B6 Rotation

B6-CRT01: Pulley and Weight—Angular Velocity-Time and Acceleration-Time Graphs
A weight is tied to a rope that is wrapped around a pulley. The pulley is initially rotating counterclockwise and is pulling the weight up. The tension in the rope creates a torque on the pulley that opposes this rotation. The weight slows down, stops momentarily, and then moves back downward.

(a) Graph of the angular velocity ($\omega$) versus time for the period from the initial instant shown until the weight comes back down to the same height. Take the initial angular velocity as positive.

(b) Graph the angular acceleration ($\alpha$) versus time for the same time period.

Explain your reasoning.

$T = mg \Rightarrow \omega$ starts out but slows because of the constant mass of the pulley $\Rightarrow$ stops the starts going down. I assumed initial direction is positive.

B6-CRT02: Angular Velocity-Time Graph—Angular Acceleration-Time Graph
Sketch an angular acceleration versus time graph given the angular velocity versus time graph shown for the same time interval.

Explain your reasoning.
B6-RT03: THREE-DIMENSIONAL POINT OBJECTS—MOment of Inertia ABOUT THE x-AXIS

Six small brass and aluminum spheres are connected by three stiff, lightweight rods to form a rigid object shaped like a jack. The rods are joined at their centers, are mutually perpendicular, and lie along the axes of the coordinate system shown. All spheres are the same distance from the connection point of the three rods at the origin of the coordinate axis. The brass spheres are shaded in the diagram and are identical. The aluminum spheres are identical, have less mass than the brass spheres, and are unshaded in the diagram. For this problem, ignore the mass of the connecting rods.

Rank the moment of inertia about the x-axis.

\[ I = \sum mr^2 \]
\[ I = m_1 r_1 + m_2 r_2 + m_3 r_3 + m_4 r_4 \]

Explain your reasoning.

B6-RT04: FLAT OBJECTS—MOment of Inertia PERPENDICULAR TO SURFACE

Three flat objects (circular ring, circular disc, and square loop) have the same mass \( M \) and the same outer dimension (circular objects have diameters of 2R and the square loop has sides of 2R). The small circle at the center of each figure represents the axis of rotation for these objects. This axis of rotation passes through the center of mass and is perpendicular to the plane of the objects.

Rank the moment of inertia of these objects about this axis of rotation.

\[ C > A > B \]

Explain your reasoning.
B6-QRT05: PULLEYS WITH DIFFERENT RADI—ROTATION AND TORQUE

A wheel is composed of two pulleys with different radii (labeled a and b) that are attached to one another so that they rotate together. Each pulley has a string wrapped around it with a weight hanging from it as shown. The pulleys rotate about a horizontal axis at the center. When the wheel is released it is found to have an angular acceleration that is directed out of the page or counterclockwise.

(a) Is the wheel going to rotate (i) clockwise, (ii) counterclockwise, or (iii) none?

Explain your reasoning.

\[ \text{Counterclockwise - application of Hooke's Law points out} \]
\[ \tau_1 = I_1 \alpha = F \cdot r = \vec{F}_1 \cdot a \quad (\vec{F} = \text{resultant}) \]
\[ \tau_2 = I_2 \alpha = F \cdot r = \vec{F}_2 \cdot b \quad (\text{smaller}) \Rightarrow \text{weight of} \ z \quad \text{smalls} \]

(b) Is the direction of the net torque on the pulley wheels (i) clockwise, (ii) counterclockwise, or (iii) none?

How do you know?

\[ \sum \tau = F \cdot r = I \]

(c) How do the masses of the two weights compare?

Explain your reasoning.

\[ \text{see above} \]
Rank the radius of the spheres.

Explain your reasoning.

\[ v = \omega \]
B6-QRT07: THREE EQUAL FORCES APPLIED TO A RECTANGLE—NET TORQUE DIRECTION

Three forces of equal magnitude are applied to a 3-m by 2-m rectangle. Forces \( \vec{F}_1 \) and \( \vec{F}_2 \) act at 45° angles to the vertical as shown, while \( \vec{F}_3 \) acts horizontally.

(a) Is the net torque about point A (i) clockwise, (ii) counterclockwise, or (iii) zero? __________

Explain your reasoning.

