person stops just above the river. *(111F2023)*

a) Determine the total energy of the system at the moment that the person jumps.
b) Determine the total energy of the system at the moment that the person stops just above the river and use the result to determine the spring constant of the bungee cord.
c) Determine the maximum force that the bungee cord exerts on this person.
d) Now suppose that a person with mass 70 kg jumps from the same bridge using the same cord. Determine the maximum stretch in the spring, the height above the river at which the person reverses direction and the maximum force exerted on the person.

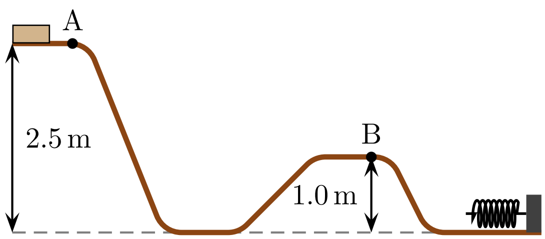
252 Box, ramp and spring

A 6.0 kg box is released from rest at on the illustrated frictionless track. The box slides down the ramp, passes B and collides with a spring (constant 6000 N/m). While it moves friction and air resistance can be ignored. *(111F2023)*



a) Determine the speed of the box at point B.
b) Determine the maximum distance by which the spring is compressed.

253 Sled and spring bumper



A 100 kg sled moves along the illustrated track. At point A it moves right with speed 5.0 m/s. While it moves friction and air resistance can be ignored. *(111F2023)*

a) Determine the energy of the sled at point A.

b) Determine the kinetic energy of the sled when it is at point B.

c) Determine the speed of the sled at point B.

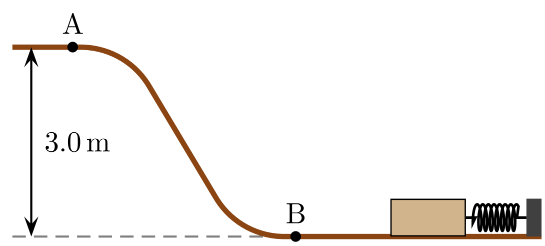
The sled approaches a spring with spring constant 5000 N/m.

d) Determine the speed of the sled just before it hits the spring.

e) Determine the maximum distance by which the spring is compressed.

f) Determine the maximum force exerted by the spring as the sled compresses it.

254 Spring-launched sled



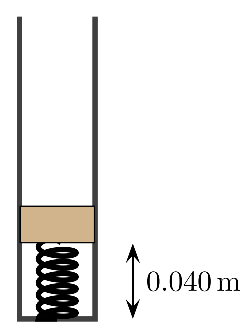
A 10.0 kg sled is pushed against a spring with spring constant 4000 N/m. The sled is held at rest while the spring is compressed by 0.45 m. It is released and then travels along the illustrated frictionless surface. *(111F2023)*

a) By the time that the sled passes point B it has left the spring. Determine the speed of the sled at point B.

b) Determine the speed of the sled at point A.

255 Spring gun

A spring gun consists of a vertical pipe with frictionless walls. A 30 g block is pushed against a spring, which is attached to the base of the pipe. In equilibrium the top of the spring is 0.050 m above the base of the pipe. The block is pushed against the spring and released from the indicated location while the pipe points vertically. *(111F2023)*



a) Determine the spring constant so that the maximum height above the base of the pipe that the block reaches is 12.00 m.

b) Determine the maximum velocity of the block.

256 Crate and ramp

A 10 kg crate is launched with speed 16 m/s at the base of a frictionless ramp that is inclined at 25° from the horizontal. Use work and energy to answer the following questions. *(111F2023)*

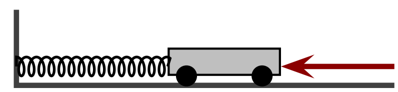
a) Ignoring air resistance, determine the distance along the ramp that the crate travels before stopping (briefly at its highest point).

b) Ignoring air resistance, determine the vertical height gained by the crate at the highest point that it reaches.

c) Suppose that the crate only travels 20 m because of air resistance that results in a force opposite to the crate's motion. Assuming that the air resistance is constant, determine the magnitude of the air resistance force.

257 Spring, cart and hand

A 5.0 kg cart can slide along a frictionless horizontal surface. A spring, with spring constant 400 N/m connects the cart to a wall. The spring is initially compressed by 0.25 m and the cart is held at rest. It is released and subsequently a hand pushes with a constant 30 N force against the spring as the spring relaxes. Determine the speed of the cart when the spring reaches its equilibrium position. *(111F2023)*



258 Power delivered by engines

Two engines pull identical objects along horizontal surfaces. Engine A delivers 2000 W of power and engine B delivers 4000 W. Engine A pulls for 5 min and engine B for 2 min. Which of the following is true? Explain your answer. *(111F2023)*

i) Engine A delivers more work than engine B.

ii) Engine A delivers less work than engine B.

iii) Engine A delivers the same work as engine B.

iv) There is not enough information to decide.

259 Lifting bananas

A 150 kg bunch of bananas is lifted by a vertical rope through a distance of 7.5 m. It takes 16 s to do this and for all but the initial and final moments it moves with constant speed. Determine the power delivered by the tension in the rope. *(111F2023)*

260 Hoisting fish

King Zog and Queen Geraldine are fishing from a bridge and they catch identical twin fish, each with mass 5.0 kg. They hoist the fish at constant speeds to the bridge 8.0 m about the water. Zog takes 10 s to hoist his fish and Geraldine 7.5 s to hoist her fish. *(111F2023)*

a) Which of the following is true? Explain your answer.

   i) Zog and Geraldine do the same work.
   ii) Zog does more work than Geraldine.
   iii) Zog does less work than Geraldine.

b) Which of the following is true? Explain your answer.

   i) Zog and Geraldine expend the same power.
   ii) Zog expends less power.
   iii) Zog expends more power.

261 Solar energy

The Sun delivers energy in the form of electromagnetic waves to Earth. At the outer edge of Earth's atmosphere, the total power per square meter *(the solar irradiance)* is 1360 W/m^2. This is diminished at Earth's surface by the atmosphere and depends on the angle of the Sun. At some location it is reduced to 1050 W/m^2. *(111F2023)*

a) A satellite uses solar panels to gather energy. If the satellite requires 10 kW of power, what would the necessary area of its solar panels be (assuming that the panels are 100% efficient)?

b) Suppose that a solar plant on Earth is required to provide 5.0×10^9 J of energy per hour. Determine the area of the Earth's surface that the solar panels would have to cover if they are only 25% efficient.

262 Raising an elevator

An 2000 kg elevator is lifted by a cable attached to a motor. It moves at a constant speed through a vertical distance of 25 m. It takes 75 s to do this. *(111F2023)*

a) Determine the work done by gravity as the elevator is lifted.

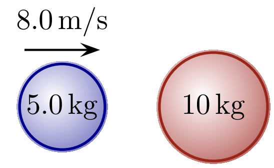
b) Determine the work done by the cable as the elevator is lifted.

c) Determine the power delivered by the motor as it raises the elevator.

d) Suppose that the elevator were raised through the same distance and starting at the same speed but with the speed decreasing at a constant rate as it ascends. How would the magnitude of the work done by the cable compare (larger, smaller,. . .) to that done by gravity? Explain your answer using physics. What would this imply for the power delivered by the motor compared to the situation where the elevator is raised at a constant speed?

Momentum

263 Colliding balls, 1



Two balls, isolated from all other objects, are initially as illustrated. The 5.0 kg ball moves directly toward the 10 kg ball. They collide and subsequently the 10 kg ball moves right with speed 3.0 m/s. The aim of this exercise will be to determine the speed and direction of motion of the smaller ball after the collision. *(111F2023)*

a) Determine the momentum of the smaller ball before the collision.

b) Determine the momentum of the larger ball before the collision.

c) Determine the momentum of the system before the collision.

