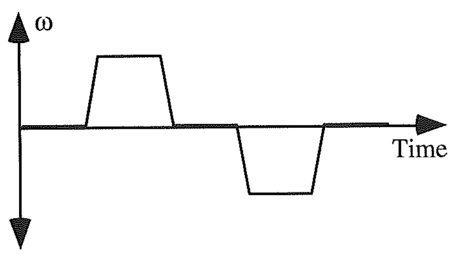
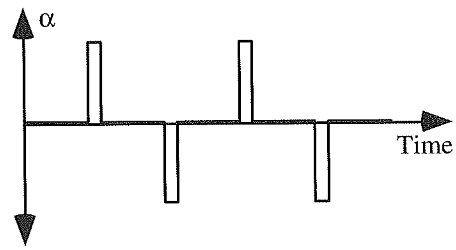
NT8 ROTATION

NT8A-WWT1: ANGULAR VELOCITY VS. TIME GRAPH—ANGULAR ACCELERATION VS. TIME GRAPH

A student obtains a graph of an object's angular velocity versus time and then draws the graph of the angular acceleration versus time for the same time interval.

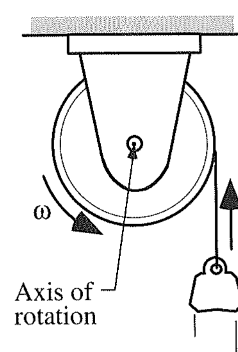




What, if anything, is wrong with this graph of the angular acceleration versus time? If something is wrong, explain how to correct it. If this graph of the angular acceleration is correct, explain why.

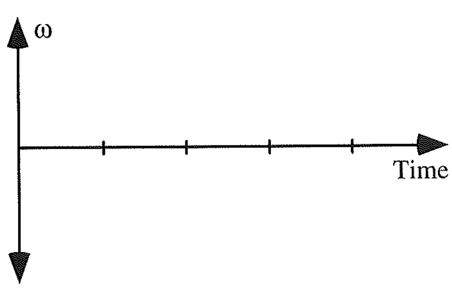
NT8A-CRT2: PULLEY AND WEIGHT—ANGULAR VELOCITY AND ACCELERATION GRAPHS

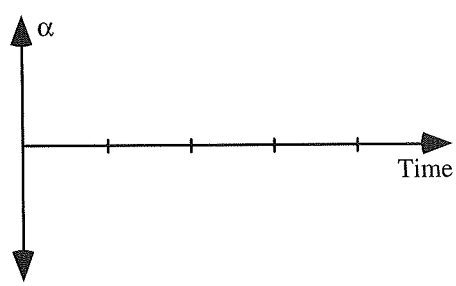
A weight is tied to a rope that is wrapped around a pulley. The pulley is initially rotating counterclockwise and is pulling the weight up. The tension in the rope creates a torque on the pulley that opposes this rotation.



a) **On the axes below, draw a graph of the angular velocity 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) **Draw a graph of the angular acceleration versus time for the same time period.**

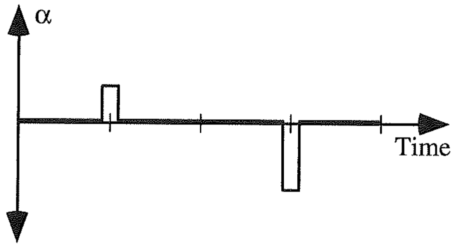


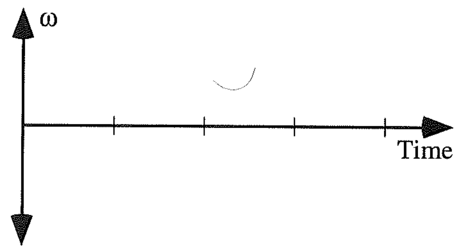


Explain.

NT8A-CRT3: ANGULAR ACCELERATION VS. TIME GRAPH—ANGULAR VELOCITY VS. TIME GRAPH

Sketch an angular velocity versus time graph given the angular acceleration graph shown for the same time interval, assuming the initial angular velocity is zero.

