UP 1 Exam 2 Fall 2022

Your Full Name: ______________________________
Class time: _____________

Academic Integrity agreement:

You acknowledge that you will not give or receive any help on this exam, and **all work will be one hundred percent your own.**

You acknowledge that there will be strict consequences for academic dishonesty.

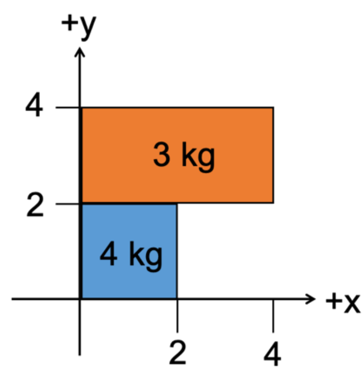
Your Signature: _________________________

Leave this exam packet closed until instructed to begin.

You CAN and SHOULD write on this exam.
Write your answer choices in the boxes provided.

1. (3 pts) Two uniform-density blocks, one of mass 4.0 kg and one of mass 3.0 kg, are located as shown. What is the location of the center of mass?

   A. (1.43, 1.43) m
   B. (2.86, 2.86) m
   C. (1.86, 2.86) m
   D. (1.43, 1.86) m
   E. (2.86, 1.86) m



1.____

A: 1
D: 3
E: 1

2. (3 pts) Two blocks, blocks A and B, are initially at rest on a frictionless table. Block A is five times more massive than Block B. An identical constant net force is applied to each block for 3 seconds. Which statement must be true?

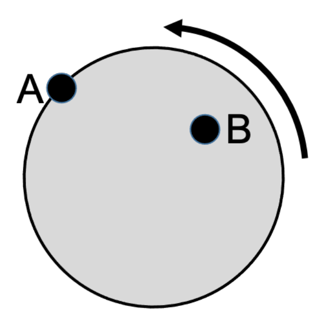
   A. The blocks have the same final speed.
   B. The blocks have the same final kinetic energy, only.
   C. The blocks have the same final momentum, only.
   D. The blocks have the same acceleration.
   E. The blocks have the same final momentum and the same final kinetic energy.

2.____

C: 3

3. (3 pts) Consider two points on a spinning turntable, as shown. Point B is closer to the center than point A. Which statement is true?

   A. Point A and B have the same angular velocities and the same linear speeds.
   B. Point A and B have the same linear speeds, but Point A has the larger angular velocity.
   C. Point A and B have the same angular velocities, but Point B has the larger linear speed.
   D. Point A and B have the same angular velocities, but Point A has the larger linear speed.
   E. Point A and B have the same linear speeds, but Point B has the larger angular velocity.



Top View

3.____

D: 3

4. (3 pts) A ball of mass *m* heads towards the right. It hits a wall perpendicularly with initial velocity $+v\,\hat{\imath}$, as shown. It bounces off perpendicularly with a final speed of $3v/4$. The ball was in contact with the wall for *t* seconds. What is the average force exerted **on the ball** during the collision with the wall?

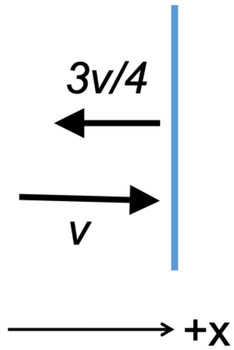
A. $-\frac{7mv}{4t}\hat{i}$

B. $+\frac{7mv}{4t}\hat{i}$

C. $-\frac{mv}{4t}\hat{i}$

D. $+\frac{mv}{4t}\hat{i}$

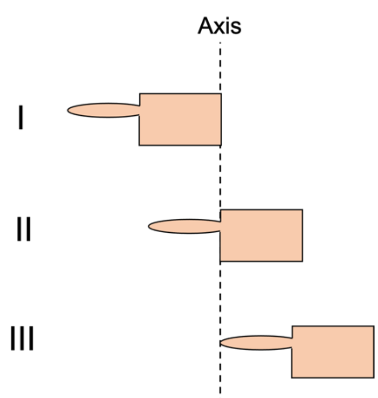
E. $+\frac{mv\,t}{4}\hat{i}$



4._____

A: 3
B: 1.5

5. (3 pts) The three objects shown are all identical and have uniform densities, but they are each being rotated about different points (as shown in situations I, II, and III). Rank the moments of inertia for each configuration.
   A. I > III > II
   B. I = III > II
   C. II > I = III
   D. III > I > II
   E. III > II > I



