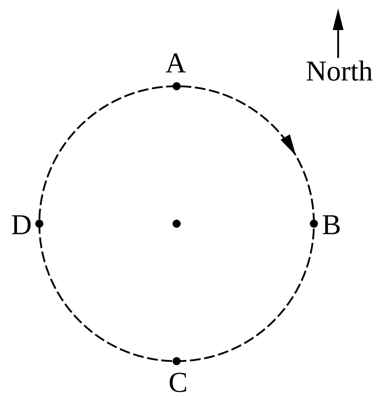
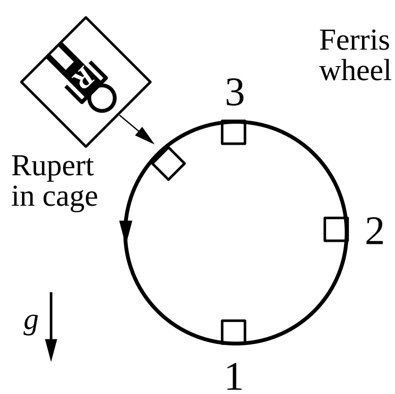
Physical Constants:

Earth's free-fall acceleration = $g = 9.80\ \mathrm{m/s^2}$
Unless stated otherwise, circle the letter of the single best answer. Each answer is worth 2 points.

1. The below displays the trajectory of a bicyclist circling a flagpole at constant speed. Where is the cyclist if his acceleration points due south? Circle the appropriate letter.

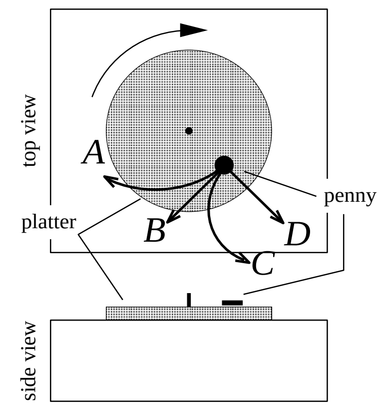


2. A giant Ferris wheel having a diameter of 40 m, is fitted with a cage and platform on which Rupert stands. The wheel rotates rapidly at constant speed allowing Rupert to stand upright in the cage. Consider the magnitude of the net force on Rupert when he is at three locations (shown below as 1, 2, and 3) on the revolving Ferris wheel.



   A. The net force is largest at #1.
   B. The net force is largest at #2.
   C. The net force is largest at #3.
   D. None of the above: the net force has constant magnitude.

3. As a turntable speeds up, static friction is unable to keep the penny on the platter, so the penny slips and kinetic friction become the only horizontal force acting on the penny. Circle the letter most accurately displaying the path of the penny as viewed by a person watching from above.



4. There is a very strong wind blowing out towards right field. A knee-high fast baseball is hit into deep right center field. The right fielder quickly runs back and towards center field. At the 10 foot high outfield fence she jumps and catches the ball an inch above the fence. The ball when caught was moving faster than immediately after it was hit. Let W_g and W_D be (respectively) the work done by gravity and the work done by air drag from immediately after the ball was hit until it was caught. During this time gravity and air drag are the only forces acting on the ball. Which combination of the below statements is correct?

   I. $W_g > 0$
   II. $W_g < 0$
   III. $W_g + W_D < 0$
   IV. $W_g + W_D > 0$

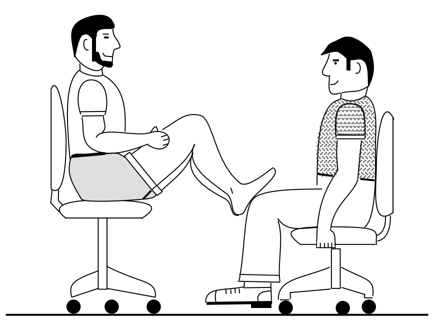
   A. I, III
   B. II, III
   C. I, IV
   D. II, IV

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

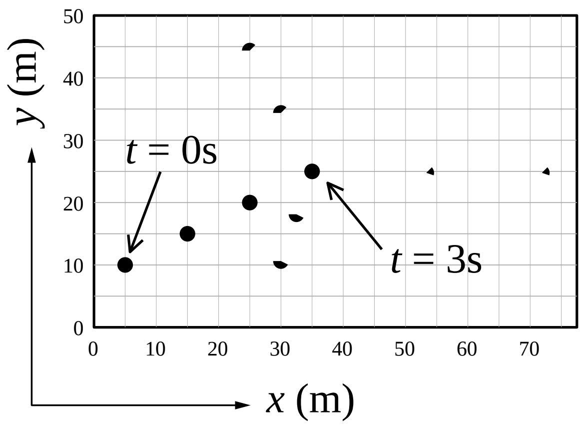
   A. she is beyond the range of gravity
   B. centrifugal force is equal but opposite to gravity
   C. she has no acceleration
   D. the space station is falling at the same rate she is