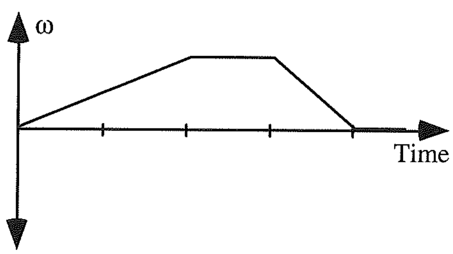


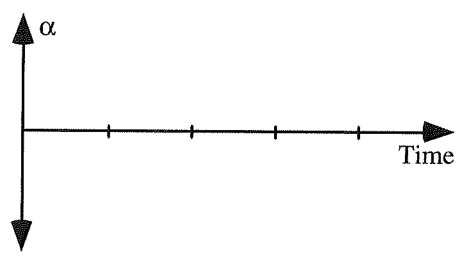


Explain.

NT8A-CRT4: ANGULAR VELOCITY VS. TIME GRAPH—ANGULAR ACCELERATION VS. TIME GRAPH

Sketch an angular acceleration versus time graph given the angular velocity versus time graph shown for the same time interval.

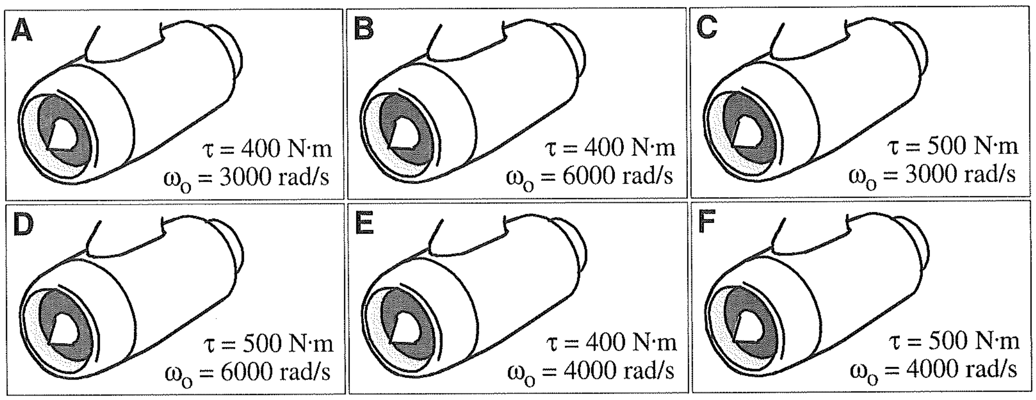




Explain.

NT8A-RT5: STOPPING JET ENGINES—ANGULAR ACCELERATION

In each figure below, the jet engine is slowing down due to the application of a constant torque. All of the engines are identical, but they start with different angular speeds and have torques of different magnitudes applied to the rotating shafts within the engines. Magnitudes of the initial angular speeds and torques are given in the figures.



Rank these situations on the basis of the magnitude of the angular acceleration of the engines as they slow down.

Greatest 1 _______ 2 _______ 3 _______ 4 _______ 5 _______ 6 _______ Least

OR, The magnitude of the angular acceleration is the same but not zero for all these engines. ___

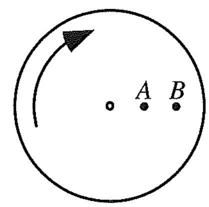
OR, The magnitude of the angular acceleration is zero for all these engines. ___

OR, We cannot determine the ranking for the angular accelerations of these engines. ___

Please explain your reasoning.

NT8A-CT6: Rotating Disc—Acceleration and Velocity

A disc with a moment of inertia of 0.2 kg·m^2 rotates at 300 revolutions per minute. It takes 40 s for the disc to reach this rotation rate starting from rest. Consider a point *A* on the disc that is 1 cm from the axis of rotation and another point *B* that is farther from this axis.