5._____

D: 3

6. (3 pts) Consider a thin rod of **nonuniform linear mass density** given by: $\lambda(y) = A + By^4$, where *y* is in meters, *y* = 0 at the axis of rotation, and A and B are constants. What are the SI units of the constant B?
   A. kg/m
   B. $kg{\cdot}m^3$
   C. $kg{\cdot}m^4$
   D. kg/m^3
   E. kg/m^5

6._____

E: 3

7. (3 pts) A disk rotates at a **non-constant** angular acceleration given in rad/s^2 by:

$$\alpha(t) = At^3$$

where *A* is a positive constant and *t* is in seconds. The disk had an angular speed of +2.0 rad/s at t = 0.0 s. At the instant *t* = 2.0 s, what is the angular speed of the disk?

A. $8A + 2$

B. $8A + 4$

C. $16A + 2$

D. $4A + 2$

E. $16A + 8$

7.____

D: 3

8. (3 pts) Consider a thin rod that lies along the *x* axis and has an axis passing through its center. It has a **non-uniform** mass density given by $\lambda(x) = Cx^4 - Dx$, where *x*=0 at the axis of rotation. The rod has a total length *L* = 8 m. Which is the correct integral for finding the **total <u>mass</u>** of this rod?

A. $M_{total} = \int_{-4}^{4} \left(Cx^4 - Dx\right) dx$

B. $M_{total} = \int_{0}^{8} \left(Cx^4 - Dx\right) dx$

C. $M_{total} = \int_{-4}^{4} x^2 \left(Cx^4 - Dx\right) dx$

D. $M_{total} = \int_{0}^{8} x^2 \left(Cx^4 - Dx\right) dx$

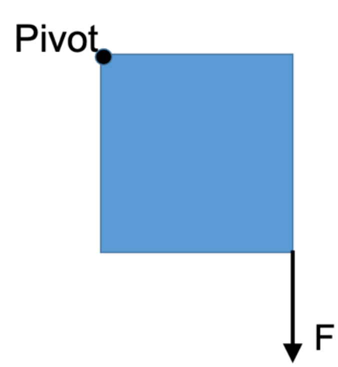
E. $M_{total} = \int_{-4}^{4} (4^2) \left(Cx^4 - Dx\right) dx$

8.____

A: 3
C: 1.5

9. (3 pts) A force acts on an object as shown. What is the **vector direction** of the torque from this force, relative to the pivot shown?

A. Towards the bottom of the page, parallel to F.
B. Into the page.
C. Out of the page.
D. The torque is zero
E. Towards the left of the page.



9.____

B: 3

10. (3 pts) A force $\vec{F} = (0,\ 2,\ 0)$ N acts at a displacement $\vec{r} = (0,\ 3,\ 3)$ m from the object's pivot. What is the torque on the object due to this force?

A. $\vec{\tau} = (0, -6,\ 0)$ N m
B. $\vec{\tau} = (+6,\ 0,\ 0)$ N m
C. $\vec{\tau} = (0, +6,\ 0)$ N m
D. $\vec{\tau} = (0,\ 0, +6)$ N m
E. $\vec{\tau} = (-6, 0,\ 0)$ N m

10.____

B: 2
E: 3

11. (3 pts) Consider the Atwood's machine shown. Say that $M_1 > M_2$ and the pulley is a solid uniform disk of mass M_p and radius R. The system moves so that M_1 accelerates downwards with magnitude of acceleration, a. The tension in the left side of the rope has magnitude T_1, and the tension is the right side of the rope has magnitude T_2.
What is the correct Rotational Newton's 2nd Law equation of motion for the pulley?