Largest force perpendicular force
giving largest — I guess — greatest torque

\[ F_1 > F_2 \]

\[ \begin{cases} \text{CW} \\ \text{CW} \end{cases} \]

(b) Is the net torque about point B (i) clockwise, (ii) counterclockwise, or (iii) zero? __________

Explain your reasoning.

\[ F_2 \sin 45° - F_1 \sin 45° = 0 \]

(c) Is the net torque about point C (i) clockwise, (ii) counterclockwise, or (iii) zero? __________

Explain how you determined your answer.

\[ F_2 \sin 0 = 0 \]

\[ F_3 \sin 0 = 0 \]

\[ F_1 \sin 0 = 0 \]

All line of actions pass through C \( \Rightarrow \) Torque = 0
**Spheres Rolling—Rotational Kinetic Energy**

The figures below show hollow spheres (not drawn to scale) that are rolling at a constant rate without slipping. The spheres all have the same mass, but their radii as well as their linear and angular speeds vary.

[A] \( \omega = 10 \text{ rad/s} \)
\( v = 30 \text{ cm/s} \)

[B] \( \omega = 10 \text{ rad/s} \)
\( v = 50 \text{ cm/s} \)

[C] \( \omega = 10 \text{ rad/s} \)
\( v = 40 \text{ cm/s} \)

[D] \( \omega = 12.5 \text{ rad/s} \)
\( v = 50 \text{ cm/s} \)

[E] \( \omega = 20 \text{ rad/s} \)
\( v = 60 \text{ cm/s} \)

[F] \( \omega = 15 \text{ rad/s} \)
\( v = 60 \text{ cm/s} \)

Rank the rotational kinetic energy of the spheres.

\[ K_\text{E} = \frac{1}{2} I \omega^2 \]

\( I \) is the same for each sphere.

\[ K_{E2} \approx \omega \]

Explain your reasoning.
B6 QRT09: Three Forces Applied to a Rectangle—Torque Direction

Three forces of equal magnitude are applied to a 3-m by 2-m rectangle. Forces \( \vec{F}_1 \) and \( \vec{F}_2 \) act at 45° angles to the vertical as shown, while \( \vec{F}_3 \) acts horizontally.

(a) Is the torque by \( \vec{F}_1 \) about point A (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(b) Is the torque by \( \vec{F}_1 \) about point B (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(c) Is the torque by \( \vec{F}_1 \) about point C (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(d) Is the torque by \( \vec{F}_2 \) about point A (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(e) Is the torque by \( \vec{F}_2 \) about point B (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(f) Is the torque by \( \vec{F}_2 \) about point C (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(g) Is the torque by \( \vec{F}_3 \) about point A (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(h) Is the torque by \( \vec{F}_3 \) about point B (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.  

(i) Is the torque by \( \vec{F}_3 \) about point C (i) clockwise, (ii) counterclockwise, or (iii) zero?

Explain your reasoning.
B6-CT10: FISHING ROD—WEIGHT OF TWO PIECES
An angler balances a fishing rod on her finger as shown.

If she were to cut the rod along the dashed line, would the weight of the piece on the left-hand side be (i) greater than, (ii) less than, or (iii) equal to the weight of the piece on the right-hand side? 

Explain your reasoning.

\[ \tau = \sum \tau_{net} = 0 \]

Left: \[ \tau = F_{rod} \cdot l \cdot H_{ur} \]

Right: \[ \tau = F_{w} \cdot B \cdot R \]

B6-RT11: SUSPENDED SIGNS—TORQUE
Signs are suspended from equal-length rods on the side of a building. For each case, the mass of the sign compared to the mass of the rod is small and can be ignored. The mass of the sign is given in each figure. In Cases B and D, the rod is horizontal; in the other cases, the angle that the rod makes with the vertical is given.

Rank the magnitude of the torque the signs exert about the point at which the rod is attached to the side of the building.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 kg</td>
<td>100 kg</td>
<td>50 kg</td>
<td>90 kg</td>
</tr>
</tbody>
</table>

\[ \tau = 90 \sin 30 \]

<table>
<thead>
<tr>
<th>Rank</th>
<th>Mass</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90 kg</td>
<td>30°</td>
</tr>
<tr>
<td>2</td>
<td>100 kg</td>
<td>60°</td>
</tr>
<tr>
<td>3</td>
<td>50 kg</td>
<td>60°</td>
</tr>
<tr>
<td>4</td>
<td>50 kg</td>
<td>30°</td>
</tr>
</tbody>
</table>

Explain your reasoning.

\[ \tau \text{ depends on Weight } \times \text{ Distance from line of action angle} \]
36-RRT12: FOUR FORCES ACTING ON A HEXAGON—TORQUE ABOUT CENTER

Four forces act on a plywood hexagon as shown in the diagram. The sides of the hexagon each have a length of 1 m.

\[ \tau_A = 4 \cdot 1 = 4 \]
\[ \tau_B = 4 \cdot 1 = 4 \]
\[ \tau_C = 4 \cdot 1 \neq 4 \]
\[ \tau_D = 0 \]

Rank the magnitude of the torque applied about the center of the hexagon by each force.