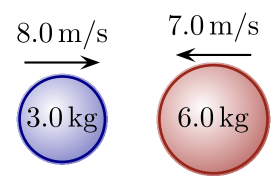
d) Determine the momentum of the larger ball after the collision.

e) Determine the momentum of the smaller ball after the collision.

f) Determine the velocity of the smaller ball after the collision.

g) Suppose that the construction of the balls was different and that after the collision the larger ball moves right with speed 5.0 m/s. Determine the velocity of the smaller ball after the collision.

264 Colliding balls, 2



Two balls, isolated from all other objects, initially move toward each other as illustrated. The 3.0 kg ball moves directly toward the 6.0 kg ball. The balls collide and subsequently the 3.0 kg ball moves left with speed 4.0 m/s. Determine the velocity of the larger ball after the collision. *(111F2023)*

265 Space collision

A 100 kg astronaut is at rest in space. A 0.0050 kg fleck of paint moves toward the astronaut with speed 15×10^3 m/s. It collides with and sticks to the astronaut. *(111F2023)*

a) Write an expression for the total momentum of the system before the collision in terms of the masses and speeds of the astronaut and paint. Determine the total momentum of the system before the collision (assume that the paint fleck initially moves along the positive x axis).

b) Write an expression for the total momentum of the system after the collision in terms of the masses and speeds (after collision) of the astronaut and paint.

c) Use momentum conservation to determine the speed of the astronaut after the collision.

d) Now suppose that the paint fleck bounced off the astronaut and reverses direction with speed 8.0×10^3 m/s. Determine the speed of the astronaut after the collision.

266 Railroad car carrying sand

An empty 3000 kg rail car has an open top and moves right with speed 5.0 m/s (it slides along the tracks without a locomotive pulling it) It passes beneath a chute that pours sand into the car. The sand hits the car vertically and after it has passed the car moves with speed 3.0m/s. Determine the mass of the sand delivered to the car. *(111F2023)*

267 Sledder catching a ball

A person sits at rest on a sled on a sheet of ice; the combined mass of the person and sled is 95.0 kg. A 5.0 kg bowling ball is launched horizontally rightwards toward the person with speed 20 m/s. The person catches the ball and the person, sled and ball slide together at the same speed. *(111F2023)*

a) Determine their velocity after the ball has been caught.

b) Is kinetic energy conserved in this process?

Suppose that the person and sled had been moving left with speed 2.0 m/s prior to catching the ball.

c) Determine their velocity after the ball has been caught.

268 Bumper carts on ice

A parent slides in a cart (mass of both 100 kg) to the right with speed 6.0 m/s. A child on another cart (mass of both 60 kg) also slides to the right, initially ahead of the parent with speed 4.0 m/s. When they collide the parent holds onto the other cart. Both slide together. Determine their velocity after the collision. *(111F2023)*

269 Bouncing ball

A ball is thrown towards a vertical wall and is traveling horizontally at the moment that it hits the wall. It bounces back horizontally with approximately the same speed. *(111F2023)*

a) Someone correctly observes that the momentum of the ball is not conserved during this process. Explain why this is true.

b) Is the momentum of the system consisting of the ball and wall conserved during this process? Explain your answer.

270 Dropping a rock on a planet

An astronaut stands on a planet, holding a rock at rest above the surface of the planet. The planet, astronaut and rock are initially at rest. The astronaut releases the rock and it falls toward the planet. *(111F2023)*

a) While the rock falls is the total momentum of the planet/astronaut/rock system zero or not? Explain your answer.
b) While the rock falls does the planet remain at rest or not? Explain your answer.

271 Rebounding subatomic particles

A subatomic particle, labeled 1, with mass m_1 travels with speed v_1 directly toward another subatomic particle, labeled 2, with mass m_2 and initially at rest. The particle with mass m_1 rebounds, traveling left with speed $0.80v_1$ and the other particle travels right with speed v_2. Determine an expression for m_2 in terms of v_1, v_2 and m_1. *(111F2023)*

272 Jumping crowd

A crowd of 100000 people, each with mass 80 kg are at rest on Earth's surface. They all jump up simultaneously, leaving Earth's surface with speed 3.0 m/s (relative to the background). Determine Earth's recoil speed. *(111F2023)*

273 Mollusc propulsion

Many molluscs (e.g. octopus, squid, scallop) can move by propelling a jet of water away from their bodies. These creatures ingest a small quantity of water which they subsequently expel. Assume that the creature and ingested water is initially at rest.

a) A particular type of squid has mass 100g and moves with speed 0.70 m/s immediately after expelling a jet of water. The jet moves with speed 1.3 m/s. Determine the mass of the expelled water in the jet.
b) A particular scallop has mass 41 g. Assume that this expels 5.0 g of water with speed 2.5 m/s. Determine the speed with which the scallop moves afterward.

274 Ball launched from a moving cart

A 400 g cart slides along a laboratory bench with velocity 10.0 m/s to the right. A 100 g ball is initially on the cart and at rest relative to the cart. It is subsequently fired to the left and, after this, the velocity of the ball relative to the laboratory is 10.0 m/s to the left. Determine the velocity of the cart after the ball has been fired. *(111F2023)*

275 Separating carts

Two carts are at rest on a frictionless horizontal track. The mass of cart A is exactly four times the mass of cart B. A spring between the carts is released, the carts separate and cart A moves left with speed v. *(111F2023)*

a) Which of the following is true for cart B after they separate? Explain your answer.

   i) B moves left with speed v.

   ii) B moves left with speed $2v$.

   iii) B moves left with speed $4v$.

   iv) B moves right with speed v.

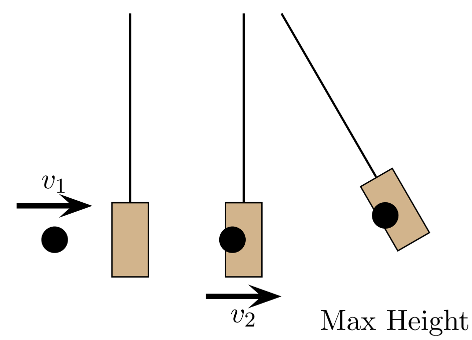
   v) B moves right with speed $2v$.

   vi) B moves right with speed $4v$.

b) Which cart gains the most kinetic energy? Explain your answer.

276 Ballistic pendulum

A ballistic pendulum consists of a 1.5 kg wooden block suspended at rest from a cord. A 0.0080 kg bullet is fired horizontally into the block. It embeds itself causing the block to swing upward, reaching a point 0.20 m above its lowest point. The idea is to use the maximum height reached by the pendulum to determine the speed of the bullet immediately before hitting the block. The process is illustrated at three instants. Let instant 1 be the moment just before the bullet hits, instant 2, the moment just after it embeds and instant 3, the moment at which it reaches its highest point. *(111F2023)*



a) Is momentum conserved from instant 1 to instant 2? Is mechanical energy, $E = K + U_{\text{grav}}$, conserved from instant 1 to instant 2?

b) Is momentum conserved from instant 2 to instant 3? Is mechanical energy, $E = K + U_{\text{grav}}$, conserved from instant 2 to instant 3?

c) Consider the period from instant 2 to instant 3 and use this to determine the speed of the bullet and block just after it embeds.

d) Consider the period from instant 1 to instant 2 and use this to determine the speed of the bullet and block just before it embeds.

277 Ballistic pendulum

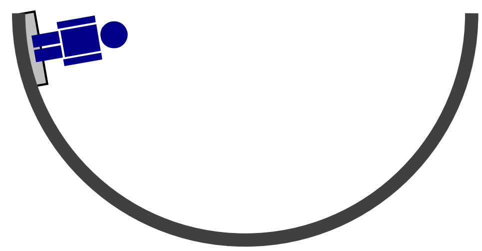
A 0.010 kg bullet is fired horizontally into a 2.0 kg block that is suspended at rest from a string just above the ground. The bullet collides with the block and sticks. The two then swing in a circle and the block reaches a height of 0.30 m above the ground. *(111F2023)*

a) Determine the speed of the bullet and block just after the bullet has stuck to the block.

b) Determine the speed of the bullet just before the bullet hits the block.