6. In the below figure, student A has a mass of 100 kg and student B has a mass of 75 kg. They sit in identical rolling office chairs facing each other. Student A places his bare feet on the knees of student B, as shown. Student A then suddenly pushes outward with his feet; as a result, both chairs roll frictionlessly away from each other. Let $\vec{p}_A$ and $\vec{v}_A$ denote respectively the momentum and velocity of student A immediately after the push; let $\vec{p}_B$ and $\vec{v}_B$ similarly denote the momentum and velocity of student B. Which of the below statements is correct?

   A. $|\vec{p}_A| > |\vec{p}_B|$ and $|\vec{v}_A| > |\vec{v}_B|$
   B. $|\vec{p}_A| = |\vec{p}_B|$ and $|\vec{v}_A| > |\vec{v}_B|$
   C. $|\vec{p}_A| = |\vec{p}_B|$ and $|\vec{v}_A| < |\vec{v}_B|$
   D. $|\vec{p}_A| < |\vec{p}_B|$ and $|\vec{v}_A| < |\vec{v}_B|$

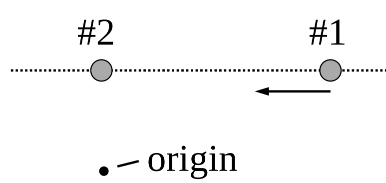


7. A puck filled with explosives slides frictionlessly on ice. A strobe light locates the puck at successive seconds: $t = 0, 1, 2, 3$ s. At $t = 3$ s, the puck explodes into three pieces as shown below, and the strobe shows where those pieces are at $t = 4, 5$ s. At $t = 5$ s the center of mass of the fragments is located most nearly at (x, y) location:



   A. $\vec{r} = (35, 25)$ (in meters)
   B. $\vec{r} = (45, 30)$ (in meters)
   C. $\vec{r} = (55, 35)$ (in meters)
   D. Not enough information given: fragment masses are required.

8. A particle moves along a straight line past the origin at constant speed as shown below. Consider the magnitude of angular momentum (L) about that origin at the two labeled spots on its trajectory. (L_1 denotes the magnitude of the particle's angular momentum at location #1, etc.)



   A. $L_1 = L_2 = 0$
   B. $L_1 = L_2 > 0$
   C. $L_1 > L_2 > 0$
   D. $L_2 > L_1 > 0$

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 frictional force (f) between the inclined plane and the rolling object, (2) the moment of inertia (I), (3) the total kinetic energy (K) when each objects crosses the finish-line, and (4) the finish-line value of the angular velocity (ω). (For example, ω_{hoop} denotes the angular velocity of the metal hoop when it crosses the finish-line.)

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

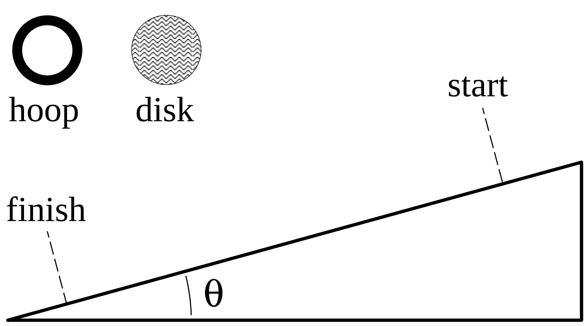
How many of these statements are true?

A. one

B. two

C. three

D. four



10. The Earth is a spinning ball completing one revolution every 24 hours (approximately). Consider identical twins one on the Earth's equator and the other in St. Joe. Take as the origin the center of the Earth. Let v_{SJ}, ω_{SJ}, L_{SJ} denote the speed, angular speed, and magnitude of angular momentum of the twin in St. Joe; similarly EQ for the twin on the equator. Then:

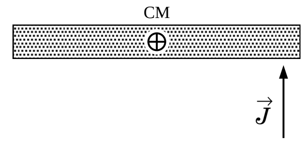
A. $\omega_{SJ} = \omega_{EQ}$

B. $L_{SJ} = L_{EQ}$

C. $v_{SJ} = v_{EQ}$

D. more than one of the above is true

11. A uniform bar resting on frictionless ice is kicked near its end providing a horizontal impulse $\vec{J}$ as shown below. The center of mass (labeled below as CM) will then:



A. remain at rest with the bar rotating around it.

B. move in a straight line at constant velocity.

C. wobble due to the unbalanced impulse.

D. none of the above

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

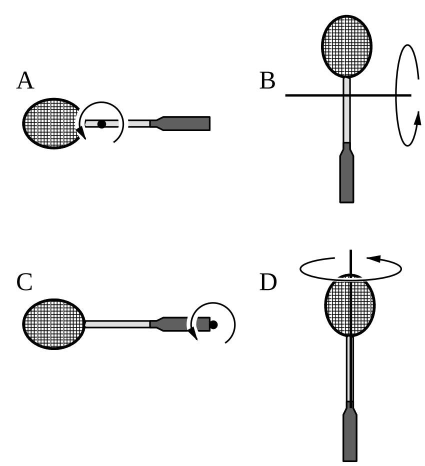
A. an axis through its center of mass and perpendicular to its face

B. an axis through its center of mass and in the plane of its face

C. an axis located at the handle's end

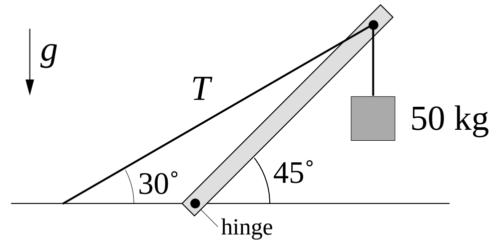
D. an axis parallel its shaft.

Which rotation axis has the largest moment of inertia?



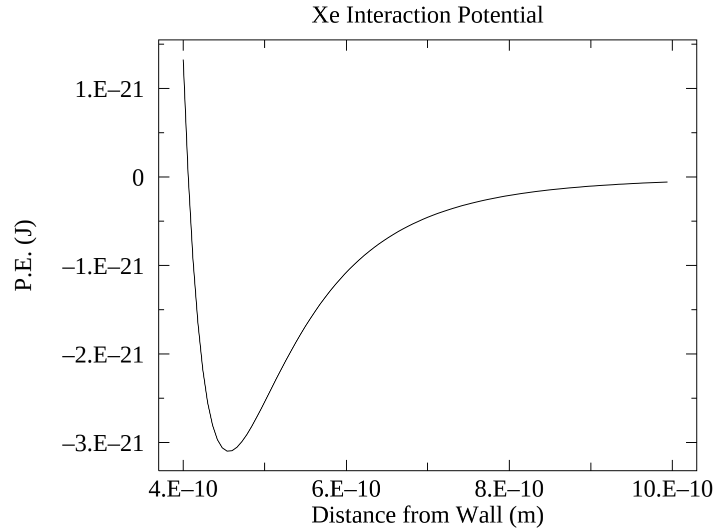
The following questions are worth 12 pts each

13. A concrete block of mass 50 kg hangs from the end of a uniform strut whose mass is 10 kg. A cable with tension T supports the structure as shown below. The length of the strut (L) is not given as it should cancel. Using the hinge as the origin draw/label (directly on the diagram) $r_\perp$ for T and $r_\perp$ for the force of gravity on the 50 kg block. Find the tension T in the cable.



14. Bullets leaving a rifle are spinning at a surprisingly fast rate (the gyroscopic effect prevents tumbling). 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 solid cylinder ($I = \frac{1}{2}MR^2$), what torque is required to achieve this bullet spin? Assuming the spin force is applied tangentially to the edge of the bullet, calculate that force.

15. All atoms feel a "small" force (van der Waals) when near a wall or another atom. Energy is of course conserved in this interaction. Below is a plot of the van der Waals potential energy for an atom of xenon (an inert gas) interacting with its container's wall. No surprise: the distances and energies are small: "`1.E-10`" m $= 1 \times 10^{-10}$ m often denoted 1 Å, "`1.E-21`" J $= 1 \times 10^{-21}$ J. The mass of a xenon atom is also "small": $M_{Xe} = 2.2 \times 10^{-25}$ kg. A xenon atom is released from rest 7 Å from the wall. (A) Read the graph to determine its potential energy at 7 Å (FYI: the number should be negative) (B) When it moves to 5 Å what is its potential energy? (C) What is its speed when it is 5 Å from the wall? (Note: accurate reading the plot's data is part of this problem.)



16. Consider a situation analogous to what you did in the Ballistic Pendulum lab. A 1 kg block of wood was at rest on a horizontal frictionless surface and connected to an unstretched spring (k=500 N/m) whose other end remains fixed to a wall. A 10 g bullet moving at 800 m/s slams into the wood and remains lodged in the wood. (A) What is the velocity of the block+bullet immediately after this perfectly inelastic collision? (B) As a result of the collision the block+bullet combination moves to the left and compresses the spring; the KE of block+bullet is converted into PE of the spring. (The objects remain in a line.) Find the maximum compression of the spring when the block+bullet is instantaneously at rest. (This is of course just a moment of rest as the spring will re-expand and the block+bullet will oscillate.)