Disc rotating clockwise – top view

Ten seconds after starting from rest:

(1) Will the magnitude of the angular acceleration of point *A* be *greater than, less than,* or *equal to* the magnitude of the angular acceleration of point *B?*

Explain.

(2) Will the magnitude of the angular velocity of point *A* be *greater than, less than,* or *equal to* the magnitude of the angular velocity of point *B?*

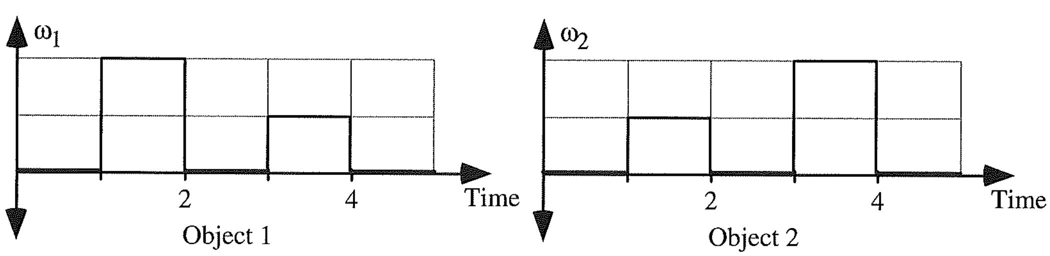
Explain.

(3) Will the magnitude of the linear velocity of point *A* be *greater than, less than,* or *equal to* the magnitude of the linear velocity of point *B?*

Explain.

NT8A-CT7: Angular Velocity vs. Time Graphs—Angular Displacement

The graphs below show the angular velocity of two objects (labeled as object 1 and object 2) during the same time interval.

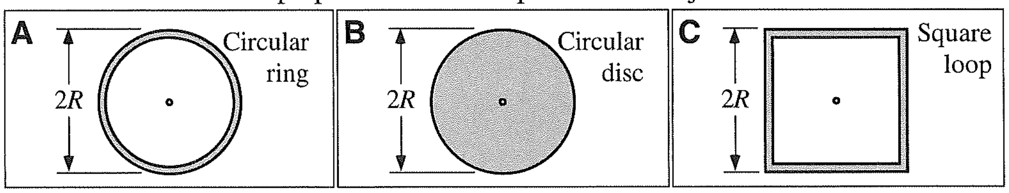


After the 5-second time interval, is the angular displacement of Object 1 *greater than, equal to,* or *less than* the angular displacement of Object 2?

Explain.

NT8B-RT10: 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.

Greatest 1 _______ 2 _______ 3 _______ Least

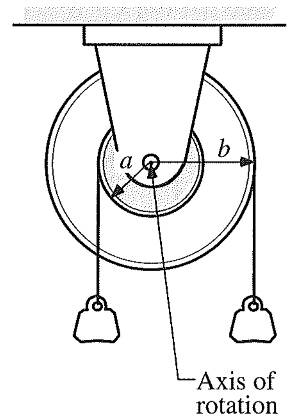
OR, The moment of inertia of these objects is the same. ___

OR, We cannot determine the ranking for the moment of inertia of these objects. ___

Please explain your reasoning.

NT8C-QRT11: PULLEYS WITH DIFFERENT RADII—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 whole system is free to 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.



(1) Which way is the wheel rotating?

Explain.

(2) What is the direction of the net torque on the system?

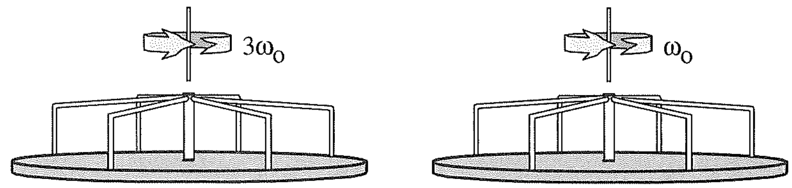
How do you know?

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

Explain.

NT8C-CT12: Merry-Go-Rounds—Net Torque

Shown below are two merry-go-rounds that are identical and rotating at different constant rates. The angular velocity of the merry-go-round on the left is three times that of the merry-go-round on the right.