278 Half pipe

A 60 kg person rides a 5.0 kg skateboard. Both are at rest at the top of a half-pipe of radius 10 m. Ignore any friction and the rotation of the wheels. *(111F2023)*



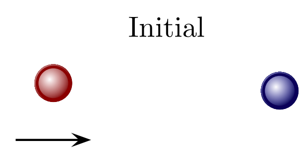
a) Determine the speed of the skateboarder at the bottom of the half pipe.

b) Suppose that there was another skateboarder, of mass 80 kg on a 5.0 kg skateboard at rest at the bottom of the pipe. The two skateboarders collide, hold each other and move together. Determine their speed moments after they collide.

c) Determine how high up the pipe the combined pair of skateboarders move.

279 Pool ball collision

A ball rolls right along a horizontal surface toward another ball, initially at rest. The diagram illustrates the approximate configuration of the balls. The balls collide and this collision is not necessarily head-on. Explain whether each of the following is a possible trajectory afterward. *(111F2023)*



i) Both balls are at rest.

ii) One ball moves $\uparrow$ and the other moves $\rightarrow$.

iii) One ball moves $\uparrow$ and the other moves $\downarrow$.

iv) One ball moves $\nearrow$ and the other moves $\rightarrow$.

v) One ball moves $\nearrow$ and the other moves $\searrow$.

Rotational Motion

280 Rotating bar bell

A rigid barbell rotates about the axle at O. The distance from the end labeled B to O is three times the distance from the end labeled A to O. *(111F2023)*

a) Which of the following is true? Explain your answer.
   i) The linear speed of B is nine times that of A.
   ii) The linear speed of B is three times that of A.
   iii) The linear speed of B is the same as that of A.
   iv) The linear speed of B is one third that of A.
   v) The linear speed of B is one ninth that of A.

b) Explain as precisely as possible how the centripetal acceleration of A is related (e.g. same, four times, ...) to that of B.

281 Bugs on a rotating disk

The PhET animation

http://phet.colorado.edu/en/simulation/rotation

illustrates bugs on a rotating disk. Use the link to run the animation. Once the animation has opened, use the Intro tab (this is the default tab). The two bugs can be moved to various parts of the disk and the disk can be made to rotate. Place one bug a quarter of the way from the center to the edge. Place the other half way from the center to the edge. *(111F2023)*

a) Predict how many times larger (or smaller) the velocity of the bug that is closer to the center is than that of the bug further from the center. Explain your prediction.

b) Predict how many times larger (or smaller) the centripetal acceleration of the bug that is closer to the center is than that of the bug further from the center. Explain your prediction.

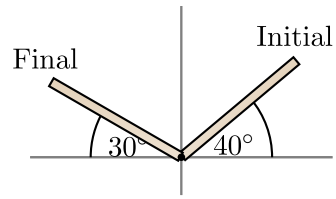
c) Run the animation by entering various angular velocities. It should display the velocity and acceleration vectors. Do your results for the previous parts agree with the observed acceleration vectors? Do your predictions from the previous parts depend on the angular velocity?

282 Rotating wheel RPM

A wheel rotates at 300 rpm (revolutions per minute). Determine the angular velocity of the wheel in rad/s. *(111F2023)*

283 Rotating beam

A narrow metal beam rotates at a constant rate about the axle through one end. Its positions are indicated at two instants 0.60 s apart. *(111F2023)*

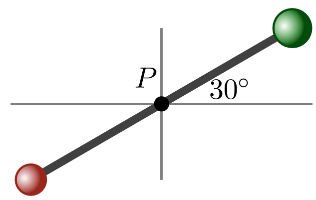


a) Determine the angular velocity of the beam in rad/s.

b) Determine the angular velocity of the beam in rpm.

284 Rotating bar bell angular position

A rigid barbell rotates about its midpoint P. At an initial moment the beam makes an angle of 30° from the horizontal. It subsequently rotates with a constant angular velocity of 1.5 rad/s. *(111F2023)*



a) Determine the angle between the bar and the horizontal at an instant 1.0 s after the initial instant.

b) Determine the angle between the bar and the horizontal at an instant 2.0 s after the initial instant.

285 Accelerating disk

A disk initially rotates with angular velocity 30 rad/s. It speeds up at a constant rate, reaching 100 rad/s at an instant 14 s later. Determine the angular acceleration of the wheel in $\mathrm{rad/s^2}$. *(111F2023)*

286 Accelerating wheel

A wheel initially rotates clockwise at 300 rpm. It speeds up at a constant rate, reaching 700 rpm at an instant 8.0 s later. Determine the angular acceleration of the wheel in $\mathrm{rad/s^2}$. *(111F2023)*

287 Hard drive rotation

A hard drive in a computer contains a disk that rotates at a rate of 7200 rpm. The diameter of the disk is 6.25 cm. *(111F2023)*

a) Determine the speed of a point at the edge of the disk while it is rotating at 7200 rpm.

b) Assume that the disk is initially at rest and accelerates at a constant rate reaching 7200 rpm in 200 ms. Determine the magnitude of the angular acceleration of the disk.

c) Determine the tangential component of the acceleration of a point on the edge of the disk and express it as a multiple of g.

288 Slowing turntable

A turntable (circular disk with an axle perpendicular to the disk through its center) initially rotates counterclockwise about the axle at 4800 rpm (revolutions per minute) and subsequently slows at a constant rate. It stops after exactly 30 revolutions. *(111F2023)*

a) Determine the angular acceleration of the turntable.

b) Determine the speed of a point 0.15 m from the turntable axle at the instant when it has completed 15 revolutions.

289 Rotating bicycle wheels

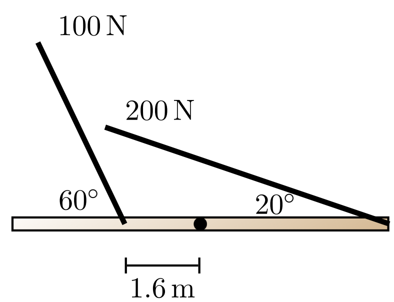
A bicycle travels with speed 6.5 m/s (about 15 mph). The diameter of the bicycle wheel is 0.700 m. Determine the angular velocity of the wheel (about the axle). *(111F2023)*

290 Rotation on Earth

Two people stand on Earth's surface. One is in Houston (latitude 29.8° N) and the other in Seattle (latitude 47.6° N). Assuming that Earth is a perfect sphere and rotates at a constant angular rate, determine the speed, the angular velocity and the acceleration of each person. *(111F2023)*

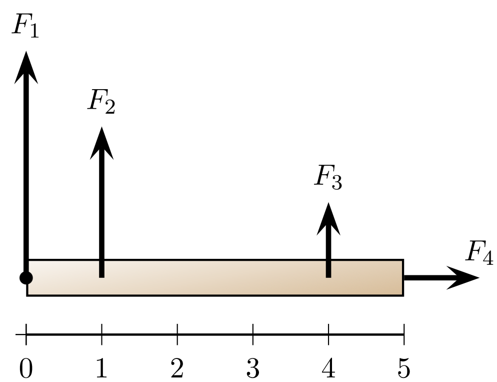
291 Multiple torques on a rod

A 3.0 kg rod with length 8.0 m can pivot about its midpoint. Two ropes pull as illustrated. The thickness of the rod is negligible. Determine the net torque on the rod. *(111F2023)*