<table>
<thead>
<tr>
<th>Force</th>
<th>Greatest</th>
<th>All the same</th>
<th>All zero</th>
<th>Cannot determine</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explain your reasoning.

B6-QRT13: BALANCE BEAM—MOTION AFTER RELEASE

Five identical keys are suspended from a balance, which is held horizontally as shown. The two keys on the left are attached to the balance 6 cm from the pivot and the three keys on the right are attached 5 cm from the pivot.

What will happen when the person lets go of the balance beam?

Explain.

\[ \sum \tau_{net} = F_2 \cdot r - F_1 \cdot r \]
\[ \sum \tau_{net} = 2g \cdot r - 3g \cdot r \]
\[ 2g \cdot 0.06 - 3g \cdot 0.05 \]
\[ 0.12g - 0.15g \]
\[ -0.03g \text{ moment} \]
B6-RT14: Rolling Objects Released from Rest—Time Down Ramp

Four objects are placed in a row at the same height near the top of a ramp and are released from rest at the same time. The objects are (i) a 1-kg solid sphere; (ii) a 1-kg hollow sphere; (iii) a 2-kg solid sphere; and (iv) a 1-kg thin hoop. All four objects have the same diameter, and the hoop has a width that is one-quarter its diameter. The time it takes the objects to reach the finish line near the bottom of the ramp is recorded.

The moment of inertia for an axis passing through its center of mass for a solid sphere is \( \frac{2}{5} MR^2 \); for a hollow sphere it is \( \frac{2}{3} MR^2 \); and for a hoop it is \( MR^2 \).

Rank the four objects from fastest (shortest time) down the ramp to slowest.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fastest</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Slowest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All the same</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannot determine</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

I = (K)mr^2

Explain your reasoning.

Remember:

\[ E_f = E_i \]
\[ \frac{1}{2}kx^2 + \frac{1}{2}kR^2 = mgh \]

No Slippage

\[ V_T = \text{final velocity} \]

B6-WWT15: Pulley with Hanging Weights—Angular Acceleration

Two pulleys with different radii (labeled \( a \) and \( b \)) are attached to one another so that they rotate together. Each pulley has a string wrapped around it with a weight hanging from it. The pulleys are free to rotate about a horizontal axis through the center. The radius of the larger pulley is twice the radius of the smaller one (\( b = 2a \)). A student describing this arrangement states:

"The larger mass is going to create a counterclockwise torque and the smaller mass will create a clockwise torque. The torque for each will be the weight times the radius, and since the radius for the larger pulley is double the radius of the smaller, and the weight of the heavier mass is less than double the weight of the smaller one, the larger pulley is going to win. The net torque will be clockwise, and so the angular acceleration will be clockwise."

What, if anything, is wrong with this contention? If something is wrong, explain how to correct it. If this contention is correct, explain why.

Students answer is correct

\[ \Sigma \tau = I \alpha \]

\[ \Sigma \tau = T_1 - T_2 \]

\[ T_1 = m_1 g a - m_0 g b \]

\[ T_2 = 1.5m_0 (g)(a) - m_0 (g)(b) \]

\[ 1.5m_0 (g)(a) - 2m_0 (g)(b) \]

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36-RT16: TILTED PIVOTED RODS WITH VARIOUS LOADS—FORCE TO HOLD RODS
Six identical massless rods are supported by a fulcrum and are tilted at the same angle to the horizontal. A mass is suspended from the left end of the rod, and the rods are held motionless by a downward force on the right end. Each rod is marked at 1-m intervals.

**Diagram:**
- **A:** 100 kg
- **B:** 100 kg
- **C:** 100 kg
- **D:** 200 kg
- **E:** 200 kg
- **F:** 200 kg

Rank the magnitude of the vertical force $F$ applied to the end of the rod.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>B</td>
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<td>C</td>
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<td>D</td>
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<td></td>
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<tr>
<td>E</td>
<td></td>
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<td></td>
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<tr>
<td>F</td>
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OR

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</thead>
<tbody>
<tr>
<td></td>
<td>All the same</td>
<td>Cannot determine</td>
</tr>
</tbody>
</table>

Explain your reasoning.