Will the net torque on the merry-go-round on the left be *greater than, less than,* or *equal to* the one on the right?

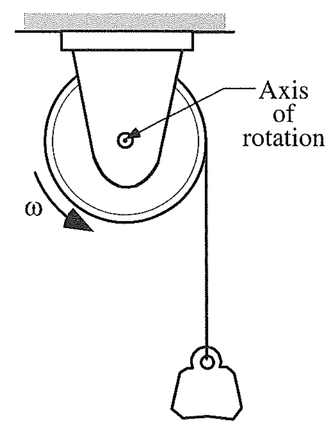
Explain.

NT8C-TT13: Pulley and Block—Torque

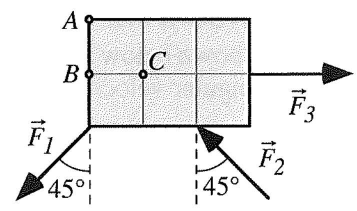
A weight is tied to a rope that is wrapped around a pulley. The pulley is initially rotating counterclockwise and is pulling the weight up. The tension in the rope creates a torque on the pulley that opposes this rotation. A student makes the following comment about the torque on the pulley at the instant it stops rotating counterclockwise before starting to rotate clockwise:

"I think the torque on the pulley at that instant will be zero since the system has stopped."

There is at least one thing wrong with this contention. Identify the error(s) and explain how to correct it (them).



NT8C-QRT14: THREE EQUAL FORCES APPLIED TO A RECTANGLE—TORQUE



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 clockwise, counterclockwise,* or *zero*?

Explain how you determined your answer.

b) Is the net torque about point *B clockwise, counterclockwise,* or *zero*?

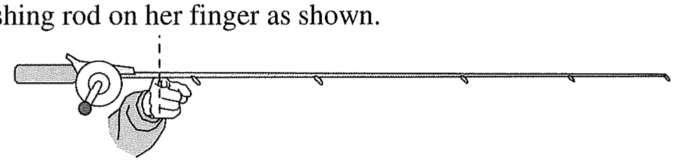
Explain how you determined your answer.

c) Is the net torque about point *C clockwise, counterclockwise,* or *zero*?

Explain how you determined your answer.

NT8C-CT15: FISHING ROD—WEIGHT OF TWO PIECES

An angler balances a fishing rod on her finger as shown.

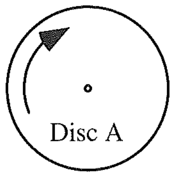


If she were to cut the rod along the dashed line, would the weight of the piece on the left-hand side be *greater than, less than,* or *equal to* the weight of the piece on the right-hand side?

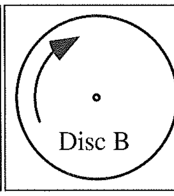
Explain your reasoning.

NT8D-CT27: Rotating Discs—Angular Momentum and Rotational Kinetic Energy

In case A, a disc with a moment of inertia of I_A rotates clockwise at a constant rate ω_A and in case B a disc with a moment of inertia of I_B is rotating clockwise at a constant rate ω_B as shown. I_A is two times larger than I_B and ω_B is two times larger than ω_A.



Angular velocity: ω_A
Moment of inertia: $I_A = 2I_B$



Angular velocity: $\omega_B = 2\omega_A$
Moment of inertia: I_B

(1) Is the magnitude of the angular momentum of the disc in Case A *greater than, less than,* or *equal to* the magnitude of the angular momentum of the disc in Case B?

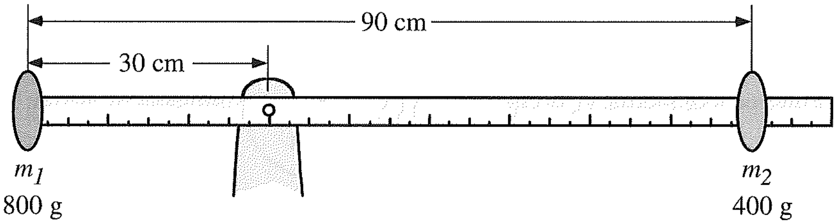
Explain.