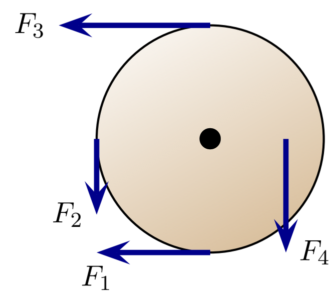
292 Torques on a beam

A beam can pivot about its left end. Various forces act on the beam as illustrated. An axis is provided for scale. The magnitudes of the forces are related via $F_1 = 3F_3$, $F_2 = 2F_3$, and $F_4 = F_3$. Rank the torques produced by the forces about the left end of the beam in order of increasing torque. Explain your answer. *(111F2023)*



293 Torques on a disk

A disk, with diameter 60 cm can rotate about an axle through its center and perpendicular to the disk. The illustrated forces act on the disk. The magnitudes of the forces are $F_1 = 15\,\mathrm{N}, F_2 = 10\,\mathrm{N}, F_3 = 20\,\mathrm{N}$ and $F_4 = 15\,\mathrm{N}$. The force F_4 acts at a point 2/3 of the distance from the center of the disk to the rim. *(111F2023)*

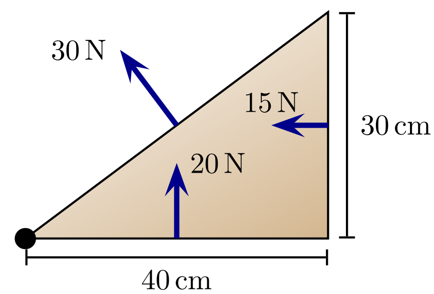


a) Determine the torque exerted by each force about the axle.

b) Determine the net torque on the disk.

294 Torques on a plywood triangle

Three forces act on a triangular piece of plywood as illustrated. Each acts midway along the edge. The plywood can pivot about the axle at the bottom left corner. *(111F2023)*

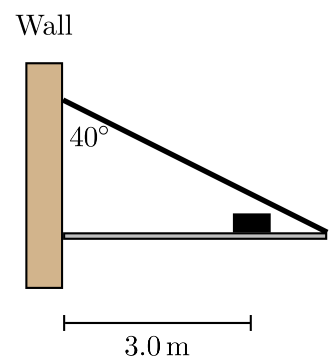


a) Determine the torque exerted by each force about the axle.

b) Determine the net torque on the plywood.

295 Beam perpendicular to a wall

A 4.0 m long, 80 kg beam is anchored to a wall and held at rest horizontally by a rope at the illustrated angle. A 10 kg box rests on the beam at the illustrated point. The aim of this exercise is to determine the tension in the rope. This would enable one to decide on the breaking strength of the rope. The thickness of the beam is negligible. *(111F2023)*



a) State the conditions for equilibrium.

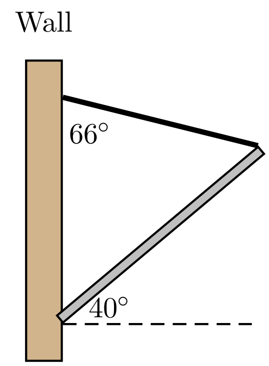
b) Draw all the force vectors on the beam.

c) Identify a pivot point (there are many correct possibilities – one is much more useful than the others) and determine expressions for the torque exerted by each force about the pivot.

d) Substitute the individual torques into one of the conditions for equilibrium and obtain an expression for the tension in the rope.

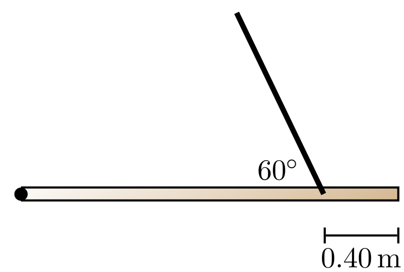
296 Raised drawbridge

A 5.0 m long, 600 kg drawbridge is anchored to a castle wall. A rope holds the drawbridge at rest at the illustrated angle. While this happens a 120 kg knight in armor dangles vertically downward from the right end of the drawbridge. Determine the tension in the rope. *(111F2023)*



297 Beam in equilibrium, 1

A 10 kg beam with length 2.0 m can pivot about its left end. A rope is attached as illustrated. The thickness of the beam is negligible. *(111F2023)*



a) State the conditions for equilibrium.

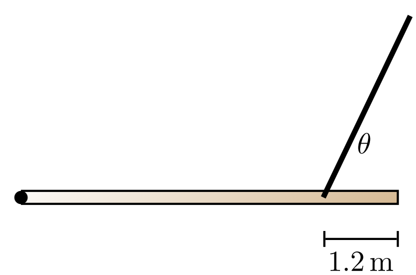
b) Draw all the force vectors on the beam.

c) Identify a pivot point (there are many correct possibilities – one is much more useful than the others) and determine expressions for the torque exerted by each force about the pivot.

d) Substitute the individual torques into one of the conditions for equilibrium and determine the tension in the rope.

298 Beam in equilibrium, 2

A 50 kg beam with length 6.0 m can pivot about its left end. A rope is attached as illustrated. The thickness of the beam is negligible. *(111F2023)*

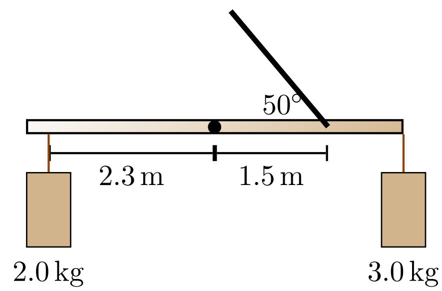


a) Determine an expression for the tension so that the beam stays at rest horizontally.

b) Does the tension needed stay constant, increase or decrease as the angle $0^\circ \leqslant \theta \leqslant 90^\circ$ increases? Explain you answer.

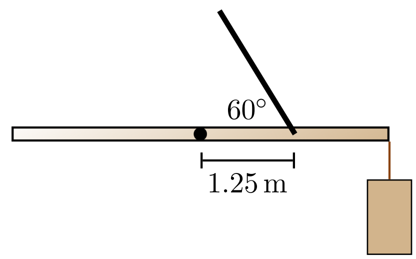
299 Balanced rod, unknown tension

A 5.0 m long rod can pivot about an axle through its midpoint. Masses are suspended at the illustrated points. A rope is attached 1.5 m from the midpoint and pulls at the illustrated angle. The thickness of the rod is negligible. Determine the tension in the rope that will keep the rod at rest horizontally. *(111F2023)*



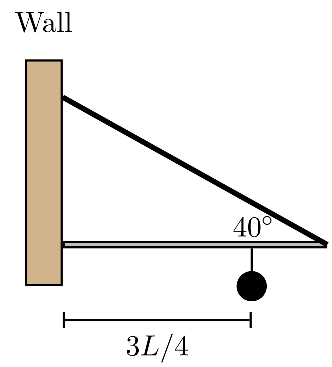
300 Balanced rod, unknown mass

A 5.0 m long rod can pivot about an axle through its midpoint. A block is suspended at the illustrated point. A rope is attached 1.25 m from the midpoint and pulls with tension 80 N at the illustrated angle. The thickness of the rod is negligible. Determine the mass of the suspended block that will keep the rod at rest horizontally. *(111F2023)*



301 Beam supporting a ball

A beam with mass M and length L is anchored to a wall and held at rest horizontally by a rope as illustrated. A ball with mass m is suspended from the beam at the illustrated point. The aim of this exercise is to determine the tension in the rope. This would enable one to decide on the breaking strength of the rope. The thickness of the beam is negligible. *(111F2023)*



a) State the conditions for equilibrium.

b) Draw all the force vectors on the beam.

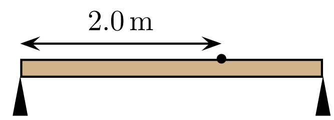
c) Identify a pivot point (there are many correct possibilities – one is much more useful than the others) and determine expressions for the torque exerted by each force about the pivot.

d) Substitute the individual torques into one of the conditions for equilibrium and obtain an expression for the tension in the rope.

e) What must be the minimum required breaking tension for the rope if it is to support a 40 kg beam with length 3.0 m while there is a 8.0 kg ball suspended as illustrated?