1. $T = F \cdot r$
2. $\eta = 0$  
3. $\eta$ and $F$ are both applied to the left end.
4. Further 100 kg weight from fulcrum $\Rightarrow$ greater torque

B6-CT17: SPECIAL ROD—MOMENT OF INERTIA
A rod is made of three segments of equal length with different masses. The total mass of the rod is 6 m.

<table>
<thead>
<tr>
<th></th>
<th>m</th>
<th>2m</th>
<th>3m</th>
</tr>
</thead>
</table>

Will the moment of inertia of the rod be (i) greater about the left end, (ii) greater about the right end, or (iii) the same about both ends?

Explain your reasoning.

1. $I = kmr^2$

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36-CT18: TILTED PIVOTED RODS WITH VARIOUS LOADS—FORCE TO HOLD RODS

In both cases, a massless rod is supported by a fulcrum, and a 200-kg hanging mass is suspended from the left end of the rod by a cable. A downward force \( F \) keeps the rod at rest. The rod in Case A is 50 cm long, and the rod in Case B is 40 cm long. (Each rod is marked at 10-cm intervals.)

\[
\begin{align*}
A: & \quad 200 \text{ N} \\
B: & \quad 200 \text{ N}
\end{align*}
\]

\[
\begin{align*}
\theta = & \text{ same} \\
or \text{ it would} \\
\text{rotate based} \\
on \text{ Figure 1}
\end{align*}
\]

Will the magnitude of the vertical force \( F \) exerted on the rod be (i) greater in Case A, (ii) greater in Case B, or (iii) the same in both cases?

Explain your reasoning.

\[
\text{SAME} \quad \Rightarrow \quad \tau = 0 \quad \text{Both NoRotation}
\]

\[
\Rightarrow \quad \tau_{cw} = \tau_{cw} \\
F, \quad \text{Case A = F, Case B}
\]

B6-RT19: HORIZONTAL PIVOTED RODS WITH LOADS I—FORCE TO HOLD

A 2-m long massless rod supports a 12-Newton weight. The left end of each rod is held in place by a frictionless pin. In each case, a vertical force \( F \) is holding the rods and the weights at rest. The rods are marked at half-meter intervals.

\[
\begin{align*}
A: & \quad 12 \text{ kg} \\
B: & \quad 12 \text{ kg} \\
C: & \quad 12 \text{ kg} \\
D: & \quad 12 \text{ kg} \\
E: & \quad 12 \text{ kg} \\
F: & \quad 12 \text{ kg}
\end{align*}
\]

Rank the magnitude of the vertical force \( F \) applied to the rods.

\[
\begin{array}{ccccccc}
& 1 & 2 & 3 & 4 & 5 & 6 \\
\text{E} & \text{F} & \text{G} & \text{H} & \text{I} & \text{J} & \text{K}
\end{array}
\]

OR \quad \text{All the same} \quad \text{Cannot determine}

Explain your reasoning.

\[
\tau = F \cdot r
\]
B6-LMCT20: HORIZONTAL PIVOTED BOARD WITH LOAD II—FORCE TO HOLD BOARD

A 100-N weight is placed on a massless board a distance $L_1$ to the left of frictionless pin. A vertical downward force $F$ is applied to the other side of the board a distance of $L_2$ from the pin as shown. The system is at rest.

Identify from choices (i)–(v) how each change described below will affect the magnitude of the applied force $(F)$ on the right side of the board needed to keep the system in equilibrium.

Compared to the case above, this change will:

(i) increase the magnitude of the support force $(F)$ on the board.

(ii) decrease the magnitude of the support force $(F)$ on the board but not to zero.

(iii) decrease the magnitude of the support force $(F)$ on the board to zero.

(iv) have no effect on the magnitude of the support force $(F)$ on the board.

(v) have an indeterminate effect on the magnitude of the support force $(F)$ on the board.

Each of these modifications is the only change to the initial situation shown in the diagram above.

(a) The 100-N weight is moved to a position closer to the pin. 

Explain your reasoning.

(b) The support force $(F)$ is moved to a position closer to the pin.

Explain your reasoning.

(c) The weight is decreased to 50 N.

Explain your reasoning.

(d) The support force $(F)$ is moved to the right end of the board.

Explain your reasoning.

