Fundamental Mechanics: Final Exam

12 May 2025

Name: _____ **Total:** **/70**

Instructions

- There are 16 questions on 10 pages.
- Show your reasoning and calculations and always explain your answers.

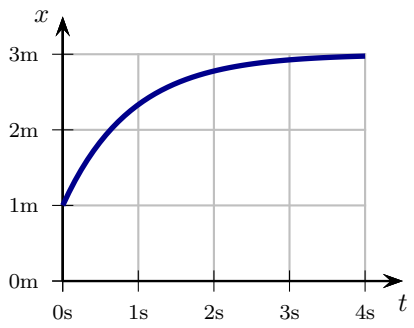
Physical constants and useful formulae

$g = 9.80\,\mathrm{m/s^2}$ $G = 6.67 \times 10^{-11}\,\mathrm{Nm^2/kg^2}$ Disk/solid cylinder: $I = \frac{1}{2}MR^2$

Hoop/hollow cylinder: $I = MR^2$ Hollow sphere: $I = \frac{2}{3}MR^2$ Solid sphere: $I = \frac{2}{5}MR^2$

Question 1

A cart is launched horizontally. A graph of position versus time is illustrated.



a) Which of the following (choose one) is true regarding the velocity of the cart during the period for which the motion is graphed?

i) $v \geqslant 0$ at all times.

ii) $v \leqslant 0$ at all times.

iii) At some times $v > 0$ and at others $v < 0$.

b) Which of the following (choose one) is true regarding the acceleration of the cart during the period for which the motion is graphed?

i) $a = 0$ at all times.

ii) $a \geqslant 0$ at all times.

iii) $a \leqslant 0$ at all times.

iv) At some times $a > 0$ and at others $a < 0$.

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Question 2

A flea jumps from a horizontal surface, leaving the ground with speed 1.8 m/s at an angle of 65° above the horizontal. Determine how far away the flea lands from its launching spot. Ignore air resistance.

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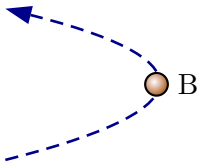
Question 3

A ball moves at a constant speed on a horizontal surface. Its trajectory as viewed from above is illustrated. Determine the direction of the the ball's instantaneous acceleration at point B.



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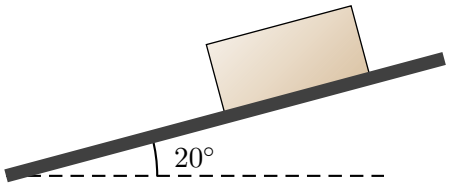
Question 4

A 30 kg box can move along the illustrated inclined ramp. It approaches the ramp from the left and slides up the ramp. The coefficient of kinetic friction between the box and the ramp is 0.50.



a) Determine the magnitude of the acceleration of the box.

b) The entire situation is repeated with a box with lower mass. Will the acceleration be different to that for the 50 kg box? Explain your answer.

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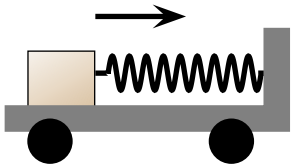
Question 5

A box lies on the frictionless surface of a cart and is anchored to one end of the cart by a spring. The cart moves horizontally and the bed of the cart stays horizontal. The cart, box and spring all move with constant speed to the right. Which of the following (choose one) is true regarding the spring?



i) The spring is relaxed (neither stretched or compressed from its equilibrium position).

ii) The spring is compressed.

iii) The spring is stretched.

iv) Whether the spring is compressed or stretched depends on the mass and speed of the block.

Briefly explain your answer.

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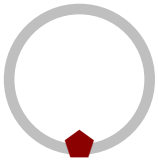
Question 6

A 0.40 kg object slides around the inside a frictionless vertical hoop with radius 0.90 m. The speed of the object at the bottom of the hoop is 0.30 m/s. Determine the normal force exerted by the hoop on the object at the bottom.



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Question 7

Two blocks, connected by a rope, and with indicated masses can move along a frictionless horizontal surface. The blocks are initially at rest and then a rope pulls right with tension 10 N.

a) Determine the acceleration of the blocks while the rope pulls and use this to determine the tension in the rope connecting the blocks.

b) Suppose that the blocks were flipped with the 2.0 kg block on the right, the 3.0 kg block on the left and the rope pulling to the right with 10 N as before. Would the tension in the connecting rope be larger than, smaller than or the same as that for the original arrangement? Explain your answer.

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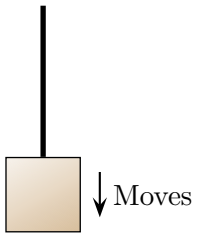
Question 8

A crate is suspended by a rope and is lowered vertically. While this happens, which of the following (choose one) is true about the work done by the rope, W?



i) $W > 0$ if the crate speeds up and $W < 0$ if it slows down.
ii) $W < 0$ if the crate speeds up and $W > 0$ if it slows down.
iii) $W > 0$ regardless of the speed.
iv) $W < 0$ regardless of the speed.

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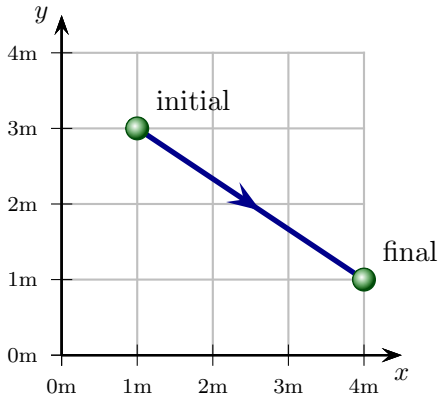
Question 9

A ball moves along the illustrated path. Throughout the motion a hidden object exerts a force $\vec{\mathbf{F}} = 4\,\mathrm{N}\hat{\mathbf{i}} + 4\,\mathrm{N}\hat{\mathbf{j}}$ on the ball. Determine the work done by this force on the ball as it moves from the indicated initial to final location.



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Question 10

A person and sled (combined mass 100 kg) move along a horizontal icy surface with speed 2.0 m/s. The person holds a 20 kg rock which initially moves moves along with the sled. The person subsequently throws the rock horizontally and after this the person and sled are at rest. Determine the speed with which the rock must be thrown for this to happen.

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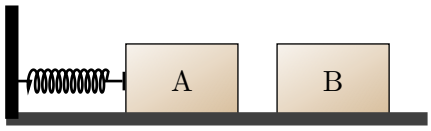
Question 11

Two 5.0 kg blocks are initially at rest on a horizontal frictionless surface. Block A is held against a spring, whose spring constant is 5000 N/m, compressing it by 0.10 m. Block A is released, and leaves the spring before colliding with block B. After the collision, the two blocks stick together. Determine the speed of the blocks after they collide.



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Question 12

A rod of mass m and length L is suspended from its left end as illustrated. A hand exerts a vertically upward force, of magnitude F at the opposite end. The rod remains at rest in a horizontal position. Which of the following (choose one) is true?

i) $F = \frac{1}{2}\, mg$

ii) $F = mg$

iii) $F = 2mg$

iv) $F = 2g$

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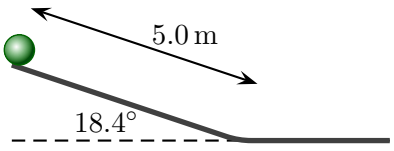
Question 13

A 0.400 kg hollow sphere with radius 0.20 m is held at rest on a 5.0 m track inclined at 18.4° above the horizontal. The sphere is released and rolls without slipping along the track. Determine the speed of the sphere at the moment that it reaches the end of the track.



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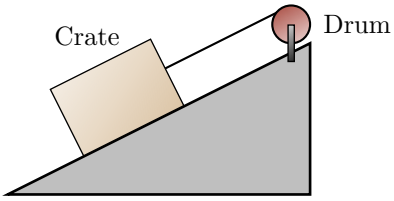
Question 14

A 5.0 kg crate can slide along a frictionless ramp angled at 26.6° above the horizontal. The crate is connected by a string to a solid drum with mass 3.0 kg and radius 0.20 m. The string runs parallel to the ramp. Determine the acceleration of the crate.



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Question 15

Two satellites, P and Q, orbit Earth in circles. They are the same distance from Earth. The mass of P is ten times the mass of Q. Let a_P be the magnitude of the acceleration of P and a_Q be the magnitude of the acceleration of Q. Assume that the only force acting on each satellite is Earth's gravity. Which of the following (choose one) is true?

i) $a_Q = \frac{1}{10} a_P$

ii) $a_Q = a_P$

iii) $a_Q = 10 a_P$

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Question 16

A 2000 kg satellite orbits Jupiter (mass 1.9×10^{27} kg and radius 7.0×10^7 m) at a constant speed in a circle. The distance from the center of Jupiter to the satellite is 2.0×10^9 m. **Starting with and using Newton's Second Law,** derive an expression for the satellite's speed and use this to determine the time taken to complete one orbit.

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