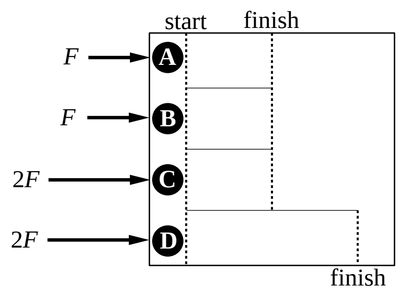
Circle the letter of the single best answer. Each question is worth 1 point

Physical Constants:

Earth's free-fall acceleration $= g = 9.80\ \mathrm{m/s^2}$

1. Four pucks race on a frictionless surface. The pucks have masses: $M_A = 4$ kg, $M_B = 3$ kg, $M_C = 2$ kg, and $M_D = 1$ kg. As shown below, they are subjected to different forces and race lengths. Circle the puck with the largest kinetic energy when it crosses its finish line.



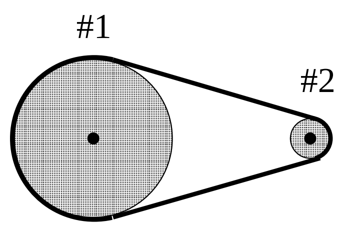
2. Two carts (A with mass 2 kg and B with mass 3 kg) moving frictionlessly along a straight line have a head-on collision softened by spring bumpers. During the collision the springs compress, the carts reach minimum separation, and then the springs re-expand until the carts are again separated. During the instant when the carts reach minimum separation:

   A. both carts have the same momentum
   B. the potential energy of the system is a maximum
   C. the kinetic energy of the system is a minimum
   D. both B and C

3. A small table cloth is placed on a table, and a glass of wine is placed on top of the table cloth. Dr. Science pulls the cloth very rapidly from underneath the glass and the glass (only slightly disturbed by the process) ends up at rest on the table top. This can be explained by: the quicker the pull,

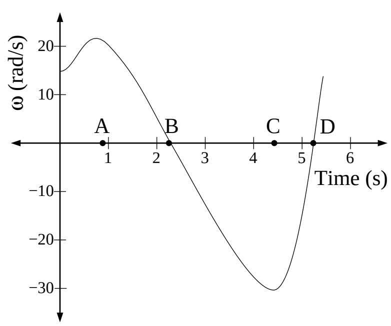
   A. the smaller the force on the glass.
   B. the smaller the impulse to the glass.
   C. the larger the momentum of the cloth.
   D. the smaller the coefficient of friction.

4. A belt drives (without slipping) a large radius pulley (#1) from a small radius pulley (#2) as shown below. Please compare the angular velocity of each pulley (ω_1, ω_2) and the speed at the edge of each pulley (v_1, v_2). Which combination of statements is correct?

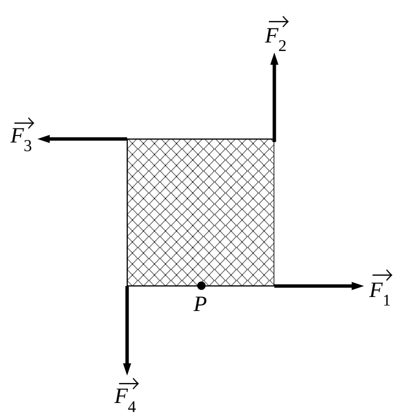


   A. $\omega_1 < \omega_2$, $v_1 > v_2$
   B. $\omega_1 = \omega_2$, $v_1 > v_2$
   C. $\omega_1 < \omega_2$, $v_1 = v_2$
   D. $\omega_1 = \omega_2$, $v_1 = v_2$

5. (Mark two letters!) The below graph displays the angular velocity, ω, of a rotating object as a function of time. Consider a point on the rim of the rotating object. Circle the letter where the magnitude of the point's centripetal acceleration is the largest. X the letter where the magnitude of the point's tangential acceleration is the largest.