(2) Is the kinetic energy of the disc in Case A *greater than, less than,* or *equal to* the kinetic energy of the disc in Case B?

Explain.

NT8D-CT28: MASSES ON METER STICK—ROTATIONAL INERTIA, ENERGY, & ANGULAR MOMENTUM

A massless meter stick is free to rotate about a frictionless pin at the 30-cm mark. An 800-gram mass labeled m_1 is attached to the end of the meter stick at the zero cm mark and a 400-gram mass labeled m_2 is attached to the 90 cm mark.



a) Is the rotational inertia of mass m_1 about the pivot pin *greater than, less than,* or *equal to* the rotational inertia of mass m_2 about the pivot point?

Explain.

b) Does the rotational inertia of the meter stick system about the pivot point *increase, decrease,* or *remain the same* if it rotates 90° from the horizontal orientation shown to a vertical orientation with mass m_2 upward?

Explain.

c) If the meter stick system is rotating at a constant angular velocity about the pivot pin, is the angular momentum of mass m_1 *greater than, less than,* or *equal to* the angular momentum of mass m_2?

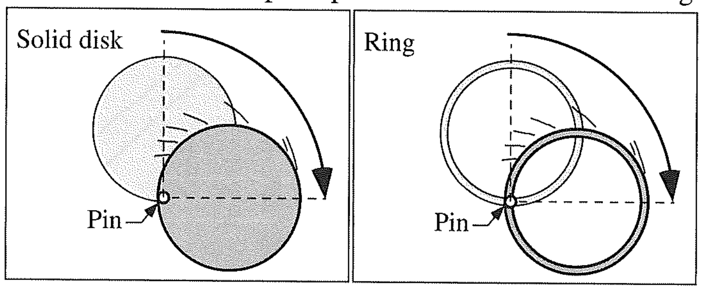
Explain.

d) If the meter stick system is rotating at a constant angular velocity about the pivot pin, is the kinetic energy of mass m_1 *greater than, less than,* or *equal to* the kinetic energy of mass m_2?

Explain.

NT8E-CT31: PIVOTING SOLID DISC AND RING—TORQUE AND ANGULAR ACCELERATION

A solid disc and a ring both with a radius of R, thickness t, and mass M are pivoted about a horizontal, frictionless pin through a point on their edge perpendicular to the vertical plane of the disc or ring. Both are released from rest with their centers just slightly to the right of directly above the pivot point. Consider the instants that the centers of each are in the horizontal position shown in the drawings. (The moment of inertia of the solid disc about this pivot point is $1.5MR^2$ and for the ring it is $2MR^2$.)



(1) At this position, will the magnitude of the torque on the solid disc about the pivot point due to its weight be *greater than, less than,* or *equal to* the magnitude of the torque on the ring about the pivot point due to its weight?

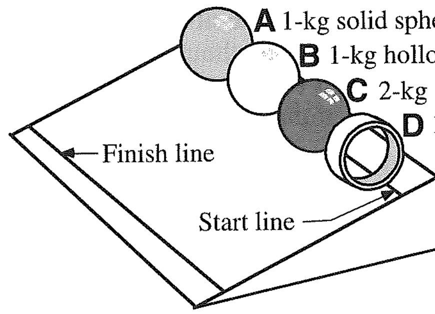
Explain.

(2) At this position, will the magnitude of the angular acceleration of the solid disc about the pivot point be *greater than, less than,* or *equal to* the magnitude of the angular acceleration of the ring due to its weight?

Explain.

NT8E-RT32: 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 (A) a 1-kg solid sphere; (B) a 1-kg hollow sphere; (C) a 2-kg solid sphere; and (D) 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.