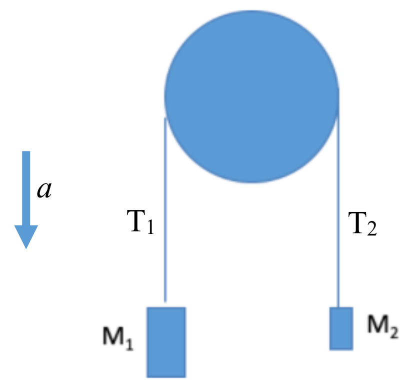
A. $T_1 - T_2 = M_p a$

B. $T_1 - T_2 = \left(\frac{1}{2}M_p R^2\right)a$

C. $T_1 R - T_2 R = \left(\frac{1}{2}M_p R^2\right)\frac{a}{R}$

D. $T_1 R + T_2 R = \left(\frac{1}{2}M_p R^2\right)\frac{a}{R}$

E. $T_1 + T_2 = \left(\frac{1}{2}M_p R^2\right)a$

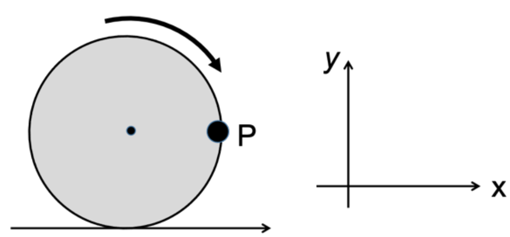


11.____

C: 3
D: 1.5

12. (3 pts) A disk of radius R rolls without slipping as shown so that its center of mass moves in +*x*. The speed of the center of mass is *v*. What is the **total velocity vector** of point P?

A. $\vec{v}_{tot} = v\hat{\imath} + v\hat{\jmath}$
B. $\vec{v}_{tot} = v\hat{\imath} - v\hat{\jmath}$
C. $\vec{v}_{tot} = 2v\hat{\imath}$
D. $\vec{v}_{tot} = 0$
E. $\vec{v}_{tot} = 2v\hat{\imath} + v\hat{\jmath}$



12.____

A: 1
B: 3

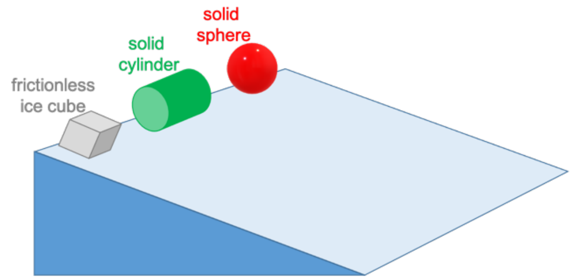
13. Consider the integral for finding moment of inertia: $\int r^2\, dm$.
What are the SI units of *dm*?

A. kg/m
B. kg
C. kg m^2
D. No units. Just a calculus placeholder.
E. kg/m^2

13.____

B: 3

14. (3 pts) A solid sphere and solid cylinder, both of uniform density, roll down a ramp without slipping. A frictionless ice cube slides down the same ramp. They all start from rest at the same time. In what order do they get to the bottom of the ramp (winner first)?



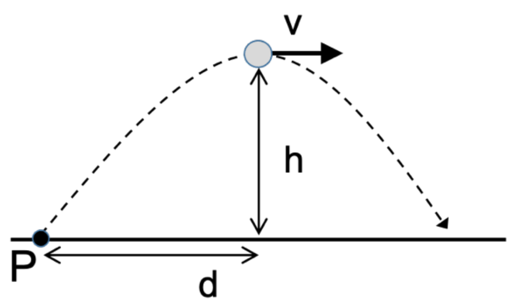
A. solid sphere, then solid cylinder, then frictionless ice cube
B. Frictionless ice cube, then solid cylinder, then solid sphere
C. Frictionless ice cube, then solid sphere, then solid cylinder
D. The sphere and the cylinder tie, and they beat the ice cube.
E. It depends on the relative masses of each object.

14.____

A: 1
C: 3

15. (3 pts) A ball of mass *m* is thrown upward from level ground at point P. It follows the parabolic trajectory shown. When it is at the peak of its trajectory, it has a speed *v*, it is a height *h* above the ground, and it is a horizontal distance *d* from the pivot. At the instant shown, what is the angular momentum of the ball relative to point P, **including the vector direction**?

A. *mvh* out of the page
B. *mvd* out of the page
C. 0
D. *mvh* into the page
E. *mvd* into the page



15.____

A: 1.5
D: 3
E: 1

16. (3 pts) An ice skater with rotational inertia I_0 is spinning with angular speed ω_0. She pulls her arms in, causing her to speed up. Why did her rotational speed increase?