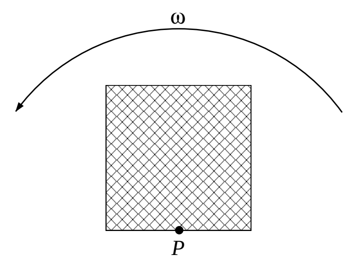


6. Four forces of equal magnitude but with directions as shown below act at the corners of a square. The square has a fixed pivot point P. Rank (from least to greatest) the torque produced by these forces about the pivot point. We define a positive torque as one in the counter-clockwise direction. Note: negative numbers are smaller than any positive number. (The torque produced by $\vec{F_1}$ is denoted τ_1, etc.)



A. $\tau_1 = \tau_2 = \tau_3 = \tau_4$
B. $\tau_1 < \tau_2 = \tau_4 < \tau_3$
C. $\tau_1 < \tau_2 = \tau_3 = \tau_4$
D. $\tau_4 < \tau_1 < \tau_2 < \tau_3$

7. A uniform square, similar to the one in the previous problem, is spinning at a constant rate about the pivot point P on a frictionless surface. No forces are acting on square, except perhaps at the pivot point. The force at the pivot point:

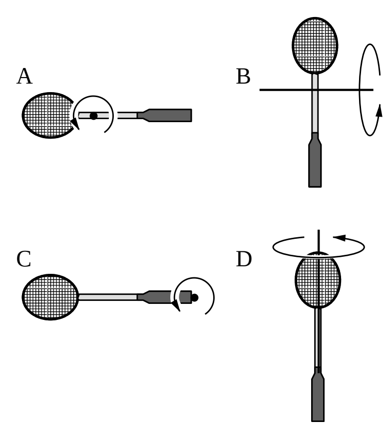


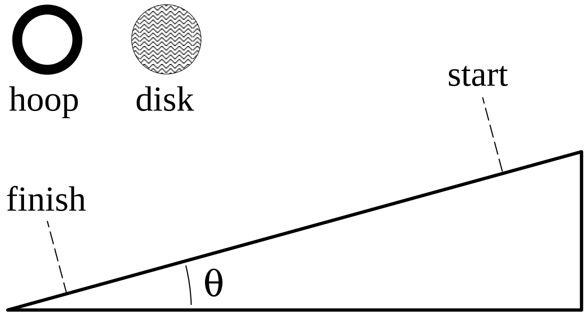
A. provides a torque to maintain the spin.
B. points down the page at the instant shown.
C. points to the left at the instant shown.
D. is in fact zero.

8. Consider the moment of inertia of a racket rotated about different axes:

A. an axis through its center of mass and perpendicular to its face
B. an axis through its center of mass and in the plane of its face
C. an axis located at the handle's end
D. an axis parallel its shaft.

Which rotation axis has the smallest moment of inertia?





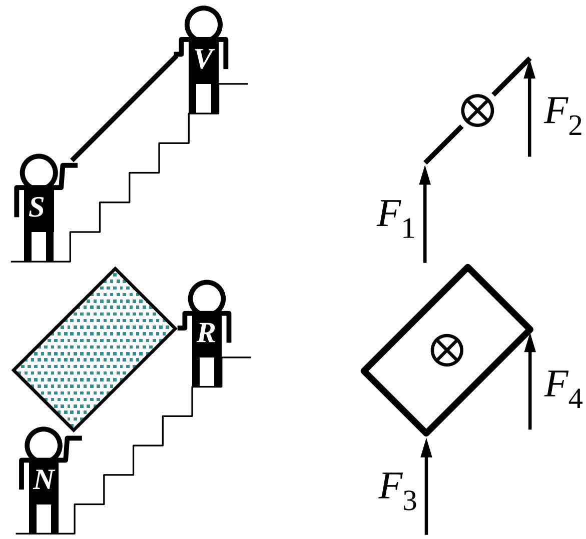
9. A solid disk made of wood and a hoop made of metal have exactly the same mass and radius. When the two objects "race" (roll without slipping down an inclined plane) the disk always wins. Consider the following statements about (1) the magnitude of the static frictional force (f) between the inclined plane and the rolling object, (2) the finish-line value of the total kinetic energy (K) and (3) the moment of inertia "about" the center of mass (I). (For example, K_{hoop} denotes the total kinetic energy of the metal hoop when it crosses the finish-line.)