(e) The board is made longer but the support force $(F)$ remains at the same location.

Explain your reasoning.

(f) The 100-N weight and the support force $(F)$ are both moved to positions closer to the pin.

Explain your reasoning.

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B6-RT21: HANGING WEIGHTS ON FIXED DISKS—TORQUE
Vertically oriented circular disks have strings wrapped around them. The other ends of the strings are attached to hanging masses. The diameters of the disks, the masses of the disks, and the masses of the hanging masses are given. The disks are fixed and are not free to rotate. Specific values of the variables are given in the figures.

Rank the magnitudes of the torques exerted by the strings about the center of the disks.

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>D</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Greatest | Less

Or

- All the same
- All zero
- Cannot determine

Explain your reasoning.

B6-RT22: SYSTEMS OF POINT MASSES—DIFFICULT TO ROTATE
Each of the ten point masses in each case is identical. The solid line in each figure represents an axis about which the masses are going to be rotated. The point masses are fixed together so that they all maintain the arrangements shown while being rotated.

Rank these arrangements on how hard it will be to start the systems rotating.

<p>| | | | |</p>
<table>
<thead>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>C</td>
<td>D</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Greatest | Least

Or

- All the same
- All zero
- Cannot determine

Explain your reasoning.
TIPERS

B6-RT31: OBJECTS MOVING DOWN RAMPS—SPEED AT BOTTOM
In each case, a 1-kg object is released from rest on a ramp at a height of 2 m from the bottom. All of the spheres roll without slipping, and the blocks slide without friction. The ramps are identical in Cases A and C. The ramps in Cases B and D are identical and are not as steep as the others.

Rank the speed of the objects when they reach the horizontal surface at the bottom of the ramp.

Explain your reasoning.

1. Starting Energy same
2. Same mg\cdot s
3. I \propto \text{Area of sphere} \Rightarrow I = (\frac{2}{5})mr^2

B6-RT32: BLOCKS ON ROTATING DISC—HORIZONTAL FRICTIONAL FORCE
A block is placed on a rotating disc and moves in a circular path. The discs have the same rotation rate in each case, but the masses of the blocks and their distance from the center varies.

Rank the magnitude of the frictional force on blocks by the discs.

Explain your reasoning.

All acceleration is centripetal \Rightarrow \Sigma F_{friction} = \frac{mv^2}{R}

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B6-QRT29: SOLID SPHERE ROLLING ALONG A TRACK—LOCATION AT HIGHEST POINT
A solid sphere rolls without slipping along a track shaped as shown at right. It starts from rest at point A and is moving vertically when it leaves the track at point B.

At its highest point while in the air, will the sphere be (a) above, (b) below, or (c) at the same height as point A?

Explain your reasoning.

\[ E_P = E_I = \frac{1}{2} I \omega^2 + \frac{1}{2} m v^2 = m g h \]

No rotation, it would go to height A but no external force when energy used to rotate.

B6-RT36: MOVING DOWN A RAMP—MAXIMUM HEIGHT ON THE OTHER SIDE OF A RAMP
In each case, a 1-kg object is released from rest on a ramp at a height of 2 m from the bottom. All of the spheres roll without slipping, and the blocks slide without friction.

A
Solid sphere

B
Solid sphere

C
Solid sphere

D
Hollow sphere

E
Hollow sphere

F
Hollow sphere

Rank the maximum height of the objects on the other side of the ramp.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Greatest
Least

OR
All the same
All zero
Cannot determine

Explain your reasoning.

1. All the same!!
2. You have torque to remove the rotation \( \Rightarrow \) converted to mg h.
**B6-BCT28: SOLID DISK ROLLING UP A RAMP—ROTATIONAL ENERGY BAR CHART**

A solid disk is initially rolling without slipping along a flat, level surface. It then rolls up an incline, coming momentarily to rest as shown.

Complete the qualitative energy bar chart below for the earth-disk system for the time between when the disk is rolling on the horizontal and when it has rolled up the ramp and is momentarily at rest. Put the zero point for the gravitational potential energy at the height of the center of the hoop when it is rolling on the horizontal surface.

<table>
<thead>
<tr>
<th>Initial system energy</th>
<th>During</th>
<th>Final system energy</th>
<th>Bar chart key</th>
</tr>
</thead>
<tbody>
<tr>
<td>$KE_{trans}$</td>
<td>$KE_{rot}$</td>
<td>$PE_{grav}$</td>
<td>$PE_{spring}$</td>
</tr>
<tr>
<td>$W_{ext}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use $g = 10 \text{ m/s}^2$ for simplicity.