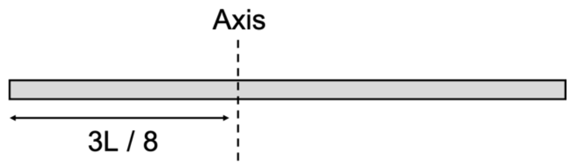
A. She speeds up because she raised her moment of inertia, and mechanical energy is conserved.
B. She speeds up because she raised her moment of inertia, and angular momentum is conserved.
C. She speeds up because she lowered her moment of inertia, and mechanical energy is conserved.
D. She speeds up because she lowered her moment of inertia, and angular momentum is conserved.
E. She speeds up because she lowered her moment of inertia, and both angular momentum and mechanical energy are conserved.

16.____

D: 3

Problems 17 – 26 involve more work and are worth 5 points each.

17. A uniform-density bar of length L is pivoted a distance 3L/8 from one end, as shown. What is the moment of inertia for this bar given this pivot?



A. $\frac{1}{12}ML^2 + \frac{9}{64}ML^2$

B. $\frac{1}{3}ML^2 + \frac{1}{64}ML^2$

C. $\frac{1}{3}ML^2 + \frac{9}{64}ML^2$

D. $\frac{1}{3}ML^2 - \frac{9}{64}ML^2$

E. $\frac{1}{12}ML^2 + \frac{1}{64}ML^2$

17.____

B: 1.5
C: 1.5
E: 5

18. A person applies a force to a block of mass *m* as the block moves in the positive x direction across a level table. The person's force **varies with time** and is given in Newtons by: $\vec{F} = (At^2)\hat{\imath}$, where A is a positive constant.
If this is the only force acting, then what is the speed of the block after it has been pushed for a time of t_1 seconds, assuming it started from rest?

A. $\frac{At_1{}^3}{3m}$

B. $\frac{At_1{}^3}{m}$

C. $\sqrt{\frac{2At_1{}^3}{3m}}$

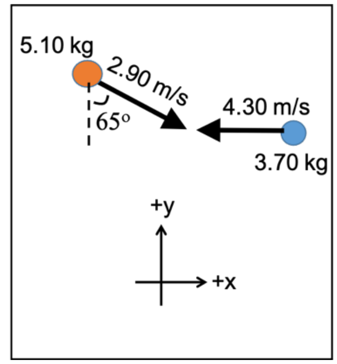
D. $\sqrt{\frac{At_1{}^3}{m}}$

E. $\frac{At_1{}^2}{m}$

18.____

A: 5
B: 2.5

19. Two objects head towards each other and collide as shown. The masses and velocities are indicated in the diagram. They stick together after the collision. Which of the following is the correct equation for finding the **x-component** of the final velocity, v_{fx}, after the collision?



A. $(5.10\ \mathrm{kg})(2.90\ \mathrm{m/s})\cos 65^o - (3.70\ \mathrm{kg})(4.30\ \mathrm{m/s}) = (5.10\ \mathrm{kg} + 3.70\ \mathrm{kg})v_{fx}$

B. $(5.10\ \mathrm{kg})(2.90\ \mathrm{m/s})\sin 65^o + (3.70\ \mathrm{kg})(4.30\ \mathrm{m/s}) = (5.10\ \mathrm{kg} + 3.70\ \mathrm{kg})v_{fx}$

C. $(5.10\ \mathrm{kg})(2.90\ \mathrm{m/s})\sin 65^o - (3.70\ \mathrm{kg})(4.30\ \mathrm{m/s}) = (5.10\ \mathrm{kg} + 3.70\ \mathrm{kg})v_{fx}$

D. $(5.10\ \mathrm{kg})(2.90\ \mathrm{m/s})\cos 65^o + (3.70\ \mathrm{kg})(4.30\ \mathrm{m/s}) = (5.10\ \mathrm{kg} + 3.70\ \mathrm{kg})v_{fx}$

E. $(5.10\ \mathrm{kg})(2.90\ \mathrm{m/s}) + (3.70\ \mathrm{kg})(4.30\ \mathrm{m/s}) = (5.10\ \mathrm{kg} + 3.70\ \mathrm{kg})v_{fx}$

19.____

A: 2.5
B: 2.5
C: 5

20. A block of mass *m* has an initial speed *v* as it travels along a level and frictionless surface. It strikes a cart of mass 2*m* that is initially at rest, and the block sticks to the cart. The block/cart combination then travels through a friction patch with coefficient of kinetic friction μ_k. What is the **length** that the block/cart combination travels **before coming to rest**?