   - $f_{\text{disk}} > f_{\text{hoop}}$
   - $K_{\text{disk}} > K_{\text{hoop}}$
   - $I_{\text{disk}} > I_{\text{hoop}}$

   How many of these statements are true?

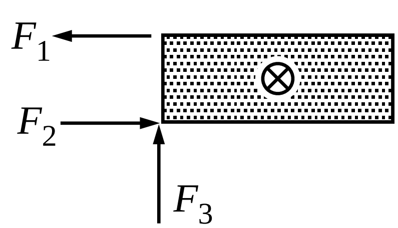
   A. none
   B. one
   C. two
   D. three

10. Moving into their upstairs apartment, Venus and Serena enlist Roger and Novak to help. Roger and Novak carry a 38" × 75" mattress that weighs 50 lbs. Venus and Serena carry an equal length steel exercise bar that also weighs 50 lbs. Rank the lifting force that each must provide. (The center of gravity of each item is located at the symbol: ⊗.)



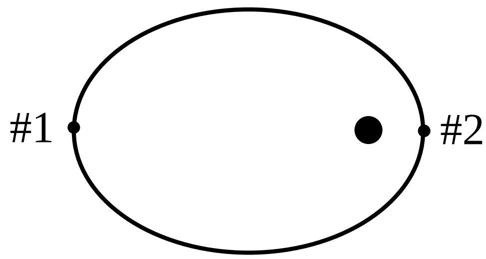
    A. $F_4 < F_1 = F_2 < F_3$
    B. $F_4 < F_1 < F_2 < F_3$
    C. $F_4 = F_2 < F_1 = F_3$
    D. $F_1 = F_2 = F_3 = F_4$
    E. none of the above

11. As shown below a 50 lb rectangular sign hangs outside of a shop supported by the three forces that act in the directions shown below. Rank the magnitude of these forces. (The center of gravity of the sign is located at the symbol: ⊗.)



    A. $F_3 < F_1 = F_2$
    B. $F_1 < F_2 < F_3$
    C. $F_1 < F_3 < F_2$
    D. none of the above

12. Consider a satellite in an elliptical orbit around the Earth. Compare the motion at the point nearest the Earth (perigee, #2) to the motion at the point farthest from the Earth (apogee, #1).



A. The kinetic energy and angular momentum will both be greater a perigee than at apogee.

B. The gravitational potential energy will be greater at apogee and angular speed will be greater at perigee.

C. The energy and momentum do not change (i.e., are the same at apogee and perigee).

D. The speed is greatest at perigee; the angular speed is greater at apogee.

13. An astronaut orbiting the Earth in the space station feels "weightless' because:

A. she is beyond the range of gravity

B. centrifugal force is equal but opposite to gravity

C. she has no acceleration

D. the space station is falling at the same rate she is

The following questions are worth 10 pts each

Record your steps! (Grade based on method displayed not just numerical result)

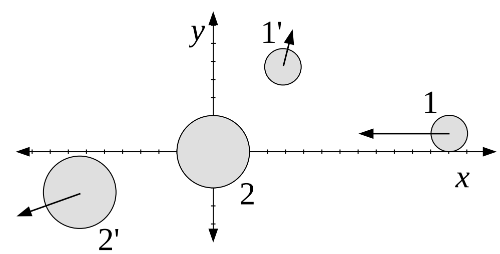
14. Particles 1 and 2 collide in space where no external forces are present. Particle 1, with mass $m_1 = 2$ kg, moves parallel to the x axis and collides with particle 2 (which has mass $m_2 = 3$ kg). The below lists a pre-collision (unprimed) and a post-collision (primed) velocity (in m/s). The x and y velocities are listed as an ordered pair: $\vec{\mathbf{v}} = (v_x, v_y)$.