Explain your reasoning.

\[ I = \frac{1}{2} I \omega^2 \]

\[ KE_{rot} = \frac{1}{2} I \omega^2 \]

\[ KE_{rot} = \frac{1}{2} (m\omega^2)(\frac{g}{I}) \]

\[ KE_{rot} = \frac{1}{2} m v^2 \Rightarrow KE_{rot} = KE_{R} \]
36-BCT27: Hoop Rolling up a Ramp—Rotational Energy Bar Chart

A thin hoop of mass with a radius of 2 m is moving so that its center of mass is initially moving at 20 m/s while also rolling without slipping at 10 rad/s along a horizontal surface. It rolls up an incline, coming to rest as shown.

Complete the qualitative energy bar chart below for the earth-hoop system for the time between when the hoop is rolling on the horizontal surface and when it has rolled up the ramp and is momentarily at rest. Put the zero point for the gravitational potential energy at the height of the center of the hoop when it is rolling on the horizontal surface.

<table>
<thead>
<tr>
<th>Initial system energy</th>
<th>During</th>
<th>Final system energy</th>
<th>Bar chart key</th>
</tr>
</thead>
<tbody>
<tr>
<td>KE_{trans}</td>
<td>KE_{rot}</td>
<td>PE_{grav}</td>
<td>PE_{spring}</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

Bar chart key:
- KE_{trans}: Translational kinetic energy
- KE_{rot}: Rotational kinetic energy
- PE_{grav}: Gravitational potential energy
- PE_{spring}: Spring potential energy
- W_{ex}: Work done by external forces

Use $g = 10 \text{ m/s}^2$ for simplicity.

Explain your reasoning.

\[ I = \frac{1}{2}mr^2 \]

\[ KE_{rot} = \frac{1}{2}(I)(\omega^2) \]

\[ KE_{rot} = \frac{1}{2}(\frac{1}{2}mL^2) \left( \frac{v}{L} \right) \]

\[ KE_{rot} = \frac{1}{4}mvL \]

\[ CE \Rightarrow KE_{rot} = \frac{1}{2} KE_{T} \]

\[ KE_{T} = \frac{1}{2}mv^2 \]
B6-RT23: Meter Stick with Hanging Mass I—Difficulty Holding

A student is holding a meter stick by one end. A 1,000 g mass is hung on the meter sticks. All of the meter sticks are identical, but the distance along the meter stick at which the 1,000 g mass is hung and the angles at which the student holds the meter stick vary. (Ignore the mass of the meter stick.)

Rank the difficulty of holding the meter stick from the left end in the position shown.

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greatest</td>
<td></td>
<td></td>
<td></td>
<td>Least</td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td>All zero</td>
</tr>
<tr>
<td></td>
<td>Cannot determine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explain your reasoning.

B6-CT24: Horizontal Meter Stick with Two Hanging Masses—Torque

In each case, a student is holding a meter stick horizontally. Each meter stick has a mass attached at the 50 cm mark and another at the 100 cm mark. The meter sticks are identical, and the specific values and locations are given in the figures.

Is the magnitude of the torque by the student on the meter stick (i) greater in Case A, (ii) greater in Case B, or (iii) the same in both cases? __________

Explain your reasoning.

\[ T_{A_{right}} = 500 \cdot 2 + 1000 \cdot 1 = 1250 \text{ Nm} \]

\[ T_{B_{right}} = 1000 \cdot \frac{1}{2} + 500 \cdot 1 = 1000 \text{ Nm} \]
B6-RT26: Four Forces Acting on a Piece of Plywood—Torque

Four 4-Newton forces (A–D) act on a 3-m by 4-m piece of plywood as shown.

\[ \begin{align*}
B &= 4N \times 3 \times \sin 45^\circ = 8.46 \\
C &= 4N \times 2 = 8 \\
D &= 4N \times 2 = 8
\end{align*} \]

Rank the magnitudes of the torques due to the four forces about point P.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greatest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

All the same
All zero
Cannot determine

Explain your reasoning.

B6-QRT26: Four Forces Acting on a Piece of Plywood—Rotation Direction

Four 4-Newton forces (A–D) act on a 3 m by 4 m piece of plywood that has a pivot point at P.

Will the plywood rotate about the pivot point P (i) clockwise, (ii) counterclockwise, or (iii) not at all? __________

Explain your reasoning.