Fastest 1 _______ 2 _______ 3 _______ 4 _______ Slowest

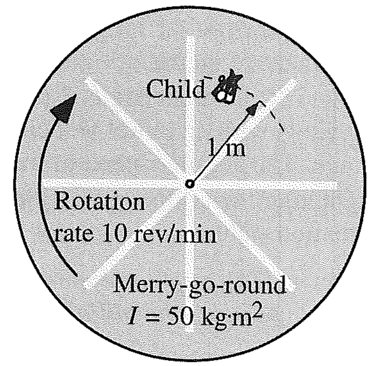
OR, The time is the same for these objects. ___

OR, We cannot determine the ranking for the times for these objects. ___

Please explain your reasoning.

NT8F-CCT39: CHILD ON ROTATING PLATFORM—FINAL ANGULAR VELOCITY

A very low friction merry-go-round (rotating platform) with a radius of 1.5 m and moment of inertia of 50 kg·m^2 is rotating at 10 rev/min. A child with a mass of 20 kg initially sits 1 m from the center, and then moves outward toward the edge of the platform. Two students are discussing how to calculate the final angular velocity of the platform:



Arno: *"I think we have to use conservation of angular momentum. The distance from the child to the axis of rotation increases, so her moment of inertia increases. The total moment of inertia goes up, and so the angular velocity has to go down."*

Belle: *"Well, I agree that the angular velocity goes down, but I think you are going to get the wrong value. We need to use conservation of energy instead of conservation of momentum, because there is no collision here. The rotational kinetic energy is what's going to stay the same here, and as the moment of inertia increases, the angular velocity goes down."*

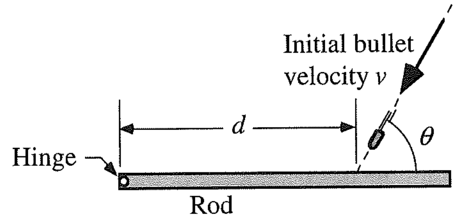
Which, if any, of these students do you agree with and think is correct?

Arno _____ Belle _____ Neither _____

Please explain your reasoning.

NT8F-CCT40: BULLET SHOT AT ROD—CONSERVED QUANTITIES

A bullet of mass m is shot at a hinged rod and hits the rod a distance d from the hinge. The rod was initially at rest and has a moment of inertia of I about an axis through its hinge. The bullet is fired at an angle θ to the rod, as shown in the topview, with an initial velocity of v at a distance d from the hinge. The angular speed of the rod with the bullet embedded right after the collision is ω. Several students discussing this situation state:



Ann: *"The angular momentum of the rod plus bullet about the hinge after the bullet is embedded is the same as the initial angular momentum of the bullet about the hinge."*

Bela: *"The kinetic energy of the bullet before the collision with the rod is equal to the rotational kinetic energy of the rod and bullet together after the bullet hits the rod."*

Carlos: *"The bullet is going straight so it does not have any angular momentum about the rod hinge before the collision, so we need to use conservation of energy. However, we can't really compare energies before and after since we do not know how much energy is lost in heat, deformation of the bullet and rod, and sound."*

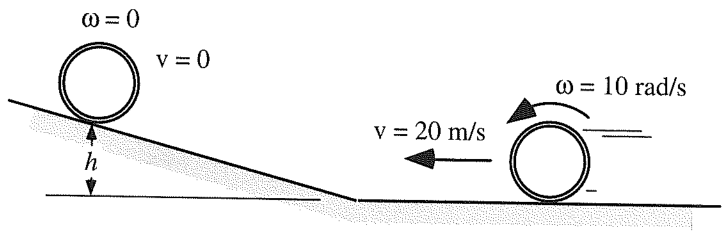
Which, if any, of these students do you agree with and think is correct?

