1. (8 points) A block of mass $2m$ is connected via a massless non-stretching rope over a pulley to another block of mass m. The pulley is a disc, with radius R and unknown mass. What mass of pulley is required so that if the system is released from rest, the acceleration will be $g/6$?

The concepts necessary to solve this problem correctly: Newton's 2nd Law, Connected Objects, Tension, Torque, Momentum of Inertia

(A) $6m$

(B) $10m$

(C) $8m$

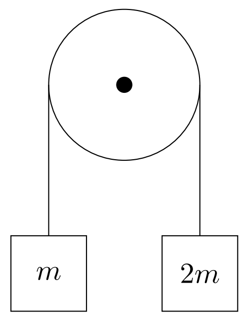
(D) $14m$

(E) $3m$

(F) m

(G) $4m$

(H) $18m$



Points Per Response:

A: 8
B: 5
C: 6
D: 5
E: 5
F:
G:
H:

2. (8 points) A metal bar holding a uniform sign is attached to the side of a building with a rope and a hinge. The metal bar is uniform, has length 8.00 m and mass 6.00 kg. The metal bar is oriented at an upward angle of 37.0 degrees relative to the building face. There is a sign attached by two massless chains such that the sign has mass 10.0 kg and the chains are attached to the bar at both the far end of the bar and at 6.00 m from the hinge. There is a massless, non-stretching rope that is horizontal and attached to the middle of the bar as well as the building. What is the magnitude of the net force acting on the hinge?

The concepts necessary to solve this problem correctly: Equilibrium, Torque, Gravity, Forces, Vectors

(A) 234 N

(B) 221 N

(C) 248 N

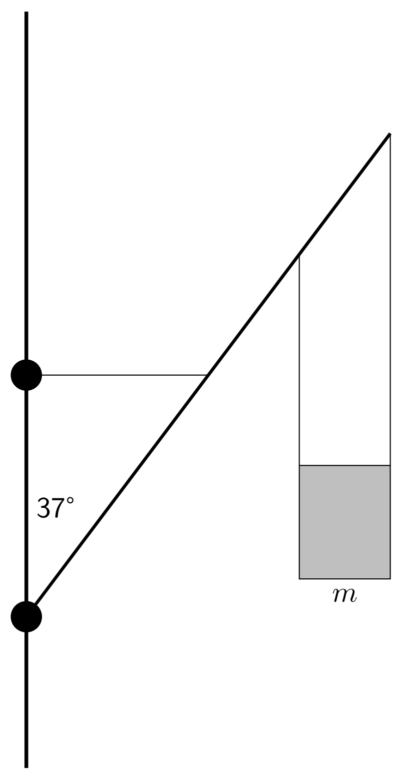
(D) 279 N

(E) 396 N

(F) 383 N

(G) 320 N

(H) 361 N



Points Per Response:

A: 8
B: 5
C: 5
D: 6
E: 3
F:
G:
H:

3. (4 points) A child is riding a merry-go-round that is spinning clockwise at an angular speed ω. The child is called home by their parent and jumps off the platform. In which direction should the child jump in order to maximize the final angular speed of the merry-go-round?

The concepts necessary to solve this problem correctly: Conservation of Angular Momentum

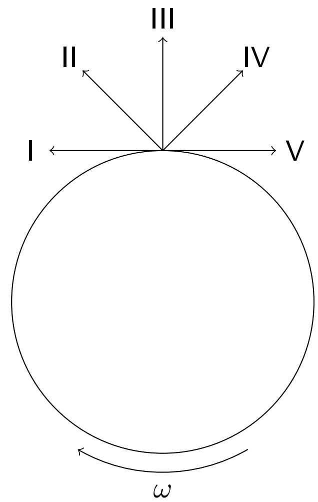
(A) I

(B) II

(C) III

(D) IV

(E) V



Points Per Response:
A: 4
B:
C:
D:
E: 1

4. (6 points) There is a stack of blocks that are 10.0 cm on each side as shown in the figure below. Each row is centered on the row below it. If the bottom left corner of the bottom left block is taken as the origin, what is the center of mass of the pyramid? Each block is labeled with its mass

The concepts necessary to solve this problem correctly: Center of Mass

(A) (15.0 cm, 11.7 cm)

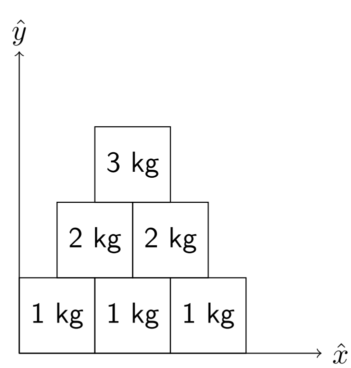
(B) (15.0 cm, 15.0 cm)