particle mass	pre-collision velocity	post-collision velocity
$m_1 = 2$	$\vec{\mathbf{v}}_1 = (-5, 0)$	$\vec{\mathbf{v}}'_1 = \left(\frac{2}{5}, \frac{9}{5}\right)$
$m_2 = 3$	$\vec{\mathbf{v}}_2 = (0, 0)$	$\vec{\mathbf{v}}'_2 = \left(-\frac{18}{5}, -\frac{6}{5}\right)$

A. Show that the initial momentum in the x direction equals the final momentum in the x direction.

B. Show that the initial momentum in the y direction equals the final momentum in the y direction.

C. Calculate the total kinetic energy in the pre-collision state and in the post-collision state. Is this an elastic collision?

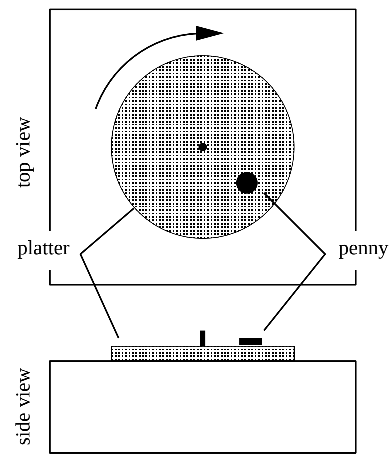


15. Bullets leaving a rifle are spinning at a surprisingly fast rate (the gyroscopic effect prevents tumbling, but we'll need another lecture to get to that). For example, the 4 gram, 5.6 mm diameter bullet from a M16 rifle is spinning at 300,000 rpm. This high spin rate is achieved in just 2 revolutions of the bullet as the bullet spirals down the barrel. (Yes, the bullet goes from zero to 300,000 rpm in just two revolutions: a huge constant angular acceleration you'll want to calculate.) Approximating the bullet as a cylinder ($I = \frac{1}{2}MR^2$), what torque is required to achieve this bullet spin?

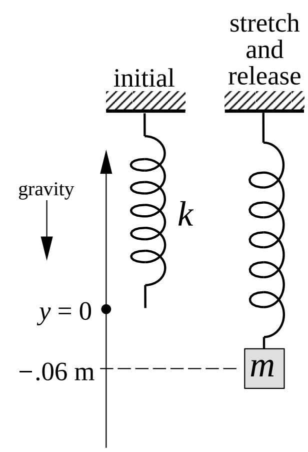
16. A record player is set for $33\frac{1}{3}$ revolutions per minute (rpm). It is found that a penny will stick with the platter as long as its distance from the platter center is less than 15 cm.

   A. Draw a free body diagram of the penny sitting on the rotating platter. Show and name all forces acting on the penny. Show the direction of the acceleration (if there is any).

   B. Calculate the coefficient of static friction for the penny on the platter.



17. A spring (spring constant $k = 250$ N/m) is hanging from the ceiling. A mass ($m = 0.35$ kg) is attached to the spring, pulled down 6 cm, and then released. What is the velocity of the mass when it rises to 1 cm above the initial (relaxed, unattached) spring-end position (i.e., at $y = +.01$ m)?



18. A spool has a large radius $R = 5$ cm and an inner radius of $r = 1$ cm. A string is wrapped around the inner radius and, after passing over a massless, frictionless pulley, is attached to a hanging mass $M = 0.75$ kg. The large radius section rubs against the surface acting like a brake with total frictional force 0.6 N. The spool's total moment of inertia is $0.004\ \text{kg} \cdot \text{m}^2$. Find the acceleration of the falling mass.