Ann _____ Bela _____ Carlos _____None of them _____

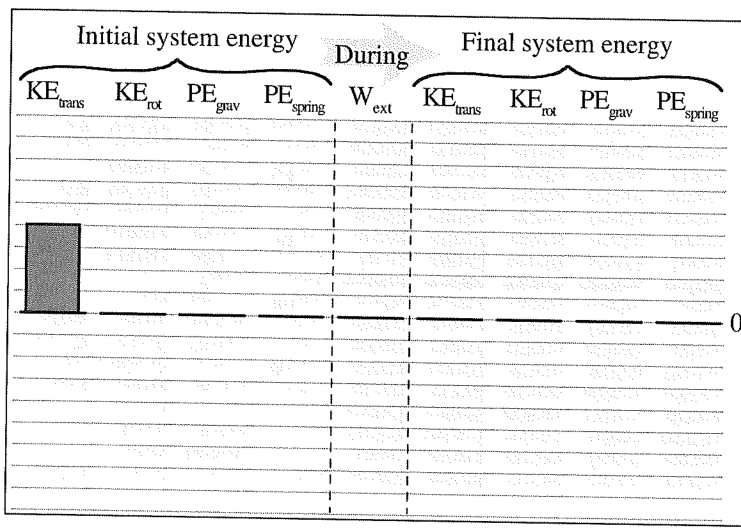
Please explain your reasoning.

NT8G-BCT45: Hoop Rolling Up a Ramp—Basic Bar Chart

A thin hoop or ring 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 below.



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.



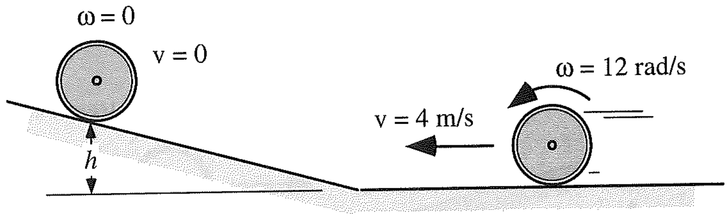
Bar chart key	
KE_{trans}	Translational kinetic energy
KE_{rot}	Rotational kinetic energy
PE_{grav}	Gravitational potential energy
PE_{spring}	Spring potential energy
W_{ext}	Work done by external forces

Use $g = 10\ m/s^2$ for simplicity

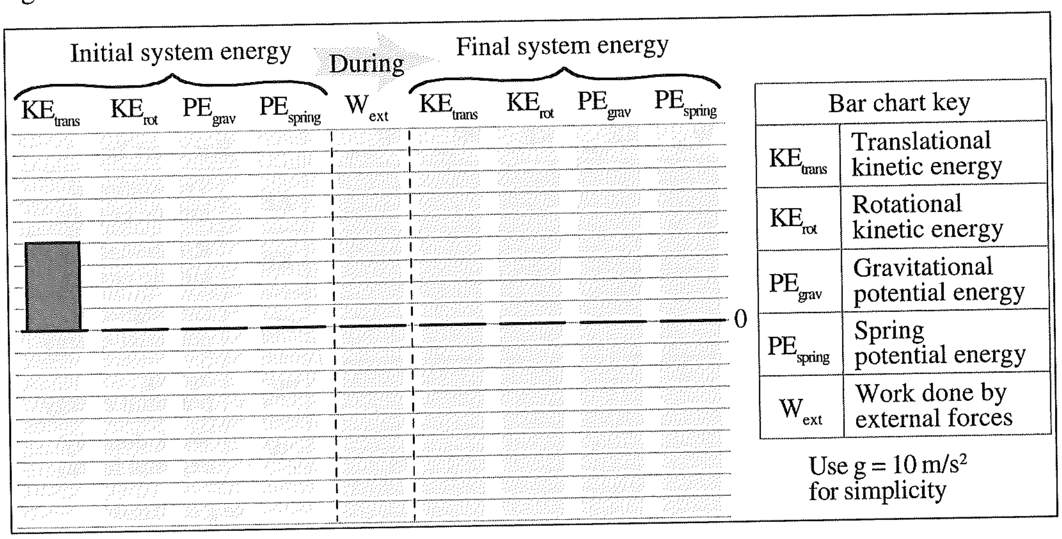
Explain.

NT8G-BCT46: Solid Disk Rolling Up a Ramp—Basic 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.



Explain.