AP® CollegeBoard

Workbook | 2021

AP® Physics 1

Workbook | 2021

Unit 7 - Torque and Rotation

NAME ______________________ DATE ______________

Scenario

A coin rests on a rotating turntable. Angela collects the following data for the distance of the coin from the center (radius): the distance the coin traveled in an arc (S) and the angle in degrees through which the coin rotated.

Trial Number	*Radius (meters)*	*Arc Length (meters)*	*Angle in Degrees*	*Angle in Radians*
1	0.20	0.07	20	0.349
2	0.20	0.10	30	0.523
3	0.20	0.16	45	0.785
4	0.20	0.21	60	1.05
5	0.20	0.26	75	1.31
6	0.35	0.55	90	1.57
7	0.40	0.84	120	2.09
8	0.45	2.83	360	6.28

Use an Equation

PART A: Remember from math class that 2π radians is equal to 360 degrees. Use this fact to fill in the last column in the table.

Analyze Data

PART B: Which trial numbers should Angela use if she wants to create a graph of arc length vs. angle in radians or can all trials be used for the graph?

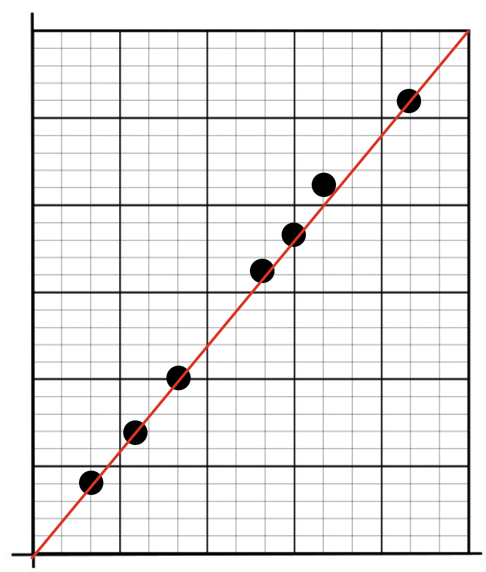
Trial number(s) 1-5

Explain why you picked the trials you identified in Part B.

The radius stays constant from trials 1-5, after 5 the radius begins to change.

Using Representations

PART C: Create a graph of arc length vs. angle in radians, sketch a best-fit line, and find the slope (with units) of the best-fit line. (Do not use data points for this calculation.)



Slope/mx = (0.18-0.04)/(0.9-0.2) = 0.2 m

PART D: What is the significance of the slope of arc length vs. angle in radians?

The slope from the line graphed is proportional to the radius.

PART E: Write an equation for the line with units and include a key for any symbols you use.

y=mx+b
the arc lenght - (radius)(radians angle)
s=R(theta)

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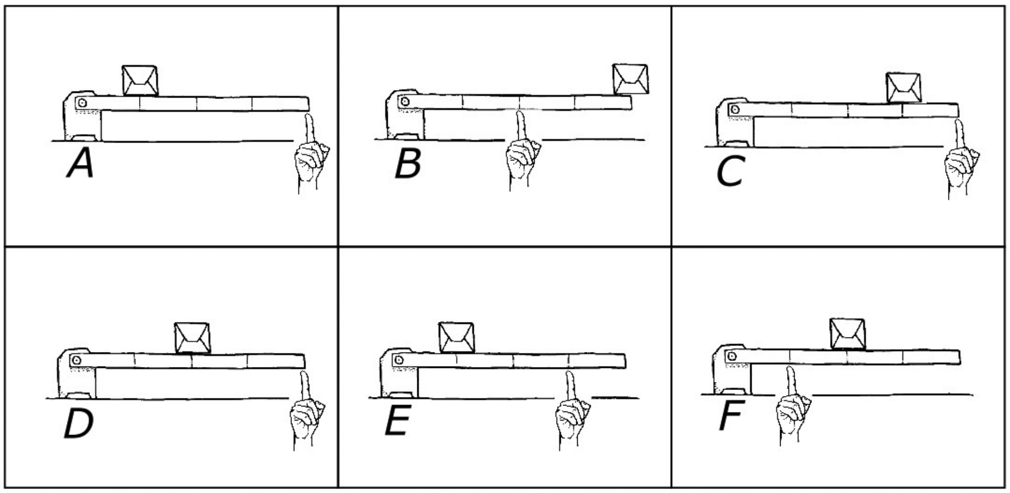
Scenario

A long rod of length L and negligible mass supports a box of mass M. The left end of each rod is held in place by a frictionless pin about which it can freely rotate. In each case, a vertical force is holding the rods and the weights at rest. The rods are marked at half-meter intervals.



Data Analysis

PART A: Rank the magnitude of the vertical force F applied to the rods to keep the rod horizontal.

Greatest Force F B=F, C, D, E, A Smallest Force F

Explain your ranking.

Due to the fact that each system is at rest, we know the sum of all three forces on each system would be 0. The torque acted on by the force at the pivot is therefor also zero, so the torque from the gravitational force at the pivot is zero. This can be shown by the relation F(x) = mg(d) where x is the distance from the finger to the pivot. Overall, the more closer the box is to the pivot point, the less amount of torque is needed to fasten it up.

Using Representations

PART B: On the diagrams above, sketch the forces acting on the rod-box system. The forces that are internal to the system can be ignored.

Argumentation

PART C: In which cases is the force from the pin up? Down? Zero? Justify your answers.

Force from pin is ***up*** in case(s): A, C, D, E

Force from pin is ***down*** in case(s): B, F

Force from pin is ***zero*** in case(s): None

PART D: Explain in a short paragraph with reference to the picture above why it is easier to hang a shopping bag from the crook of your elbow than to carry it suspended from your hand with your arm at a 90-degree angle.

Under the assumption that the elbow would be used as the pivot point, when holding multiple bags with ones hand, there is a specific torque around the pivot point. This is proportional to the magnitude of the gravitational force exerted on the bag multiplied by the length of the forearm. On the contrary, when the bag is positioned on the elbow, no torque is created due to distance between the pivot point.

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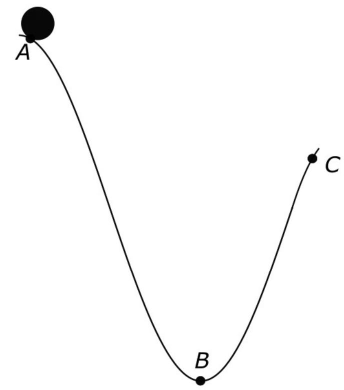
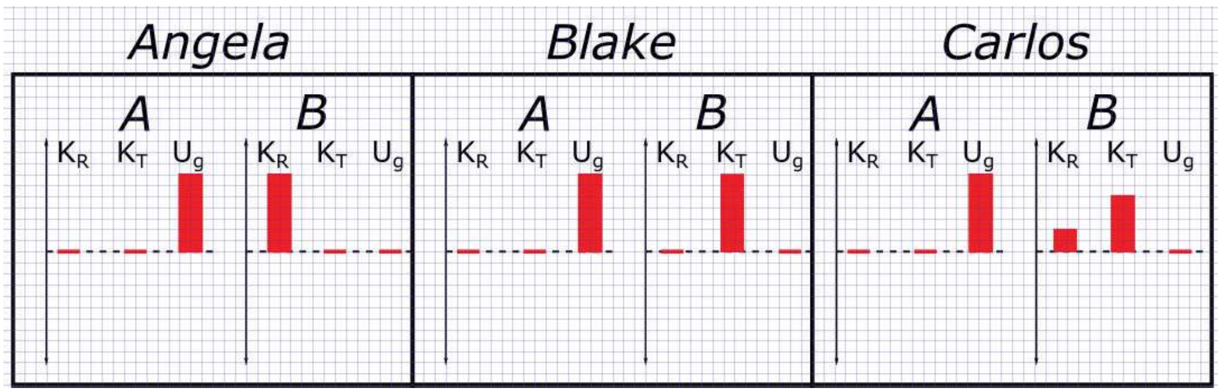
Scenario

A solid sphere is initially at rest at the top of a tall, rough hill. It rolls down the hill and up the next hill.



Using Representations

PART A: Angela, Blake, and Carlos each create an energy bar chart for the sphere-Earth system for the time between when it is released from rest at point A and when it reaches point B. For each graph, explain why it is either correct or incorrect.



I personally would say that Angela's graph is incorrect because it shows all of the rotational kinetic energy, that came from gravitational potential energy. An object that only contains rotational kinetic energy is really only spinning, and it has no forward motion. This does not correctly represent the motion of the sphere at point b.

Additionally, Blake's graph is also incorrect. This is because it shows that all of the intial gravitational potential energy has been turned into translational kinetic energy. An object that only has translational kinetic energy, will have virtually no rotation. This does not represent the motion of the sphere at point b.

On the contrary, Carlo's Graph is Correct. This is because it shows the sphere will have both rotational and translational kinetic energy at point b. The ratio between rotational and kinetic energy is derived from this equation for rotational interia: r = 2/5(M(r)^2)

PART B: How would each of the bar charts drawn in Part A be different if Earth were not part of the system?

If the earth was not apart of the system, then there would be little to no initial gravitational potential energy and we would have to include work done by the gravitational force, since that forces would be outside the system.

PART C: The sphere continues to roll along the track without slipping and at point C, it leaves the track. At the sphere's highest point, will it be above, below, or at the same height as point A? Explain your reasoning.

________ Above X________ Below ________ Same Height

When the sphere leaves the track, it has both vertical and horizontal velocity components. T he horizontal velocity remains constant, while the vertical component changes due to gravity. S ome of the initial energy converts into rotational kinetic energy due to friction, reducing the energy available for gravitational potential energy.
As a result, the sphere does not reach as high as it would if all kinetic energy were converted into gravitational potential energy.

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PART D: The sphere is then taken to an identically shaped track with negligible friction and released from point A. Is the sphere's maximum height after leaving the track greater than, less than, or the same as the height it reached on the rough track?

x________ Greater than ________ Less than ________ Same as

Explain your reasoning.

On a smooth track, the sphere will not roll. meaning no energy is lost to rotational motion. T his results in a greater speed when leaving the track, g iving it a larger vertical velocity component and allowing it to reach a higher maximum height than on the rough track.

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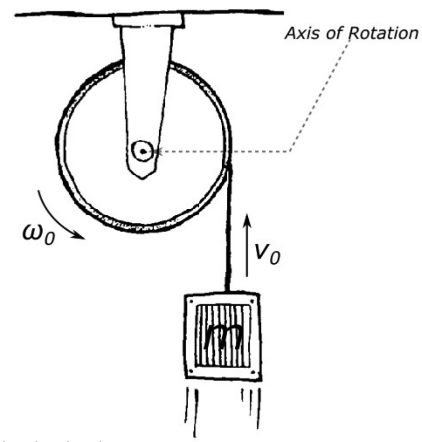
Scenario

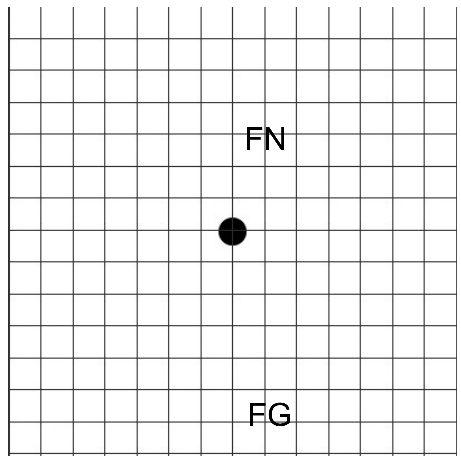
A box of mass m is tied to a rope that is wrapped around a pulley. The pulley is initially rotating counterclockwise and is pulling the box up. The box slows down, stops instantaneously, and then moves back downward.

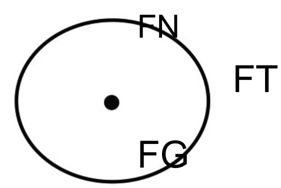


Using Representations

PART A: i. The dot below left represents the box. Draw a free-body diagram showing and labeling the forces (not components) exerted on the box initially. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces. Each force must be represented by a distinct arrow starting on and pointing away from the dot.

ii. On the diagram at right, draw and label the forces (not components) that are exerted on the pulley as it initially rotates. Clearly indicate at which point on the wheel each force is exerted. Draw each force as a distinct arrow starting on and pointing away from the point at which the force is exerted.

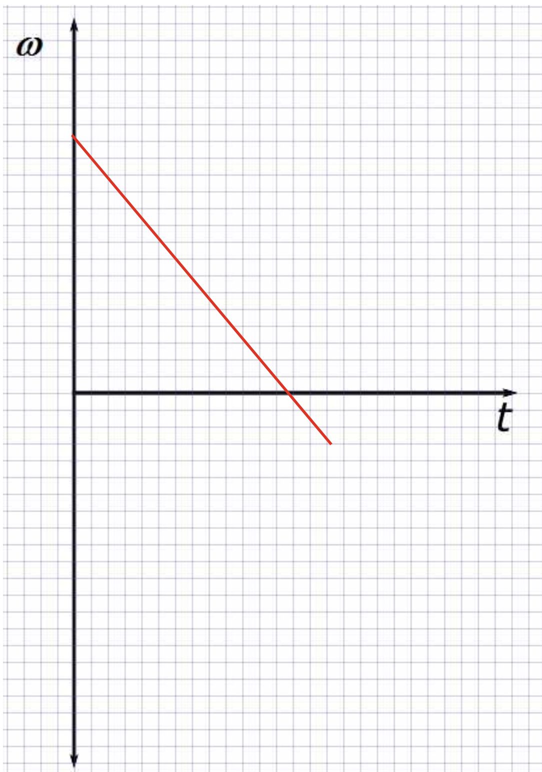




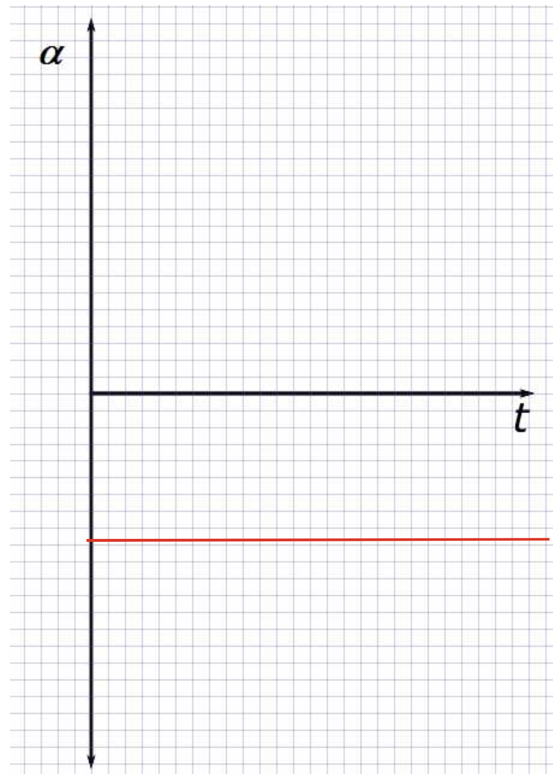
PART B: What force is responsible for the net torque on the pulley?

The force of tension is responsible. Even with the three forces on the pulley, (the force of gravity), the force from the pivot, and the force from the tension The pivot force and the gravitational force are exerted at the pivot point. This means that they exert no torque to the pulley.

PART C: Sketch a graph of the angular velocity as a function of time from the initial instant until the weight comes back down to the same height. (Take counterclockwise as positive.)



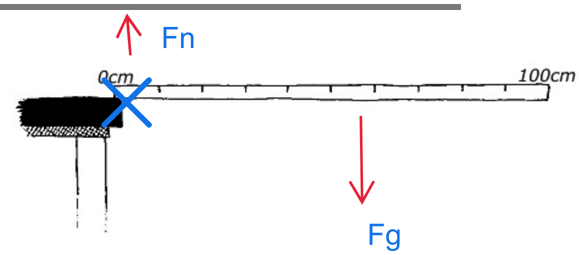
PART D: Sketch a graph of the angular acceleration of the pulley as a function of time for the same period.



NAME ____________________ DATE ____________

Scenario

A meterstick is set on the edge of a table so that all but a negligible bit of its length is off the edge of the table as shown. The meterstick is released from rest horizontally. The meterstick's mass is M and its length is L. The rotational inertia of the meterstick around the end is $I = \frac{1}{3}ML^2$.



Using Representations

PART A: Sketch a force diagram for the meterstick just after it has been released—meaning that it is still horizontal, but there is no longer anyone supporting the right end of the meterstick. (Remember that a force diagram differs from a free-body diagram in that the forces are drawn *at the point of application* rather than just at the center of mass.)

PART B: Identify the point on the meterstick around which the meterstick is pivoting. Mark this point with an X.

Is there more than one choice for the pivot point? What are the implications?

When it comes to pivoting, you can choose any point. However, you would need to figure out the new moment of interia of the rod at this point. Addtionally, you would also need to know/find out the magnituded of the normal force upward on the meterstick.

Use an Equation

PART C: Determine the net torque about the meterstick's left end, instantaneously after being released.

sum(F) = F-Tf

The net torque on the stick includes both the torque from the force of gravity and the torque from the normal force on the left end of the stick. Since we chose the left end as our pivot point, the distances from between the application's normal forces and pivot point is 0.

Ft = (F)1/2*sin(90)

Ft = mgl/2

PART D: Starting with Newton's second law in rotational form, derive an expression for the initial angular acceleration of the meterstick in terms of M, L, and physical constants.

$\sum r = Ia$	The net torque on the meterstick is equal to the rotational interia times the object's angular acceletation
$r = Mg(L/2)$	The torque, from the force of gravity on the meterstick is essentially the net torque on the stick.
$I = 1/3ML^2$	Since the net torque is = to Ia
$Mg(L/2) = (1/3ML^2)a$	Rotational interia of a meterstick about the end is I = 2/gMR
$a = 3g/2L$	Solving for the rotational acceleration

PART E: Derive an expression for the linear acceleration of the far end of the meterstick (not on the table) in terms of g. What is the consequence of your answer? Explain in terms of what would happen to a penny placed on the end of the rod before it was released.

$3g/2l = a$

$a = u/l$

$u/l = 3g/2l$

$a = 3x/2$

~~The right end of the meterstick accelerates faster than gravity. If a penny is placed the~~

~~g, while the meterstick accelerates at~~
3

2
2
3g

~~, causing the meterstick to move away from the penny.~~

The right end of the meterstick accelerates faster than gravity. If a penny is placed there before it releases, it falls at g. While the meterstick accelerates at 3g/2 causing the meterstick to move away from the penny

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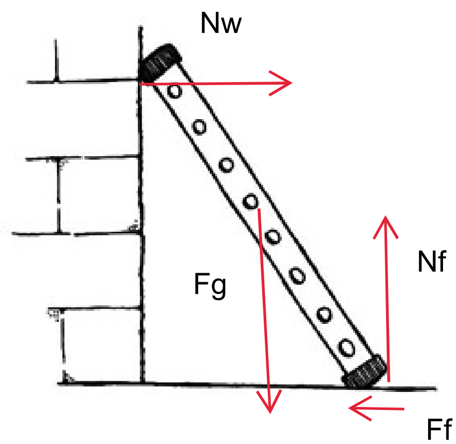
Scenario



A ladder is set against a wall so that the ladder makes a 30° angle from the floor. The wall is very smooth, but the floor is not. The ladder only remains motionless as long as a person holds it in place. When the person lets go, the ladder accelerates down and to the right.

Blake analyzes this scenario and identifies that the four forces acting on the ladder are its weight F_g, the normal force from the wall N_w, the normal force from the floor N_f, and the friction between the ladder and the floor F_F. He then correctly ranks the magnitudes of these forces as $F_g > N_F > N_w > F_F$.

Using Representations

PART A: On the diagram above, draw and label the forces that are exerted on the ladder. To clearly indicate at which point on the ladder each force is exerted, draw each force as a distinct arrow starting on, and pointing away from, the point at which the force is exerted. The lengths of the arrows should indicate the relative magnitudes of the forces.

Argumentation

PART B: Explain why $F_g > N_f$. Equations may be a part of your answer, but equations alone are insufficient.

At the moment the ladder is relased, the center of mass accelerates downward. Therefore, the doward force has to be greater than the upward normal force between the ladder and the floor.

PART C: Explain why $N_f > F_f$. Equations may be a part of your answer, but equations alone are insufficient.

There are multiple reasons for this imbalance. The force of friction is equal to the coefficient of friction multiplied by the normal force exerted by the floor. Since, the coeifficent of friction is less than one between most standard surfaces, the Coefficent of friction is most likely less than the floor's normal force. Another potential reason, is that the ladder rotates counter clockwise, as it slides. The torque provided by the normal force between the ladder and the floor has to be greater than the clockwise torque made by frcition plus the clockwise torque produced by the walls normal force.

PART D: Explain why $N_w > F_f$. Equations may be a part of your answer, but equations alone are insufficient.

Due to the fact that the ladder accelerates to the right, therefore, the right direction force has to be larger than the left direction force.

Use an Equation

PART E: Blake states that the ranking could not be completely determined until it was demonstrated that $N_f > N_w + F_f$. Explain how this expression is demonstrated by the scenario described.

Friction force (Ff) and wall normal force (Nw) produce clockwise torque. Floor normal force (Nf) must exceed these combined torques for the ladder to rotate counter clockwise.

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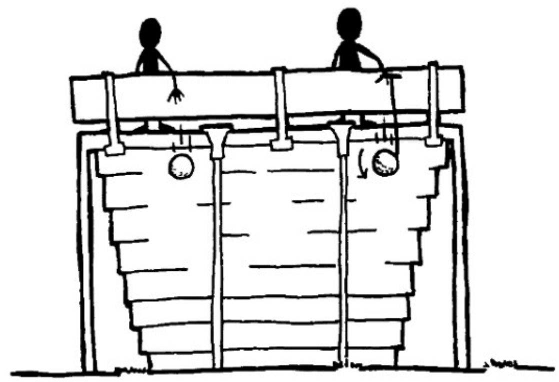
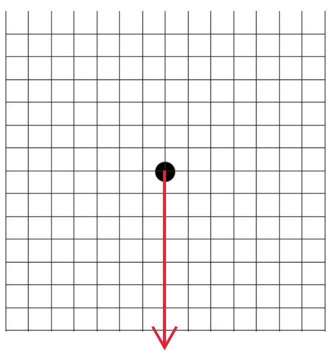
Scenario

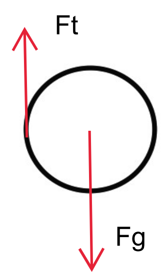
Carlos brings a pair of identical yo-yos (modeled as solid disks with rotational inertia $I = \frac{1}{2}MR^2$) to the top of the stadium bleachers of height H. The yo-yos both have a mass M and a radius R and are wound with a string so thin that the mass of the string can be ignored. Carlos simultaneously drops one yo-yo while he lets the other unwind.



Using Representations

PART A: Sketch a free-body diagram for the dropped yo-yo and a force diagram for the unwinding yo-yo while they are in the air. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces. For the free-body diagram, each force must be represented by a distinct arrow starting on and pointing away from the dot. For the force diagram, each force must be represented by a distinct arrow positioned where the force is exerted.





Quantitative Analysis

PART B: Which yo-yo will land first, the dropped yo-yo or the unrolled yo-yo? Explain without deriving a mathematical expression.

The

The dropped yo-yo will land first. There is no upward force with the dropped yo-yo. So it is accelerating as a rate equal to g. The unwinding yo-yo is less. Therefore, it will have a smaller acceleration and take a longer time to travel the same distance.

PART C: Derive an expression for the time for yo-yo 1 (dropped) to the time for yo-yo 2 (unwinding).

Yo-Yo 1	*Yo-Yo 2*
d = 1/2 gt^2 Rdrop = sqrt(2H/g)	I = 1/2MR^2 a = g(1+I/MR^2) a = g/(1+1/2) = 2g/3 T2 = sqrt(2H/a) = sqrt(2H/2g/3) = sqrt(3H/g) sqrt(2/3) = 0.816

Argumentation

PART D: Each yo-yo lands on sticky tape and does not bounce upon landing. In a clear, coherent, paragraph-length response, explain which yo-yo experiences a greater impulse due to the normal force from the ground.

Type text here

The dropped yoyo experiences greater impluse because both yo yo's reach zero momentum after impact, but the dropped yoyo has larger initial momentum. Since impulse is equal to the change in momentum, and both yo-yos greater acceleration produces higher impact velocity requiring more impluse from the ground to stop.

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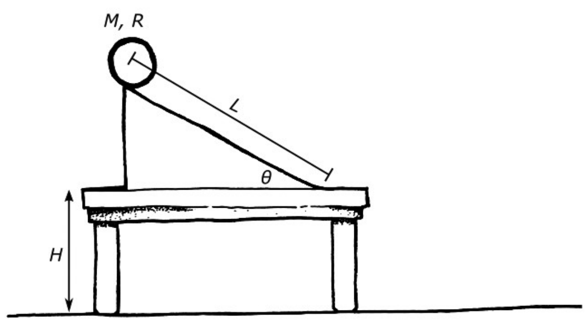
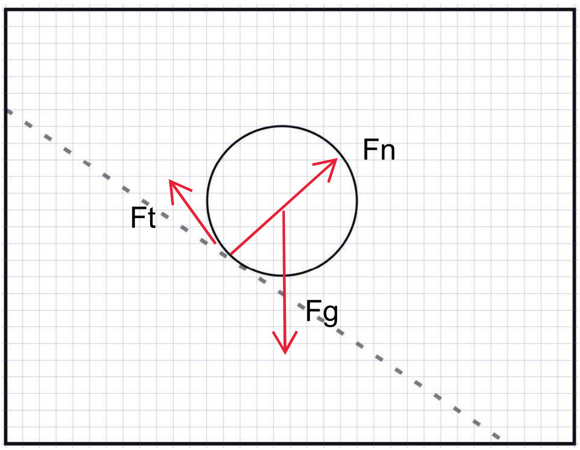
Scenario

A thin hoop of mass M and radius R is released from rest at the top of a ramp of length L as shown at right. The ramp makes an angle θ with respect to a horizontal tabletop to which the ramp is fixed. The table top is height H above the floor. Assume that the hoop rolls without slipping down the ramp and across the table. Express all algebraic answers in terms of given quantities and fundamental constants.

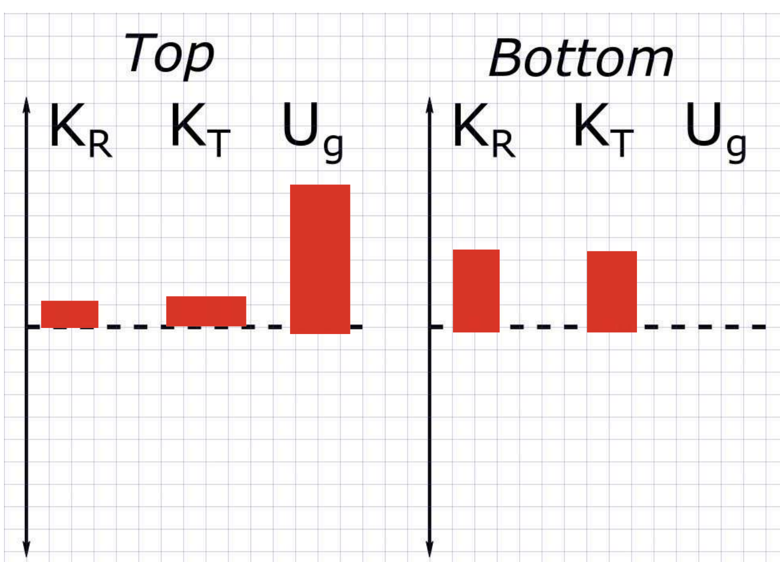


Using Representations

PART A: On the diagram below, draw and label the forces (not components) that act on the wheel as it rolls down the ramp, which is indicated by the dashed line. To clearly indicate at which point on the wheel each force is exerted, draw each force as a distinct arrow starting on and pointing away from the point at which the force is exerted.



PART B: Sketch an energy bar chart for the hoop-Earth system from the time when it is at the top of the ramp to the time when it reaches the bottom of the ramp.



PART C: Derive an expression for the speed of the center of mass of the hoop when it reaches the bottom of the ramp.

E1 = E2	The system consisting of the hoop and earth, there are no net external forces that do work on the system. The mechanical energy will be the same at top and bottom
Ur = K1 + K2	Substituting in the equation for each type of mechanical energy
mgh = 1/2mv^2+1/2Lw^2	Energy conservation
mgh=1/2v^2+1/2v^2	Substituting w=v/r for rolling without slipping
mgh=1/2v^2+1/2v^2	mass and radius cancelled
mgh=v^2	combined equation
v = sqrt(gLsin(theta)	Final velocity equation

PART D: Determine an expression for the distance D from the edge of the table to where the hoop lands on the floor in terms of given variables and physical constants.

D = v * t

D = (sqrt(gLsin(theta))

H=y-y0

y = y0 + 1/2at^2

y-y0=1/2gt^2

sqrt(2H/g) = t

D = sqrt(2HLsin(theta))

PART E: Suppose that the hoop is now replaced by a disk having the same mass M and radius R. How will the distance from the edge of the table to where the disk lands on the floor compare with the distance determined in Part D?

________ Less than ________ The same as ________ Greater than

Briefly justify your response in terms of energy.

The disk has a smaller rotational interia than the thin loop because the mass of the disk is distributed centered while the thin hoop mass is only located at the outward.

Type text here

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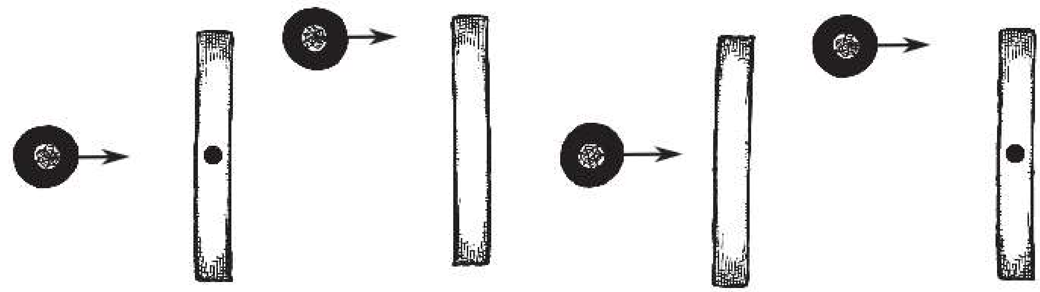

Case A *Case B* *Case C* *Case D*

Scenario

The four cases above show four pucks (viewed from above) sliding to the right on a smooth table. Each puck collides with and sticks to a rod that can move or rotate with negligible friction. In all four cases, the pucks are identical, the rods are identical, the initial rightward velocities of the puck are identical, and the initial velocities of the pucks are perpendicular to the rods' lengths. In Cases A and D, the rod is fixed to the table by a pin with negligible friction, but in Cases B and C, the rod is free to move. In Cases A and C, the puck collides with the center of the rod.

Analyze Data

PART A: For each case, determine whether angular momentum, linear momentum, and kinetic energy are constant. Put a check mark in the box if the quantity is constant and an *x* in the box if the quantity changes during the collision.

	Case A	*Case B*	*Case C*	*Case D*
Angular Momentum	✓	✓	✓	✓
Linear Momentum	X	✓	✓	X
Kinetic Energy	X	X	X	X

PART B: Rank the cases according to which case has the most rightward linear momentum instantaneously *after the collision* from "least rightward momentum" to "most rightward momentum." Include <, >, or = to clarify your ranking.

A < D < B = C

Least rightward momentum — Most rightward momentum

Justify your ranking.

Due to the fact that there are no external forces in Cases B and C, the systems in Cases B and C do not lose and linear momentum, so they have the same linear momentum as the ball at the start. D has some decrease of momentum in the rod-puck systems because the external force from the axis is not negliglable compared to the internal interaction and transfer momentum out of the system by an impulse, while the ball sticks to the rod and the system rotates about the pin.

PART C: Rank the cases according to which case has the most clockwise angular momentum taken about the center of the rod instantaneously *after the collision* from "least clockwise" to "most clockwise" angular momentum. Include <, >, or = to clarify your ranking.

A = C < B = D

Least clockwise angular momentum — Most clockwise angular momentum

Justify your ranking.

No external torques exist in any system as forces at the pivot don't create torque. Angualr momentum is conserved in all cases. In case A and C, the puck mves directly toward the pivot resulting in zero angualr momentum before and after collision. In cases B and D, angualr momentum remains unchanged because the puck maintains the same speed and postion relative to the rods center.

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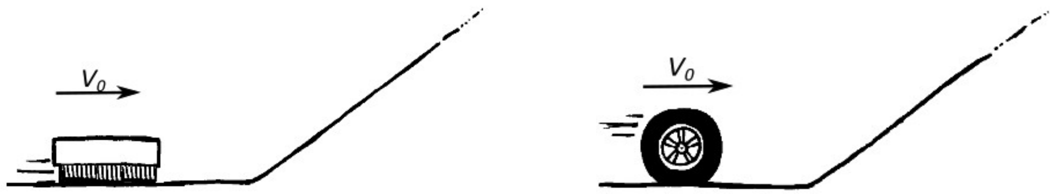
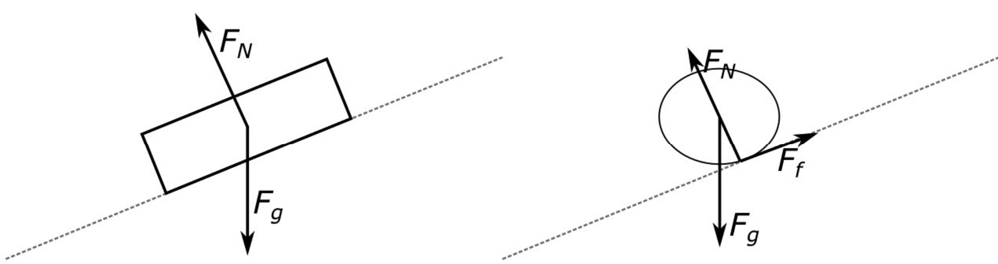
Scenario

A cart of mass M that slides across a surface with negligible friction, with initial speed v encounters an incline with an angle θ to the horizontal. At the same time, a wheel of mass M and radius R rolls with speed v without slipping and encounters an identical incline. Both the cart and the wheel reach the bottom of their respective inclines at the same time. The wheel does not slip as it rolls up the incline. Assume no energy is dissipated in the bearings in the cart.



Argumentation

PART A: The forces acting on the cart (shown as a rectangle) and the wheel (shown as a circle) are shown below while both objects are on their respective inclines. The incline is shown as a dotted line for reference.



i. Is the friction force acting on the wheel static or kinetic? Explain your reasoning.

Static friction because the wheel is instantaneously at rest comapred to the incline if the wheel was sliding instead of rolling, Kinetic friction would be involved.

ii. Explain why the friction force on the wheel points up the incline even though this is not the direction opposite to the wheel's translational motion.

If the wheel is to roll up the inclince without slipping, its linear velocity and rotational velocity must slow down the same at the same time. This means that while the friction force is not opposite to the translational velocity, it is opposite to the angualr velocity as it goes counter clockwise.

PART B: Both the cart and the wheel will eventually come momentarily to rest at some point on their respective inclines. However, the wheel takes a longer time and travels a longer distance up its incline to come momentarily to rest than the cart does.

i. Explain why this happens in terms of the forces on the above diagrams.

The wheel has the friction force going at the same area/direction of its motion.
The total accleration of the wheel is greater than the cart. Having more acceleration,
the wheel will take more time to slow down and travel a larger distance.

ii. Explain why this happens in terms of conservation of energy principles.

The wheel has both translational and rotational kinetic energy at the bottom
of the ramp. In comparision to the cart, which only has translational kinetic energy
As both objects go up, each of their kinetic energies gets converted to graviational
potential energy at the end.

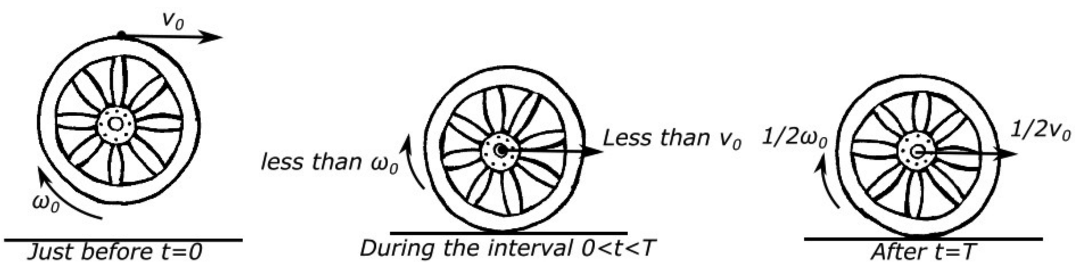
PART C: While on the incline not including friction, the cart and wheel have identical forces $F_{||}$ acting on them directed down the incline. If it were determined that the frictional force on the wheel is 75% of the strength of $F_{||}$, and the cart travels a distance L up the incline before coming momentarily to rest, how far does the wheel travel in terms of L before coming momentarily to rest? Explain your method.

The wheel experiences only 25% of the net force that he cart does. This is because
of friction cancles 75% of the downward parrallel force on the wheel. Since both have equal mas
the wheels acceleration is just 25% of the carts. Using v^2-vo^2=2al. We deduce that
the wheel travels 4 times farther than the cart before stopping.

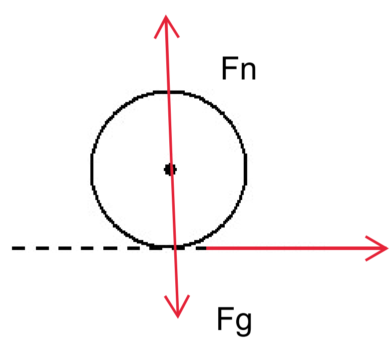
NAME ______________________ **DATE** ____________

Scenario

A wheel of radius R and mass M is held at rest just above a rough table (coefficient of kinetic friction μ). The wheel spins with initial angular speed ω_0 so that all points on the edge of the wheel circle the wheel's center with speed v_0. At time $t = 0$, the wheel is released from rest, lands on the table, and does not bounce. The wheel's rotational speed decreases while the linear speed of its center of mass increases until the wheel begins to roll without slipping at time $t = T$.



PART A: i. On the circle that represents the wheel, draw and label the forces exerted on the wheel during the interval $0 < t < T$. The dotted line represents the table. Each force should be represented by a single arrow that starts on and points away from the location on the wheel where that force is applied.



ii. In terms of the forces you drew above, explain why the center of mass of the wheel increases in speed and the rotational speed of the wheel decreases during the interval $0 < t < T$.

The center of mass of the wheel increases in translational speed. This is so due to the forcee of friction is pointing in the same direction. However, the force of friction points in the opposite direction (counter clockwise) of the rotational speed. This overall, decreases the rotational speed.

Create Equation

PART B: Dominique derives an expression for T, makes a mistake, and obtains the incorrect expression $T = \frac{\mu\omega_0 R}{2g}$. Without deriving the correct expression, explain how one can know that this expression is not plausible.

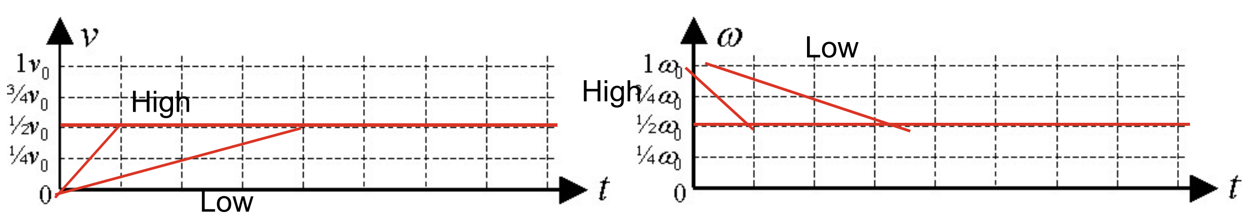
The equation suggests that as angular velocity increases, the period also increases. This is very wrong, due to the fact that as the distance is covered at a higher velocity, the time is takes should go down, not up.

Analyze Data

PART C: Dominique experiments with different wheels and surfaces and finds that, regardless of the values of R or μ, the final motion of the wheel is to roll without slipping with linear speed $\frac{1}{2}v_0$ and angular speed $\frac{1}{2}\omega_0$. On the grids below (linear speed on the left, angular speed on the right), draw graphs of the linear and angular speeds of the wheel from time $t = 0$ to a time after the wheel begins to roll without slipping for the two cases indicated below. Label the graphs as you are instructed.

i. The table has a low coefficient of kinetic friction. Label these two graphs "low."

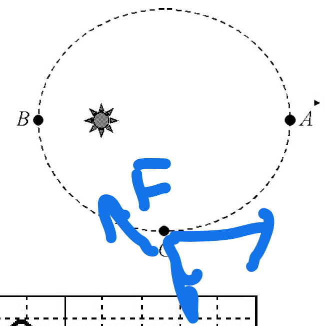
ii. The table has a high coefficient of kinetic friction. Label these two graphs "high."

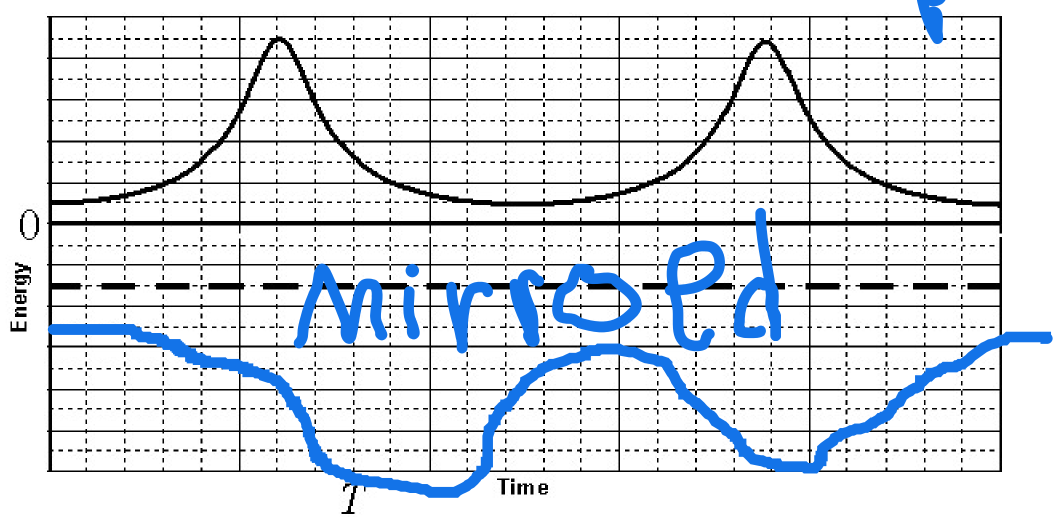


NAME ______________________________ DATE ______________

Scenario

A planet orbits a star in the counterclockwise orbit shown in the diagram at right. At time $T = 0$, the planet is at point A in its orbit. At a later time, the planet is at point B. At a still later time $t = T$, the planet is at point C in the diagram. The kinetic energy of the planet is shown in the graph below (solid line) as a function of time. The total energy of the star-planet system is shown on the same grid by the dashed line as a function of time.





Analyze Data

PART A: Suppose that it takes 1.25 years for the planet to travel from point A to point B. How many years are shown on the graph above? Explain your reasoning.

The path from point A to point B is only half the orbit. To get a full degree orbit, you need to double what is given, 1.25*2. So the full orbit, should take 2.5 years. The graph shows 2 full orbits, so the graph shows a total of 5 years.

PART B: Half of 1.25 years is 0.625 years. Does it take 0.625 years for the planet to go from point B to point C? Explain your reasoning.

No, the acceleration of the planet increases while it's closer to the star so the quarter of the full ordbit between points B and C will take less than .625 years while the quarter from c to a will take more as it slows.

Using Representations

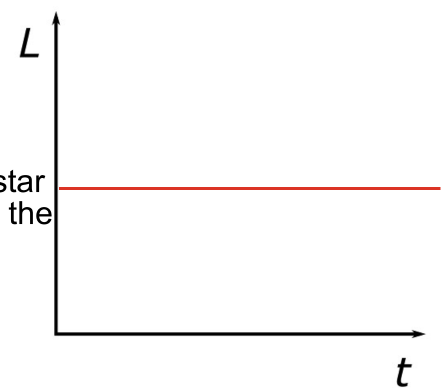
PART C: On the graph above Part A, sketch the graph of the potential energy of the star-planet system over the same interval. Draw your graph to scale using the grid lines.

PART D: On point C on the orbital diagram above, draw a vector labeled v representing the velocity of the planet at point C, and draw a vector labeled F representing the net force exerted on the planet at point C.

PART E: At time $t = T$, when the planet is at point C, the kinetic energy of the planet is decreasing. Use your vectors drawn in Part D to explain why this is the case.

The planet follows an elliptical orbit. This has two major components, the tangential velocity and an inward acceleration and also force. From point B to C, the plant will move by the star and will distance itself away from the star. the objects lose velocity from the velocity vector and the F net vector being an obtuse angle.

PART F: Sketch a graph of the angular momentum of the planet taken about the star as a function of time in the space at the right, where counterclockwise angular momentum is positive. Using your vectors drawn in Part D, explain why the graph has the shape that you drew.

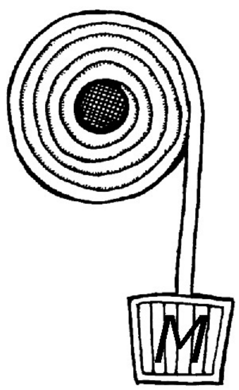


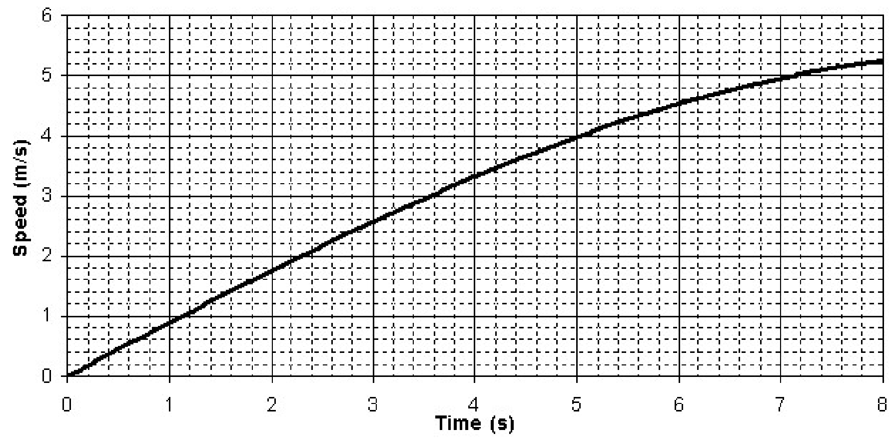
The planets angualr momentum remains constant because the gravitational force points directly at the star creating zero torque since t = r x F eqauls zero when the vectors are parralel.

NAME ______________________ DATE ______________

Scenario

An axle with a large amount of rotational inertia is lubricated so that it rotates with negligible friction. A light but thick rope is wrapped around the axle so that the rope is layered on top of itself several times as shown in the diagram. The free end of the string is connected to an object of mass $M = 2\text{ kg}$ that is much heavier than the rope but much lighter than the axle. The mass is released at time $t = 0$ and is allowed to fall, causing the axle to accelerate rotationally. The downward speed of the mass is shown on the graph as a function of time.





Create an Equation

PART A: Write an equation that represents Newton's second law as applied to the mass. Then use the equation and the graph to estimate the tensions in the string T_0 (at time $t = 0$) and T_8 (at time $t = 8$ seconds).

∑F(y) = ma(y)

F(g) - F(t) = ma(y) a(y) at t=0 is around 0.8 since thats the slope of the graph
mg - F(t) = m(.8)
2(10)-F(t)=2(.8)
F(t)=18.4N

20-F(t)=2a(y) at time t = 8, a(y) is around .25 since that is the slope
20 - F(t) = 2(.25)
F(T) = 19.5N

The slope of the graph decreases slightly during the 8-second interval.

Analyze Data

PART B: Your answers in Part A should show that the tension increases slightly during the 8-second interval. Explain why this is the case.

Since, the force of gravity stays constant, for the acceleration to decrease there needs to be a bigger force of tensions subtracting from it.

Argumentation

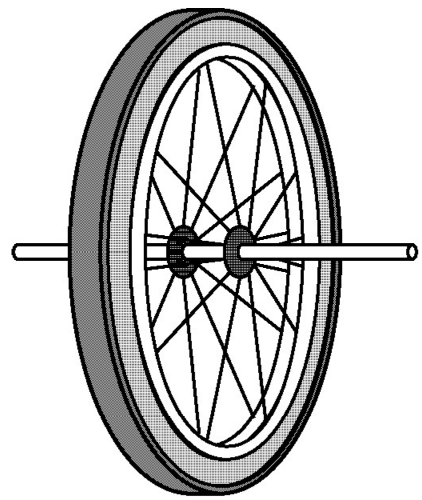
PART C: Explain why the slope of the above graph decreases slightly. Cite specific physical principles and relationships.

As the rope begins to unwind, the radius at which the rope is attached decreases, exerting less torque on the axle. This essentially means, that there is less rotational acceleration which causes less translational acceleration.

NAME ______________________ DATE ____________

Scenario

A bicycle wheel is mounted on a horizontal axle as shown in the diagram. Angela is first tasked with finding the torque that is applied to the wheel by the force of friction at the axle. She is not able to remove the wheel from its bearings or change the orientation of the axle but does have access to materials commonly found in a school physics laboratory.



PART A: Explain how Angela can calculate the frictional torque applied to the wheel. State what apparatus is to be used, what measurements are to be made, and what calculations must be done to obtain a value for the frictional torque.

Materials needed:
String
An object with small mass (m)
A stopwatch
A ruler

Procedure:
Wrap a piece of string around the wheel with attached mass, measure radius and fall time, calculate tension (mg-T=ma) and torque (t=rxT), then determine angualr acceleration from kinematics

Upon finding a significant frictional torque, Angela drips oil on the axle. She supposes that the bearings now exert negligible friction and wishes to determine the rotational inertia of the wheel.

PART B: Briefly explain what Angela can do to show that the wheel's axle bearings now exert negligible friction.

You should spin the wheel manually and observe how long it takes to stop.

If friction is negligable, the wheel should rotate for a longer period than it should stop.

She could also measure the angular deceleration by timing the slowing down of the wheel.

If the angular deceleration is very small (close to zero), then friction is negligible.

PART C: Explain how Angela can calculate the rotational inertia of the wheel. State what apparatus is to be used, what measurements are to be made, and what calculations must be done to obtain a value for the rotational inertia.

Apparatus that is needed:
String
An object with small mas (m)
A stopwatch
A ruler

Procedure:

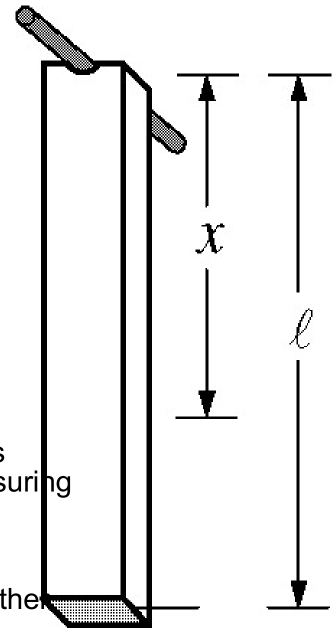
1. Wrap a string around the wheel and secure the object to the free end
2. Position the wheel's radius at the point where the string makes contact
3. Measure the wheels radius at the point where the string makes contact
4. Release the mass and use a stopwatch to measure the time t it takes to fall a predetemined height.
5.Calculate the linear acceleration to angualr acceleration of the wheel.
6. Convert linear to acceleration to angular acceleration.

Calculations:
1. Using newtons second law to the falling mass: mg-T = ma
The torque exerted on the wheel by the tension in the string is torque = rT
Using Newton's second law for rotational motion: I(angular acceleration) = rT
Substituting for T from the first equation: I(angular accleration) = r(mg-ma) Solving for I = r(mg-ma) / angular acceleration

NAME ______________________ DATE ______________

Scenario

A bar of length ℓ is constructed so that it is not uniform in its density. At one end, the alloy is rich in aluminum, which has low density. At the other end, more tin is mixed in, which is more dense. The materials are painted over so that it is not possible to determine visually which end is made of which metal. Blake must determine the rotational inertia of the bar if it is pivoted about its less-dense end.



PART A: The center of mass is located a distance x from the less-dense end. Explain how Blake can determine the location of the center of mass of the bar and determine which end of the bar is less dense.

Procedure:
Place the bar perpendicular to the kinfe's edge and adjust's its postion until it balances

The position where the bar is balanced marks the center of mass which is a distance x from on end. Find this distance with a measuring tool.

To determine the less dense end:
Since the bar is not equally dense, the less dense end will be farther from the balance point is the less dense end.

PART B: Once the less-dense end and the distance x are determined, the bar is fixed to a horizontal axle as shown in the diagram. Write a procedure that Blake could follow to make measurements that could be used to calculate the rotational inertia of the bar about this axis assuming friction is negligible. Give each measurement a meaningful algebraic symbol and explain how commonly available equipment is used to make that measurement.

Measure Length I:
Use a measuring tape or ruler to determine the total length I of the bar

Measure the Period T and its Oscillation:
Displace the bar slightly and release it, allowing it to move back and forth

Use a stopwatch to measure the time for multiple oscillations and calculate the period Tby averaging

Use the physical pendulum formula
The period of a physical pendulum pivoted at one end is T = 2(pi)(I/mgx)^1/2

Rotational Interia I is the calculated with the formula I = mgx(T/2pi)^2

PART C: Explain how the measurements that you made can be used to calculate the rotational inertia of the bar about its axis. State clear equations using the algebraic symbols defined in Part B, explain how these equations are chosen, and what each term of the equation represents.

Using rotation from the interia formula from the problem above: I = mgx(t/2pi)^2

T is the measured period of oscillation.
I is the rotational interia
m is the mass of the bar
g is the acceleration due to gravity
x is the distance from the pivot to the center of mass

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