A. $\frac{v^2}{18\mu_k g}$

B. $\frac{v^2}{6\mu_k g}$

C. $\frac{v^2}{9\mu_k g}$

D. $\frac{v^2}{2\mu_k g}$

E. $\frac{v^2}{\mu_k g}$

20.____

A: 5
B: 2.5

21. An object rotates with a non-constant time-varying angular acceleration. The angular position as a function of time is given by:

$$\theta(t) = At - Bt^3 \,,$$

where *A* and *B* are positive constants. At what time is the object instantaneously at rest?

A. 0

B. $\sqrt{\frac{A}{B}}$

C. $\sqrt{\frac{A}{3B}}$

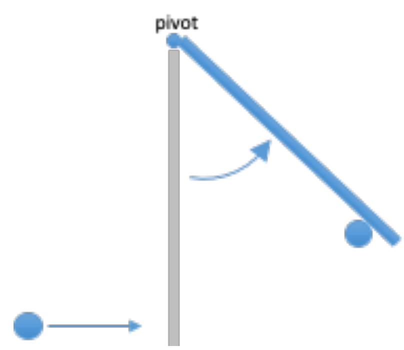
D. $\sqrt{\frac{A}{2B}}$

E. $\frac{A}{B}$

21.____

C: 5

22. A uniform-density rod of mass *M* and length *L* is pivoted at one end and is initially hanging vertically at rest. A piece of clay of mass *m* is shot at the rod perpendicularly with a speed *v*. The clay sticks to the rod at a length L from the pivot. As a result, the rod/clay combination swings upward. Find the **angular speed** of the clay/rod combination **immediately after** the collision.



A. $\dfrac{mvL}{\frac{1}{3}ML^2}$

B. $\dfrac{mvL}{\frac{1}{12}ML^2 + mL^2}$

C. $\dfrac{mvL}{\frac{1}{3}ML^2 + mL^2}$

D. $\sqrt{\dfrac{\frac{1}{2}m\frac{v^2}{L^2}}{\frac{1}{3}ML^2 + mL^2}}$

E. $\sqrt{\dfrac{\frac{1}{2}m\frac{v^2}{L^2}}{\frac{1}{12}ML^2 + mL^2}}$

22.____

A: 2.5
B: 2.5
C: 5

23. Consider a thin rod that lies along the x-axis and has a total length of 2.0 meters. It is pivoted at the left end, at x = 0. It has a non-uniform linear mass density given in kg/m by:

$$\lambda(x) = 10x^2 + 6,$$

where *x* is in meters. What is the moment of inertia of this rod for this axis through the left end?

23.____

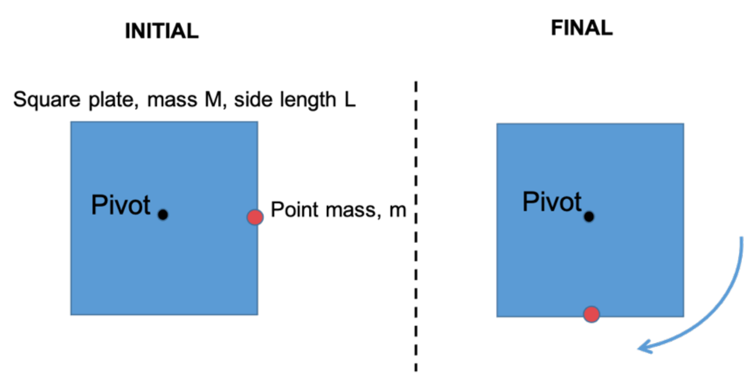
E: 5

A. 40 kgm^2
B. 50 kgm^2
C. 70 kgm^2
D. 60 kgm^2
E. 80 kgm^2

24. A square plate of side length *L* and mass *M* is pivoted at its center as shown. A point mass (mass *m*) is glued to the center of an edge, also as shown. The plate/point-mass is initially held stationary in a gravitational field with the point mass located as indicated. It is released from rest, and the plate/point-mass combination swings downwards. Find the **angular speed** of the plate/point mass combination just as it passes through the vertical position, as shown.