(C) (10.0 cm, 6.67 cm)

(D) (10.0 cm, 10.0 cm)

(E) (15.0 cm, 9.29 cm)

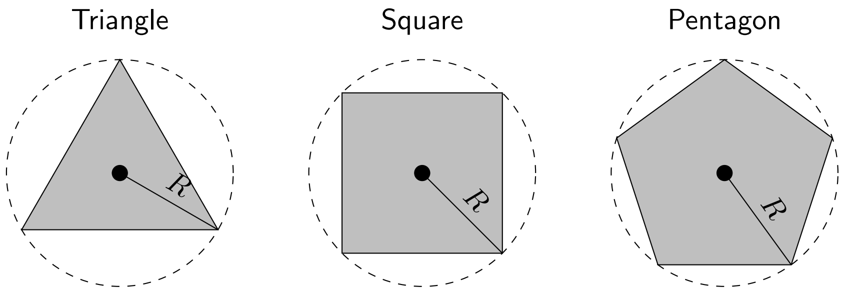
(F) (10.0 cm, 4.29 cm)



Points Per Response:
A: 3
B: 6
C:
D: 3
E: 3
F:

5. (4 points) There are three rigid objects (with the mass distributed uniformly in the shaded area in the figure), each having the same mass M, constant thickness and all inscribed in a circle with the same radius R. Which one has the greatest moment of inertia when rotated about an axis perpendicular to the plane of the drawing at the center marked by the small black circle?

The concepts necessary to solve this problem correctly: Moment of Inertia



(A) Triangle

(B) Square

(C) Pentagon

Points Per Response:
A: 1
B:
C: 4

6. (6 points) A ball of radius $R = 11.3$ cm and mass 426 g rolls up a hill without slipping and reaches a maximum height of 6.00 m above the bottom of the hill. The ball can be approximated as a thin-walled hollow sphere. What was the angular speed of the ball at the bottom of the hill?

   The concepts necessary to solve this problem correctly: Mechanical Energy Conservation, Potential Energy, Translational Kinetic Energy, Rotational Kinetic Energy, Identifying correct moment of inertia, Rolling without Slipping condition

   (A) 0.650 rad/s

   (B) 0.743 rad/s

   (C) 0.960 rad/s

   (D) 50.0 rad/s

   (E) 62.8 rad/s

   (F) 71.0 rad/s

   (G) 74.3 rad/s

   (H) 96.0 rad/s

   Points Per Response:

   A:
   B: 4
   C: 2
   D:
   E: 5
   F:
   G: 6
   H: 3

7. (6 points) A glider of mass m_1 is on a frictionless horizontal track and is connected to an object of mass m_2 by a massless string. Assume that $m_1 = 5m_2$. When released m_1 accelerates to the right while m_2 accelerates downward and the string rotates the pulley without slipping. The pulley has an inertia of $I = m_1 R^2$. Rank the kinetic energy of the different objects.

   The concepts necessary to solve this problem correctly: Mechanical Energy Conservation, Translational Kinetic Energy, Rotational Kinetic Energy, Connected Objects

   (A) $K(m_1) > K(\text{pulley}) > K(m_2)$

   (B) $K(m_1) > K(\text{pulley}) = K(m_2)$

   (C) $K(m_2) > K(\text{pulley}) > K(m_1)$

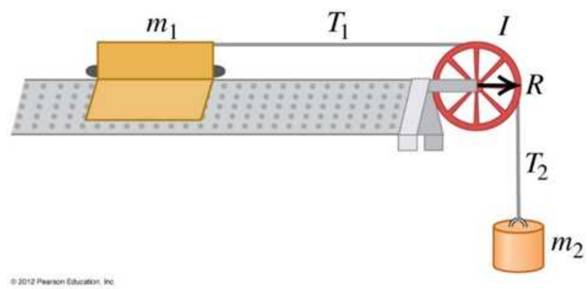
   (D) $K(m_2) > K(\text{pulley}) = K(m_1)$

   (E) $K(\text{pulley}) > K(m_2) > K(m_1)$

   (F) $K(\text{pulley}) > K(m_1) > K(m_2)$

   (G) $K(\text{pulley}) = K(m_2) > K(m_1)$

   (H) $K(\text{pulley}) = K(m_1) > K(m_2)$



   Points Per Response:
   A: 2
   B: 2
   C:
   D: 3
   E:
   F: 2
   G:
   H: 6

8. (4 points) In the previous problem, what is the correct relationship between the tensions?

