Fundamental Mechanics: Final Exam (Version 1)

9 December 2024

Name: _____ **Total:** **/139**

Instructions

- There are 16 questions on 11 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$g = 9.80\,\text{m/s}^2$ $G = 6.67 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$ 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 car travels to the right along a flat surface. At one moment has speed 25 m/s. It then slows down with constant acceleration and, while doing this, covers 68 m in 4.0 s. Determine the acceleration of the car.

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Question 2

A person launches a 0.250 kg ball from the ground. The ball leaves the person's hand with speed 20 m/s at an angle of 30° above the horizontal. Determine the time taken for the ball to hit the ground.

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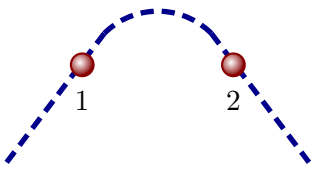
Question 3

A ball moves with constant speed along a table top and follows the illustrated trajectory, moving from location 1 to location 2. Determine the direction of the average acceleration of the bug from instant 1 to instant 2. Explain your answer.



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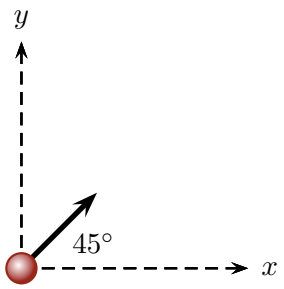
Question 4

A ball is fired into the air at an angle of 45° above the horizontal. Which of the following (choose one only) best represents the velocity and acceleration at the *moment at which the ball reaches its highest point*? Ignore air resistance.



i) both are 0 and so directions are irrelevant,
ii) $\vec{\mathbf{v}}$ is $\rightarrow$ and $\vec{\mathbf{a}}$ is $\rightarrow$,
iii) $\vec{\mathbf{v}}$ is $\rightarrow$ and $\vec{\mathbf{a}}$ is $\downarrow$,
iv) $\vec{\mathbf{v}}$ is $\nearrow$ and $\vec{\mathbf{a}}$ is $\downarrow$,
v) $\vec{\mathbf{v}}$ is 0 and $\vec{\mathbf{a}}$ is $\rightarrow$,
vi) $\vec{\mathbf{v}}$ is $\rightarrow$ and $\vec{\mathbf{a}}$ is 0.

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Question 5

A phone, with mass m, is suspended in an elevator as illustrated. The elevator moves up with a decreasing speed. The rope suspending the phone has no slack throughout the motion. Which of the following (choose one) is true regarding the tension in the rope that suspends the phone?

i) $T = 0\,\text{N}$.
ii) $T = mg$.
iii) $T > mg$.
iv) $0 < T < mg$.

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Question 6

A 0.25 kg phone hangs from a rope in an elevator. The elevator is initially at rest. It then moves upwards and the rope exerts a constant upward force of 3.0 N on the phone. Determine how much time it takes for the phone to reach a speed of 2.0 m/s.

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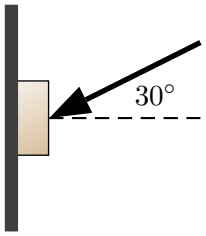
Question 7

A 1.5 kg book is pushed against a rough vertical wall by a hand which exerts a force at an angle of 30° from the horizontal. The coefficient of static friction between the book and wall is 0.80. Determine the minimum force that must be exerted by the hand to keep the book at rest.



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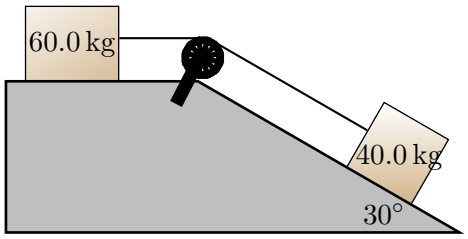
Question 8

Blocks connected by a massless string are able to slide on the illustrated frictionless surfaces. The strings run parallel to the surfaces. The mass of the block on the horizontal surface is 60.0 kg and that of the block on the ramp is 40.0 kg. The angle between the ramp and the horizontal is 30°. Determine the acceleration of the block on the ramp. Ignore friction, air resistance and the mass of the pulley.



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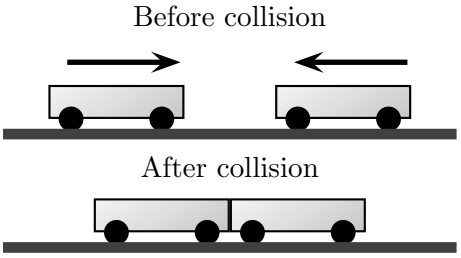
Question 9

Two identical carts travel on a frictionless surface toward each other with identical speeds and collide and stick together as illustrated. Which of the following (choose one) is true after the collision?



i) The carts are at rest and total kinetic energy is the same as before the collision.

ii) The carts are at rest and total kinetic energy is **not** the same as before the collision.

iii) The carts are **not** at rest and the total kinetic energy is the same as before the collision.

iv) The carts are **not** at rest and the total kinetic energy is **not** the same as before the collision.