A. $\sqrt{\dfrac{2mg\frac{L}{2}}{\frac{1}{6}ML^2 + \frac{1}{4}mL^2}}$

B. $\sqrt{\dfrac{2(m+M)g\frac{L}{2}}{\frac{1}{6}ML^2 + \frac{1}{4}mL^2}}$



C. $\sqrt{\dfrac{2mgL}{\frac{1}{6}ML^2 + \frac{1}{4}mL^2}}$

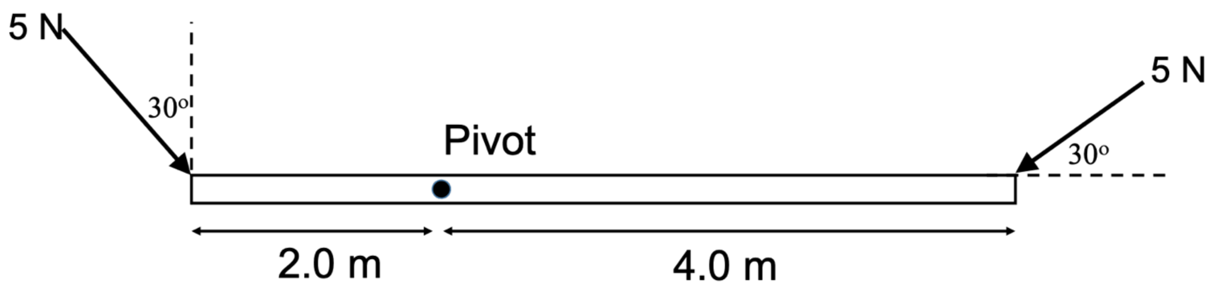
D. $\sqrt{\dfrac{2(m+M)gL}{\frac{1}{6}ML^2 + mL^2}}$

E. $\dfrac{mg\frac{L}{2}}{\frac{1}{6}ML^2 + \frac{1}{4}mL^2}$

24.____

A: 5
B: 2.5
C: 2.5
D: 1

25. A rod is pivoted a shown. A 5-N force is applied 2.0 m from the pivot at an angle of 30 degrees **with the vertical**. A second 5-N force is applied 4.0 meters from the pivot, but this one makes a 30 degree angle **with the horizontal**. Both forces act as shown. What is the magnitude of the **net torque** about the pivot?

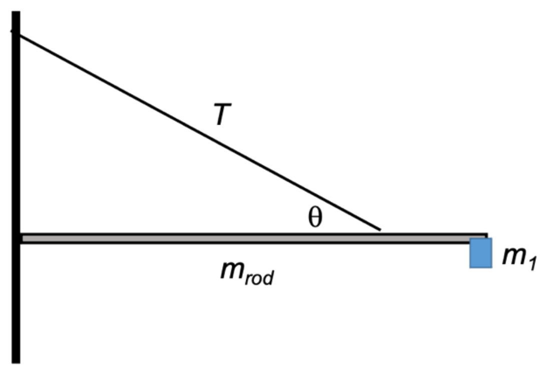


A. 22.3 N.m
B. 5.00 N.m
C. 18.7 N.m
D. 12.3 N.m
E. 1.34 N.m

25.____

C: 1.5
D: 1.5
E: 5

26. An object of mass m_1 is suspended from the end of a uniform-density rod of length L and mass m_{rod}. The rod is supported at one end by a hinge at a wall and by a cable that is attached $3L/4$ from the wall and makes an angle θ from the horizontal. What is the correct torque equation (N2L for rotation) for the pivot taken at the hinge?



A. $\frac{3L}{4}T - \frac{L}{2}m_{rod}g - Lm_1g = 0$

B. $\frac{3L}{4}T\cos\theta - \frac{L}{2}m_{rod}g - Lm_1g = 0$

C. $\frac{3L}{4}T\cos\theta - Lm_{rod}g - Lm_1g = 0$

D. $\frac{3L}{4}T\sin\theta - \frac{L}{2}m_{rod}g - Lm_1g = 0$

E. $T\sin\theta - m_{rod}g - m_1g = 0$

26.____

B: 2.5
D: 5