   The concepts necessary to solve this problem correctly: Newton's 2nd Law as it applies to torque, Direction of torque

   (A) $T_1 > T_2$

   (B) $T_1 = T_2$

   (C) $T_1 < T_2$

   Points Per Response:
   A:
   B:
   C: 4

9. (4 points) There is a collision between two objects where you do not know either mass. You do know that before the collision the kinetic energy of object 1 was K_0 and object 2 was at rest. After the collision you know that the kinetic energy of object 1 is $K_0/3$ but you do not know the kinetic energy of object 2. What type of collision was this?

   The concepts necessary to solve this problem correctly: Classification of and definitions of the different types of collisions

   (A) It must be elastic.

   (B) It must be inelastic.

   (C) It must be completely inelastic.

   (D) It is impossible to tell with the given information.

   Points Per Response:
   A:
   B: 1
   C:
   D: 4

10. (8 points) A block with mass $m = 5.00$ kg is sliding across a surface with a speed of 18.0 m/s at the instant it collides with and sticks to a block with mass $M = 25.0$ kg. Both blocks have a coefficient of kinetic friction of $\mu_k = 0.220$ with the surface. How far do the two blocks slide before they come to rest?

    The concepts necessary to solve this problem correctly: Completely inelastic collisions and either Work-Kinetic Energy theorem or kinematics

    (A) 2.09 m

    (B) 12.5 m

    (C) 2.50 m

    (D) 1.39 m

    (E) 4.37 m

    (F) 5.84 m

    (G) 7.36 m

    (H) 8.52 m

    Points Per Response:
    A: 8
    B: 5
    C: 4
    D: 2
    E:
    F:
    G:
    H:

11. (8 points) In the figure below there are two uniform, solid spheres, one with radius $2R$ and the other with radius R. They are connected by a thin, uniform rod with length $\ell = 4R$. Both spheres and the rod each have the same mass M. What is the moment of inertia about the axis through the center of rod as shown in the figure?

The concepts necessary to solve this problem correctly: Parallel-Axis Theorem, Moment of Inertia

(A) $\frac{85}{3}MR^2$

(B) $\frac{10}{3}MR^2$

(C) $\frac{79}{3}MR^2$

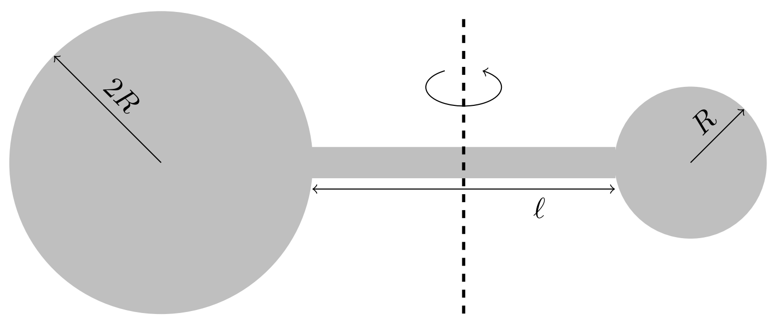
(D) $\frac{82}{3}MR^2$

(E) $\frac{28}{3}MR^2$

(F) $\frac{13}{3}MR^2$

(G) $\frac{53}{3}MR^2$

(H) $\frac{65}{3}MR^2$

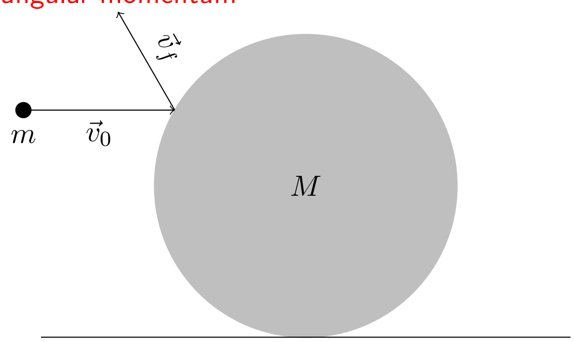


Points Per Response:

A: 8
B: 5
C: 4
D: 6
E: 3
F:
G:
H:

12. (4 points) A tennis ball with mass m is traveling horizontally at speed v_0 when it strikes a heavy cylindrical drum with mass M which is at rest on the ground. Which of the following properties are conserved in the system if the system is defined to be the tennis ball and the drum?