Briefly explain your choice.

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Question 10

An elevator is suspended by a cable and ascends vertically upward.

a) The elevator slows down as it ascends. Is the work done by the cable positive, negative or zero? Explain your answer.

b) The elevator speeds up as it ascends. The cable does not become slack. Is the work done by the cable positive, negative or zero? Explain your answer.

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Question 11

A 40.0 kg box is pushed against a spring with spring constant 200 N/m. The spring is compressed by 0.50 m. The box is held at rest and then released. As the box moves, a constant kinetic friction force of 30 N acts on the box.

a) Determine the work done by the friction force from the moment that the box is released until the moment that the spring first reaches its unstretched length.

b) Determine the speed of the box when the spring first reaches its unstretched length.

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Question 12

Consider the vectors

$$\vec{\mathbf{A}} = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}},$$
$$\vec{\mathbf{B}} = 40\hat{\mathbf{i}} + 30\hat{\mathbf{j}}, \text{ and}$$
$$\vec{\mathbf{C}} = -40\hat{\mathbf{i}} + 30\hat{\mathbf{j}}.$$

Which of the following (choose one) is true?

i) $\vec{\mathbf{A}} \cdot \vec{\mathbf{B}} = \vec{\mathbf{A}} \cdot \vec{\mathbf{C}}$

ii) $\vec{\mathbf{A}} \cdot \vec{\mathbf{B}} > \vec{\mathbf{A}} \cdot \vec{\mathbf{C}}$

iii) $\vec{\mathbf{A}} \cdot \vec{\mathbf{B}} < \vec{\mathbf{A}} \cdot \vec{\mathbf{C}}$

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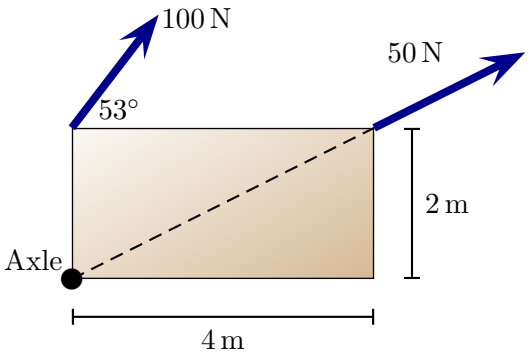
Question 13

A rectangular plate can pivot about an axle at the lower left corner and perpendicular to the page. Only two forces act on the plate, as illustrated.

a) Determine the net torque about the axle.



b) Suppose that the plate is initially rotating clockwise about the axle and the two forces then act for a while. The forces maintain their magnitudes and angles (relative to the plate). Which of the following (choose one) is true *while the forces act?*

i) The plate continues to rotate clockwise at a constant rate.

ii) The plate immediately speeds up and then rotates at a constant rate.

iii) The plate rotates at a rate which constantly increases.

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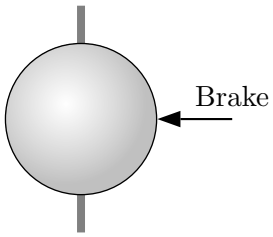
Question 14

A solid sphere with uniformly distributed mass 2.0 kg and radius 0.10 m rotates about an axle with negligible mass. At an initial moment the sphere rotates at 1800 rpm. Subsequently a brake pushes with a constant force on the sphere at its midpoint and this brings the sphere to a stop in 5.0 s.



a) Determine the angular acceleration of the sphere.

b) Determine the magnitude of the frictional force exerted by the brake.

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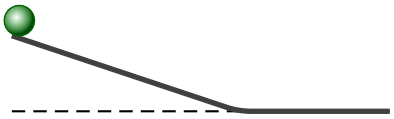
Question 15



Solid disks with various masses and radii are released from rest at the same point on an inclined track. The disks roll without slipping along the track.

a) Which of the following is true regarding the speeds of the disks when they reach the bottom of the ramp?

   i) The speed of a heavier disk is larger than the speed of a lighter disk.

   ii) The speed of a heavier disk is smaller than the speed of a lighter disk.

   iii) The speed of a heavier disk is the same as the speed of a lighter disk.

b) Which of the following is true regarding the speeds of the disks when they reach the bottom of the ramp?

   i) The speed of a larger disk is larger than the speed of a smaller disk.

   ii) The speed of a larger disk is smaller than the speed of a smaller disk.

   iii) The speed of a larger disk is the same as the speed of a smaller disk.

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Question 16

A planet has radius $2.0 \times 10^6\,\text{m}$ and the acceleration due to gravity at its surface is $7.0\,\text{m/s}^2$. Determine the mass of the planet. **To receive full credit, your solution must start with Newton's second law and use this to derive the answer.**

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