302 Balance beam, 1

A 60 kg person stands on a 20 kg horizontal beam, with length 3.0 m, at the point illustrated by the dot. The beam is supported by stands at either end and is in equilibrium. Each support exerts an upward force. The thickness of the beam is negligible. *(111F2023)*

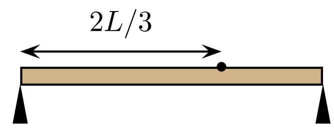


a) Determine the force provided by the support on the right. *Hint: Consider torques about the left support and don't forget the mass of the beam.*

b) Determine the force provided by the support on the left. *Hint: Consider torques about the right support and don't forget the mass of the beam.*

303 Balance beam, 2

A person with mass m_p stands on a horizontal beam, with mass m_b and length L, at the point illustrated by the dot. The beam is supported by stands at either end and is in equilibrium. Each support exerts an upward force. The thickness of the beam is negligible. *(111F2023)*

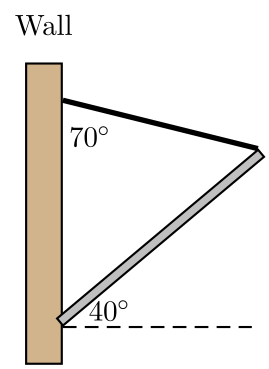


a) Determine an expression for the force that each support provides. Does this depend on the length of the beam?

b) Determine the force that each support provides if the beam has mass 40 kg and the person 90 kg.

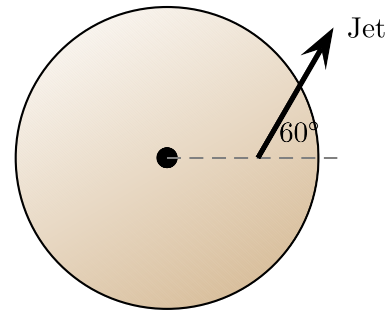
304 Raising a drawbridge

A 5.0 m long, 400 kg drawbridge is anchored to a castle wall. A rope with tension 2000 N raises the drawbridge at the illustrated angle. Determine the net torque on the drawbridge about the point where the drawbridge is attached to the wall. *(111F2023)*



305 Jet-propelled disk

A 3.0 kg solid, uniform disk has radius 0.25 m and can rotate horizontally about a frictionless axle through its center. A small jet, which is attached 0.15 m from the center of the disk, exerts a 4.0 N force as illustrated. The aim of this exercise is to determine the angular acceleration of the disk. *(111F2023)*



a) Write the rotational version of Newton's second law.

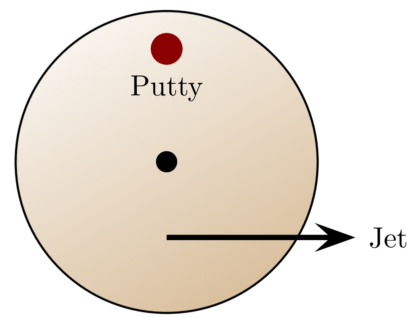
b) Determine the moment of inertia of the disk.

c) Determine the net torque acting on the disk.

d) Determine the angular acceleration of the disk.

306 Rotating turntable and putty

A 2.0 kg turntable (disk) has radius 0.10 m and can rotate horizontally about a frictionless axle through its center. A 1.2 kg blob of putty is stuck to a point on the disk three quarters of the distance from the center to the edge. A jet attached halfway from the center to the edge of the disk exerts a 4.0 N tangential force as illustrated. The aim of this exercise is to determine the angular acceleration of the disk. *(111F2023)*



a) Write the rotational version of Newton's second law.

b) Determine the moment of inertia of the disk plus putty.

c) Determine the net torque acting on the disk.

d) Determine the angular acceleration of the disk.

e) Suppose that a brake pad presses on the rim of the disk, producing a frictional force with magnitude 1.5 N while the jet is operating. If the wheel is rotating counterclockwise, determine the angular acceleration of the disk in this situation.

307 Rotational energy

A 5.0 kg solid sphere with radius 0.15 m is initially at rest. Determine how much energy must be supplied to get it to rotate at 300 rpm. *(111F2023)*

308 Rotational kinetic energy

Various spheres have the same mass and rotate about a diametrical axis with different angular velocities as listed in the table. *(111F2023)*

Object	type	radius	ω
A	Solid sphere	1.0 m	8 rad/s
B	Solid sphere	2.0 m	4 rad/s
C	Hollow sphere	2.0 m	4 rad/s
D	Hollow sphere	3.0 m	2 rad/s

Rank these in order of increasing rotational kinetic energy. Explain your answer. *(111F2023)*

Additional Problems

309 Ball thrown back and forth

Two people, each mass 70 kg, stand at opposite ends of a small 100 kg cart. The person on the left holds a 10 kg brick. They are all at rest initially. *(111F2023)*

a) The person on the left throws the brick to the person on the right horizontally with speed 8.0 m/s. Determine the speed of the cart after the ball has been launched.

b) The person on the right catches the ball and eventually holds it at rest relative to the cart. Determine the speed of the cart after this.

Fluids

310 Vacuum pump

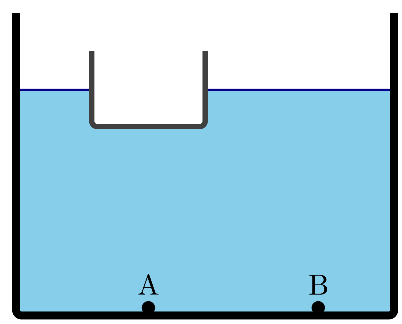
A vacuum pump creates creates a vacuum region that is connected by a pipe to a pool of water. Assuming that the pool of water is at sea-level, determine the maximum height which the pump can lift water. *(111F2023)*

311 Forces at the ocean floor

The deepest point beneath sea level is 10994 m below sea level. A cubic box with sides 2.0 m long is lowered to this point. Determine the force exerted by the water on one side of the box. How many times larger is this than the force exerted by Earth's atmosphere on this side when the box is at sea level? *(111F2023)*

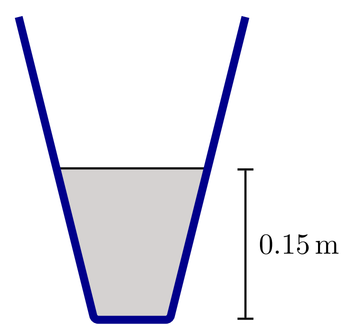
312 Forces beneath a floating object

A container holds a liquid. A small metal tub floats, displacing some liquid as illustrated. Is the pressure at B the same as, larger than smaller than the pressure at A (beneath the tub)? Explain you answer. *(111F2023)*



313 Beaker of mercury

A beaker with tapered sides holds mercury (density $13.6 \times 10^3\,\text{kg/m}^3$). The depth of the mercury is 0.15 m and the top is open to the atmosphere at sea-level. The area of the base of the beaker is $0.0015\,\text{m}^2$ and of the top of the mercury pool is $0.0060\,\text{m}^2$. Determine the force exerted by the mercury on the base of the beaker. *(111F2023)*



314 Wooden block in water

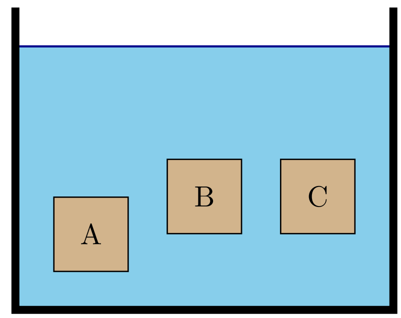
A piece of wood has volume $8.00 \times 10^{-3}\,\text{m}^3$ and density $910\,\text{kg/m}^3$. It is submerged in water (density $1000\,\text{kg/m}^3$) and held at rest by a hand. *(111F2023)*

a) Determine the buoyant force exerted by the wood.

b) Determine the downward force exerted by the hand on the block.

315 Buoyant forces

A container is filled with water and there objects are immersed in the container as illustrated (the block sizes are not to scale). The mass of A is 80 g, the mass of B is 60 g and the mass of C is 80 g. *(111F2023)*



a) Suppose that the volumes of the blocks are all the same. Rank the buoyant forces on each block in order of increasing magnitude.

b) Suppose that the densities of the blocks are all the same. Rank the buoyant forces on each block in order of increasing magnitude.

316 Magnesium cylinder suspended in cooking oil

A magnesium cylinder with volume $1.26 \times 10^{-5}\,\text{m}^3$ is suspended by a vertical string in cooking oil (density $930\,\text{kg/m}^3$). Determine the tension in the string. *(111F2023)*

317 Raising an object through water

A 20 kg treasure chest is raised by a rope at constant speed from the bottom of a lake (density $1000\,\text{kg/m}^3$). The volume of the chest is $12 \times 10^{-3}\,\text{m}^3$. *(111F2023)*

a) Determine the tension in the rope while the chest is being raised and is still completely submerged. *Note that this involves Newton's second law and the solution should include the usual ingredients used in applying Newton's second law, i.e. a free body diagram, etc,. . .*

b) The chest eventually begins to emerge from the water and is held at rest with half of its volume still submerged. Determine the tension in the rope at this point.

Thermal Physics

318 Temperature scales

a) The highest recorded temperature on Earth's surface was 134.1° F, which was recorded in Death Valley National Park in California. Determine this temperature in degrees Celsius and Kelvin.

b) The boiling point of liquid Helium-4 is 4.2 K. Determine this temperature in degrees Celsius and degrees Fahrenheit. *(111F2023)*

319 Air pressure on a hand

A 65 kg person is in a location where the air pressure is 100 kPa. The person's hand can be regarded as a rectangle with length 18 cm and width 8.0 cm. The had is held out so that it is horizontal. *(111F2023)*

a) Determine the force exerted by the air above the hand on the hand. How does this compare to the gravitational force exerted by Earth on the person?

b) Explain why despite the force exerted by the air above the hand, why it is relatively easy for the person to hold their hand up?

320 Thermal expansion of the Golden Gate bridge

The roadway across the Golden Gate Bridge is supported by connected steel beams with a total length of 1300 m. The bridge must be able to function over a temperature range of about 39° C (approximately 70° F). *(111F2023)*

a) By how much will the bridge expand across this temperature range? The coefficient of linear expansion for steel is $\alpha = 11 \times 10^{6}$ /C.

b) Copper has a coefficient of linear expansion of $\alpha = 24 \times 10^{6}$ /C. In terms of its thermal properties, would it be better to use copper or steel in the construction of the bridge? Explain your answer.

321 Gas expansion

An ideal gas is heated at constant pressure. The temperature is initially 25° C and the volume is 3.0 L. The gas is heated at a constant pressure. Determine its volume when the temperature reaches 100° C. *(111F2023)*

322 Helium balloon

A spherical balloon with radius 0.50 m contains helium at pressure 1.00 atm (1.01×10^5 Pa) at temperature 20.0° C. *(111F2023)*

a) Determine the number of moles of helium in the balloon.

b) The balloon rises to a point where the pressure is 0.480 atm and the temperature is −24.0° C. Determine the volume of the balloon at this altitude.

323 Cylinder pressure

A 0.600 m^3 cylinder is filled with gas and sealed at temperature 20°. The gas inside is heated at constant volume until the temperature reaches 95° C. Determine the gas pressure at this point. *(111F2023)*

324 Box of gas

A cubic box has sides 0.50 m long. The box is in a room whose temperature is $23°C$. *(111F2023)*

a) Suppose that the box is at sea level where the pressure is 101 kPa. Determine the number of moles of gas inside the box. Determine the number of gas particles in the box.

b) Suppose that the box is at an altitude comparable to Grand Junction where the pressure is 87 kPa. Determine the number of moles of gas inside the box.

325 Venus' atmosphere

Venus has a surface temperature of about $737K$ and a pressure about 91 times that of Earth's atmosphere. The atmosphere is made up mostly of Carbon Dioxide (CO_2). *(111F2023)*

a) Determine the number of moles of gas in Venus' atmosphere per meter cubed at the surface of Venus.

b) Determine the density (mass per meter cubed) of Venus' atmosphere. How does this compare to the density of Earth's atmosphere (about 1.2 kg/m^3)?

326 Elephant trunk capacity

An elephant's trunk has volume 14 L. The elephant is in a tropical region where the air temperature is 36° C and the air pressure is 100 kPa. The elephant inhales, filling the trunk. *(111F2023)*

a) Determine the number of moles of air in the elephant's trunk.

b) Look up the usual composition of air and determine the number of moles of each of oxygen, nitrogen and water vapor that the elephant inhales.

327 Argon gas processes

A sealed container contains argon, a gas that behaves as an ideal gas. Suppose that initially the volume is initially V_i, the pressure is P_i, the temperature (in Kelvin) is T_i. The argon undergoes a compression process that reduces its volume to $V_i/5$ and increases the temperature to $3T_i$. Which of the following is the pressure at the end of this process? Explain your choice. *(111F2023)*

i) $P_f = \frac{3}{5}\,P_i$
ii) $P_f = \frac{5}{3}\,P_i$
iii) $P_f = 3P_i$
iv) $P_f = 5P_i$
v) $P_f = 15P_i$

328 Ideal gas constant volume process

An ideal gas is initially at temperature 40° C. Heat is supplied to the gas while its volume is held constant. At the end of this process the pressure is double what it had been initially. Which of the following is true about the temperature at the end of the process, T_f? *(111F2023)*

i) $T_f = 40^\circ$ C
ii) $T_f = 80^\circ$ C
iii) T_f is somewhere between 40° C and 80° C.
iv) T_f is more than 80° C

Explain your answer.

329 Ideal gas: isothermal process

An isothermal process is one in which the temperature of a gas stays constant while its pressure and volume change. An ideal a gas is initially at pressure P_i and has volume V_i. The gas is allowed to expand in an isothermal process so that its volume eventually reaches $4V_i$. Which of the following gives its pressure at this point? *(111F2023)*

i) $\frac{P_i}{4}$
ii) $\frac{P_i}{2}$
iii) P_i
iv) $2P_i$
v) $4P_i$

Explain your answer.

330 Pressures of distinct gases

Several containers all have the same volume but each contain distinct gases at the same temperature. The information about these gases is given below:

Container	Gas	Mass per mole	Number of moles
A	Oxygen	32 g	2
B	Hydrogen	2 g	16
C	Carbon Monoxide	28 g	2
D	Carbon Monoxide	28 g	1

Rank these gases in order of increasing pressure, indicating equality whenever applicable. Explain your answer. *(111F2023)*

331 Helium atom speed

Helium is a monoatomic gas. Each atom has mass 6.65×10^{-27} kg. Determine the typical speed of a helium atom at room temperature (20° C). *(111F2023)*

332 Titan atmosphere

Titan is a moon of Saturn and it has an atmosphere composed mostly of nitrogen (N_2). The surface temperature of Titan is about $-180°$ C. Determine the typical (rms) speed of a nitrogen molecule in Titan's atmosphere. *(111F2023)*

333 Helium isotope speeds

Helium forms a monoatomic gas containing the two most common isotopes of helium. Helium-4 (abundance on Earth about 99.999863%) contains two protons and two neutrons and each atom has mass 6.646×10^{-27} kg. Helium-3 (abundance on Earth about 0.000137%) contains two protons and one neutron and each of these atoms has mass 5.008×10^{-27} kg. *(111F2023)*

a) Determine the ratio of the typical speed of helium-3 to that of helium-4 for a gas at 0.0° C.

b) Does the ratio of typical helium isotope speeds depend on the temperature of the gas? Explain your answer.

334 Energy and temperature

Neon is a monoatomic gas. A bulb holds 0.025 mol of Neon gas and this is initially at temperature 40° C. *(111F2023)*

a) The temperature is increased to 50° C. Determine the amount by which the energy increased as a result of the temperature increase.

b) Suppose that, with the gas initially at temperature 40° C, the gas undergoes a process which increases its energy by 50%. Determine the temperature of the gas at the end of this process.

335 Neon versus argon balloons

One balloon is filled with neon and another with argon. Each of these is a monoatomic gas. The balloons contain identical numbers of atoms, have the same volumes and are at the same pressure. The mass of one mole of neon is 20.18 g and the mass of one mole of argon is 39.95 g *(111F2023)*

a) Which of the following is true? Explain your answer.
   i) The total energy of the neon is the same as the total energy of the argon.
   ii) The total energy of the neon is more than the total energy of the argon.
   iii) The total energy of the neon is less than the total energy of the argon.
b) Which of the following is true? Explain your answer.
   i) The typical speed of a neon atom is the same as that of an argon atom.
   ii) The typical speed of a neon atom more than that of an argon atom.
   iii) The typical speed of a neon atom less than that of an argon atom.

336 Energy of a balloon of gas

A balloon is filled with Helium, a monoatomic gas, and at sea level atmospheric pressure and temperature 20° it forms a sphere with radius 0.50 m. *(111F2023)*

a) Determine the thermal (internal) energy of the gas in the balloon.
b) To get an idea of the energy in this balloon, suppose that a person is initially at rest on a skateboard. The mass of the person and skateboard is 70 kg. The imagine that all of the energy is the balloon was somehow used to get the person to move and the kinetic energy of the person and skateboard was equal to the thermal energy of the gas. Determine the resulting speed of the person and skateboard in miles per hour.

337 Gold and water

A 10.0 kg piece of gold is initially at 100° C. It is immersed in 1.00 kg of water which is initially at 20.0° C. The aim of this exercise is to determine temperature, T_f of the gold and water after they have reached equilibrium. The heat capacity of gold is 129 J/kg K and that of water is 4190 J/kg K. *(111F2023)*

a) Determine an expression for the heat lost by the gold in terms of T_f and the data provided.
b) Determine an expression for the heat gained by the water in terms of T_f and the data provided.
c) Combine your expressions to determine the equilibrium temperature T_f.

338 Heating air and water

Air and water have vastly different densities and $1\,\mathrm{m}^3$ of each have the following masses: $m_{\mathrm{air}} = 1.225\,\mathrm{kg}$ and $m_{\mathrm{water}} = 1000\,\mathrm{kg}$. Their specific heat capacities are $c_{\mathrm{air}} = 449\,\mathrm{J/(kg\ °C)}$ and $c_{\mathrm{water}} = 4182\,\mathrm{J/(kg\ °C)}$. *(111F2023)*

a) Suppose that $1\,\mathrm{m}^3$ of air at temperature 40° C (104° F) is brought into contact with $1\,\mathrm{m}^3$ of water at temperature 10° C (50° F). If the two are allowed to reach thermal equilibrium, what will their temperature be?

b) Suppose that $1\,\mathrm{m}^3$ of air at temperature -10° C (14° F) is brought into contact with $1\,\mathrm{m}^3$ of water at temperature 10° C (50° F). If the two are allowed to reach thermal equilibrium, what will their temperature be? (Note: the water will not freeze).

c) Explain why the average winter air temperature in Seattle, WA (located near to the Pacific Ocean) is considerably higher than that of Minneapolis, MN (located well over a thousand miles from the nearest ocean) despite the fact that they are located at similar latitudes.

339 Heating water

A (typical) cup holds 0.250 kg of water. Suppose that the water is initially at temperature 20° C. The water is then heated by a kettle that provides a power of 750 W. *(111F2023)*

a) Assuming that the heat transfer from the kettle to the water is perfectly efficient, determine the increase in the water temperature per second of heating.

b) Determine the amount of time needed to heat the water to a temperature of 80° C.

340 Heating water

Two polystyrene cups, one red and the other blue, contain the same amount of water. The red cup is initially at 70° C and cools to 40° C, while the blue cup is initially at 90° C and cools to 60° C. The effect of the cups on the cooling is negligible. Which of the following is true? *(111F2023)*

i) The water in the red cup loses the same heat as that in the blue cup.
ii) The water in the red cup loses more heat than that in the blue cup.
iii) The water in the red cup loses less heat than that in the blue cup.

Explain your answer.

341 Hammering a nail

A block of lead, of mass 0.10 kg, is dropped from rest toward a copper nail, of mass 0.005 kg, protruding 0.020 m from the top of a block of wood. The block of lead is released 0.5 m above the top of the nail and, upon striking the nail, pushes it a further 0.015 m into the wood before they both come to rest. *(111F2023)*

a) Determine the speed of the block of lead immediately before hitting the nail.

b) Describe the flow of energy between its various forms from the moment that the lead block is released until the block and nail have both come to rest.

c) One consequence of this process is that the temperature of the nail may increase as it is pushed further into the wood. Describe a method to calculate the maximum possible increase in the nail's temperature. Mention any additional physical constants or properties of the various materials which you would need to do this.

342 Cooling with a fluid

Suppose that you would like to cool a piece of copper initially at 70° C. You can do this by immersing the copper in equal masses of water or ethanol (ethyl alcohol), both initially at 20° C. Which of these fluids will result in the larger reduction in copper temperature? Explain your answer. *(111F2023)*

343 Cooling coffee

A 250 ml cup of coffee is initially at 95° C. You would like add ice to the coffee to cool it (and the added ice) to 75° C. *(111F2023)*

a) Determine the mass of ice required, assuming that coffee is almost entirely water.

b) Determine volume of water added via the melted ice. By what factor has the coffee been diluted?

Oscillations

344 Frequency of oscillation

A mechanical device contains a part that oscillates with frequency 250 Hz. *(111F2023)*

a) Determine the number of cycles that the part completes in 1.0 minute.

b) Determine the number of cycles that the part completes in 1.0 hour.

c) Determine the period of oscillation.

345 Oscillating spring and mass frequency

A block is attached to a spring and allowed to slide back and forth across a frictionless horizontal surface. The spring has constant 50.0 N/m. Determine the mass that must be attached to the spring so that the frequency of oscillation is 2.00 Hz. *(111F2023)*

346 Oscillating spring and mass

A 0.125 kg block is suspended from a spring. The block oscillates, taking 3.0 s to complete 10 cycles. *(111F2023)*

a) Determine the spring constant of the spring.

b) The block is replaced by another with mass 0.500 kg. Determine the amount of time that this takes to complete 10 cycles of oscillation.

347 Children on swings

Two children swing on swings whose seats are attached by ropes to a tree branch above the children. The lengths of the ropes are the same. One child, Jordi, has mass 40 kg and the other, Montserrat, has mass 30 kg. Which of the following is true? Consider the swing to be a pendulum oscillating with small amplitude. *(111F2023)*

i) The time for Jordi to swing back and forth once is the same as that for Montserrat.

ii) The time for Jordi to swing back and forth once is larger than that for Montserrat.

iii) The time for Jordi to swing back and forth once is smaller than that for Montserrat.

348 Pendulum and Earth's gravity

The acceleration due to Earth's gravity varies with distance from Earth's center. At a particular location on Earth a pendulum with length 0.800 m swings with a period of 1.797 s. Determine the acceleration due to Earth's gravity at this location. *(111F2023)*

349 Pendulum at different places on Earth

A clock is regulated by a pendulum, such that for every cycle of the pendulum's motion the clock counts exactly 2.00 s (this is called a second's pendulum). This length of the pendulum is adjusted so that the clock keeps perfect time in Paris, France where the acceleration due to Earth's gravity is $9.803\,\mathrm{m/s^2}$. It is then moved to a location in Cayenne, French Guyana (South America) where the acceleration due to Earth's gravity is $9.775\,\mathrm{m/s^2}$. Determine the period of the pendulum in Cayenne. *These details correspond to an experiment conducted in the 1670s by Jean Richer. The results were known to Newton who concluded that Earth bulges at the equator (other physics interpretations exist for this). (111F2023)*

350 Oscillating piano string

A piano string oscillates with frequency 256 Hz (middle C note). This is sustained for 3.0 s *(111F2023)*

a) Determine the number of cycles completed during this time.

b) Determine the time taken to complete 20 cycles.

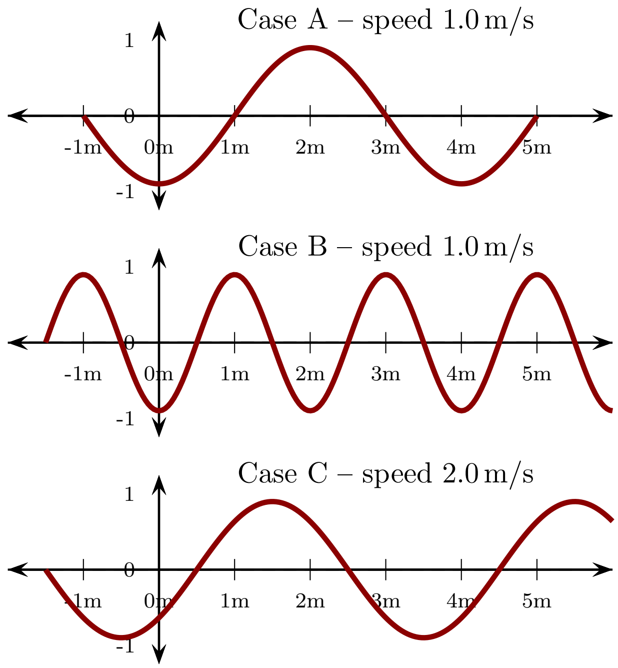
Waves

351 Wavelength and frequency

Various waves on strings are as illustrated. The wave speeds are provided for each case. *(111F2023)*

a) Rank the waves in order of increasing wavelength. Indicate equality whenever it occurs. Explain your answer.

b) Rank the waves in order of increasing frequency. Indicate equality whenever it occurs. Explain your answer.

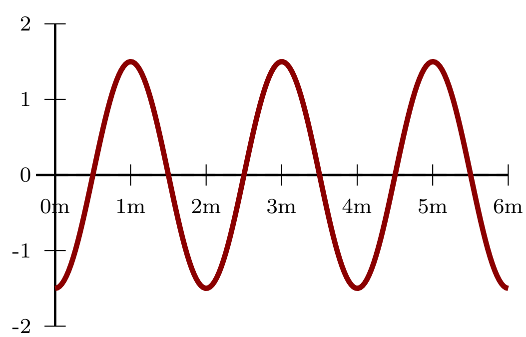


352 Waves on a string

A snapshot of a wave on a string is illustrated. *(111F2023)*

a) Determine the wavelength of the wave.

b) The wave is observed as time passes and it is found that 20 crests pass the 4 m mark in 5.0 s. Determine the wave speed.



353 Waves on a string with an oscillating end

The PhET animation "Waves on a String" allows you to visualize transverse waves on a string. Find the animation at

https://phet.colorado.edu/en/simulation/wave-on-a-string

and open it. Adjust the settings as follows:

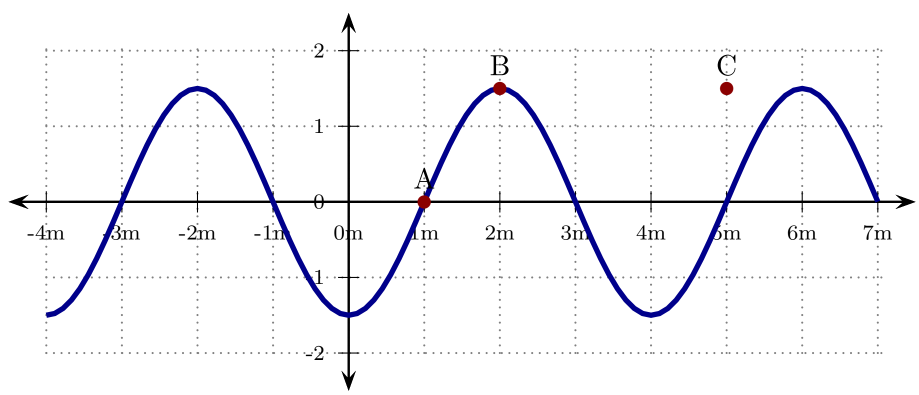
1. Check the button "No end" at the upper right.
2. Check the button "Oscillate" at the upper left.

3. In the control panel at the bottom, adjust "Damping" to none.
4. In the control panel at the bottom, adjust "Tension" to low.
5. In the control panel at the bottom, check the "Rulers" and "Timer" buttons.

a) Set the frequency to 0.30 Hz. Using the rulers and timer, determine the speed of the wave. Using the ruler, determine the wavelength of the wave. Determine the frequency of the wave by counting crests that pass a given point.
b) Set the frequency to 0.60 Hz. Repeat part a).
c) Is the speed the same in both cases?
d) Check that $v = \lambda f$ in both cases.
e) For one of the frequencies, vary the amplitude and show that it does not affect the wave speed or wavelength. *(111F2023)*

354 Sinusoidal waves

A snapshot of a segment of a wave on a string at a particular instant is illustrated. *(111F2023)*



a) The portion of the wave at A takes 0.0050 s to complete one cycle. Determine the frequency of the wave.
b) Determine the wavelength and speed of the wave.
c) Determine how long it will take the crest labeled B to reach the point C.
d) Using the graph above, sketch the wave at an instant 0.0025 s after that illustrated above.

355 Guitar string

A guitar string has length 0.80 m and mass 0.0028 kg and vibrates with frequency 440 Hz. The wavelength of the waves on the string is 1.60 m. Determine the tension in the string. *(111F2023)*

356 Waves on a string with variable tension

The tension in a stretched string can be varied. The string is at a particular initial tension and waves are produced by oscillating one end at a fixed frequency. explain your answers in the following. *(111F2023)*

a) Suppose that the tension in increased to 9 times of what it was initially. How does this affect the speed of waves on the string?

   i) It has no effect.
   ii) The speed decreases to 1/9 of what it was initially.
   iii) The speed increases to 1/3 times what it was initially.
   iv) The speed increases to 3 times what it was initially.
   v) The speed increases to 9 times what it was initially.

b) Suppose that the tension in increased to 9 times of what it was initially and but the end of the string oscillates with the same frequency as before. How does this affect the wavelength of the waves on the string?

   i) It has no effect.
   ii) The wavelength decreases to 1/9 of what it was initially.
   iii) The wavelength increases to 1/3 times what it was initially.
   iv) The wavelength increases to 3 times what it was initially.
   v) The wavelength increases to 9 times what it was initially.

357 Standing waves on a stretched string

A wire string has length 1.25 m and mass 0.0025 kg. It is stretched horizontally between supports that are 1.00 m apart, with the remaining portion of wire dangling vertically beyond one of these supports. A 0.400 kg mass is suspended from this portion of wire. Possible wavelengths of waves on this string are 2.00 m, 1.00 m, 0.667 m. Determine the frequency of each of these waves. *(111F2023)*

358 Traveling waves on a stretched string

A string with mass per unit length 0.0100 kg/m is stretched with tension 900 N. A wave travels along the string and a snapshot at one instant is illustrated. Determine the time between the arrival of successive crests at the 6.0 m location. *(111F2023)*