The concepts necessary to solve this problem correctly: Conditions for conservation of momentum and angular momentum



(A) The horizontal component of linear momentum only

(B) The vertical component of linear momentum only

(C) Angular momentum only

(D) The horizontal component of linear momentum and angular momentum

(E) The vertical component of linear momentum and angular momentum

(F) The horizontal component of linear momentum and the vertical component on linear momentum

(G) Both components of linear momentum and angular momentum

(H) None of the properties

Points Per Response:

A: 2
B:
C: 2
D: 4
E:
F:
G: 1
H:

13. (6 points) Three children are riding on the edge of a merry-go-round that has a mass of 105 kg and a radius of 1.60 m. The merry go round is spinning at 18.0 rpm. The children have masses of 22.0, 28.0, and 30.0 kg and are sitting on the outside edge of the merry-go-round. If the 28.0 kg child moves to the center, what is the new angular velocity in revolutions per minute? Ignore friction and assume that the merry-go-round can be treated as a solid disk and the children as point masses.

The concepts necessary to solve this problem correctly: Conservation of angular momentum

(A) 22.8 rpm

(B) 2.31 rpm

(C) 45.5 rpm

(D) 27.7 rpm

(E) 20.3 rpm

(F) 5.49 rpm

(G) 15.4 rpm

(H) 68.1 rpm

Points Per Response:

A: 6
B: 4
C: 4
D: 4
E: 3
F:
G:
H:

14. (8 points) A bicycle tire is rolling down the street without slipping and has an angular velocity of 34 rad/s. At $t = 0$, the wheel experiences an angular acceleration of $\alpha(t) = -0.25t$ which is slowing the wheel down. How far does the center of mass of the wheel travel in 13 seconds if the radius of the wheel is 28 cm?

The concepts necessary to solve this problem correctly: Rotational kinematics, Rolling without Slipping condition

(A) 98.1 m

(B) 118 m

(C) 149 m

(D) 350 m

(E) 68.0 m

(F) 385 m

(G) 419 m

(H) 228 m

Points Per Response:

A: 8
B: 4
C: 6
D: 6
E:
F:
G:
H:

15. (8 points) A cylindrical object with total mass M and radius R has a mass distribution such that the moment of inertia about its axis is $\frac{1}{4}MR^2$. This object is suspended from the ceiling by an ideal rope that is wrapped around the outside of the object. If the object is released and allowed to fall the rope will unroll and will not slip. What is the tension in the rope?

The concepts necessary to solve this problem correctly: Newton's 2nd Law for Force and Torque, Rolling without Slipping condition

(A) $\frac{1}{5}Mg$

(B) $\frac{2}{5}Mg$

(C) $\frac{3}{5}Mg$

(D) $\frac{4}{5}Mg$

(E) $\frac{1}{3}Mg$

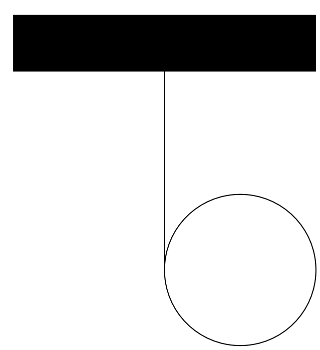
(F) $\frac{2}{3}Mg$

(G) $\frac{1}{4}Mg$

(H) $\frac{3}{4}Mg$

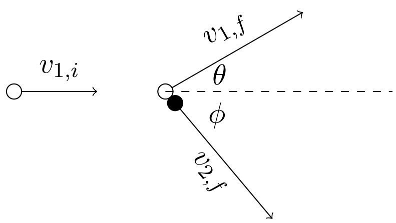
Points Per Response:

A: 8
B:
C:
D: 6
E:
F:
G: 3
H:



16. (8 points) A 6.00-kg mass is traveling at 10.0 m/s in the positive x-direction when it strikes an 18.0-kg mass which is at rest. After this elastic collision, you know that the 6.00-kg mass is moving in a direction 24.0 degrees away from its initial velocity and you know that the 18.0-kg mass is moving with a speed of 1.37 m/s. What is the angle ϕ that the 18.0-kg mass is travelling at as shown in the figure below? (Note that the figure will not be to scale)

The concepts necessary to solve this problem correctly: Elastic Collisions, Conservation of momentum



(A) 74.0 degrees

(B) 35.7 degrees

(C) 8.03 degrees

(D) 66.0 degrees

(E) 24.0 degrees

(F) 51.3 degrees

Points Per Response:

A: 8
B: 4
C: 5
D: 1
E:
F: