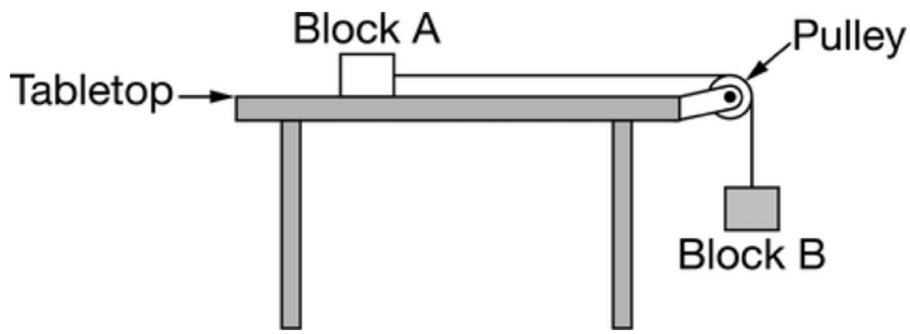
Practice FRQ's

Name

1. This question is a long free-response question. Show your work for each part of the question.



(12 points, suggested time 25 minutes)

This problem explores how the relative masses of two blocks affect the acceleration of the blocks. Block A, of mass m_A, rests on a horizontal tabletop. There is negligible friction between block A and the tabletop. Block B, of mass m_B, hangs from a light string that runs over a pulley and attaches to block A, as shown above. The pulley has negligible mass and spins with negligible friction about its axle. The blocks are released from rest.

(a)

i. Suppose the mass of block A is much greater than the mass of block B. Estimate the magnitude of the acceleration of the blocks after release.

Please respond on separate paper, following directions from your teacher.

Briefly explain your reasoning without deriving or using equations.

Please respond on separate paper, following directions from your teacher.

ii. Now suppose the mass of block A is much less than the mass of block B. Estimate the magnitude of the acceleration of the blocks after release.

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Please respond on separate paper, following directions from your teacher.

Briefly explain your reasoning without deriving or using equations.

Please respond on separate paper, following directions from your teacher.

(b) Now suppose neither block’s mass is much greater than the other, but that they are not necessarily equal. The dots below represent block A and block B, as indicated by the labels. On each dot, draw and label the forces (not components) exerted on that block after release. Represent each force by a distinct arrow starting on, and pointing away from, the dot.

Please respond on separate paper, following directions from your teacher.

(c) Derive an equation for the acceleration of the blocks after release in terms of m_A, m_B, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (b) to assist in your solution, use the space below. Do NOT add anything to the figure in part (b).

Please respond on separate paper, following directions from your teacher.

(d) Consider the scenario from part (a)(ii), where the mass of block A is much less than the mass of block B. Does your equation for the acceleration of the blocks from part (c) agree with your reasoning in part (a)(ii)?

Yes No

Please respond on separate paper, following directions from your teacher.

Briefly explain your reasoning by addressing why, according to your equation, the acceleration becomes (or approaches) a certain value when m_A is much less than m_B.

Please respond on separate paper, following directions from your teacher.

(e) While the blocks are accelerating, the tension in the vertical portion of the string is T_1. Next, the pulley of negligible mass is replaced with a second pulley whose mass is not negligible. When the blocks are accelerating in this scenario, the tension in the vertical portion of the string is T_2. How do the two tensions compare to each other?

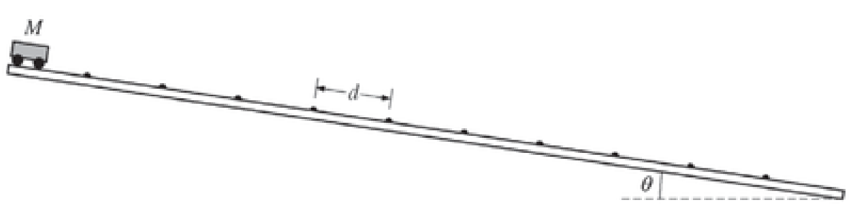
$T_2 > T_1$ $\quad$ $T_2 = T_1$ $\quad$ $T_2 < T_1$

Please respond on separate paper, following directions from your teacher.

Briefly explain your reasoning.

Please respond on separate paper, following directions from your teacher.

2.



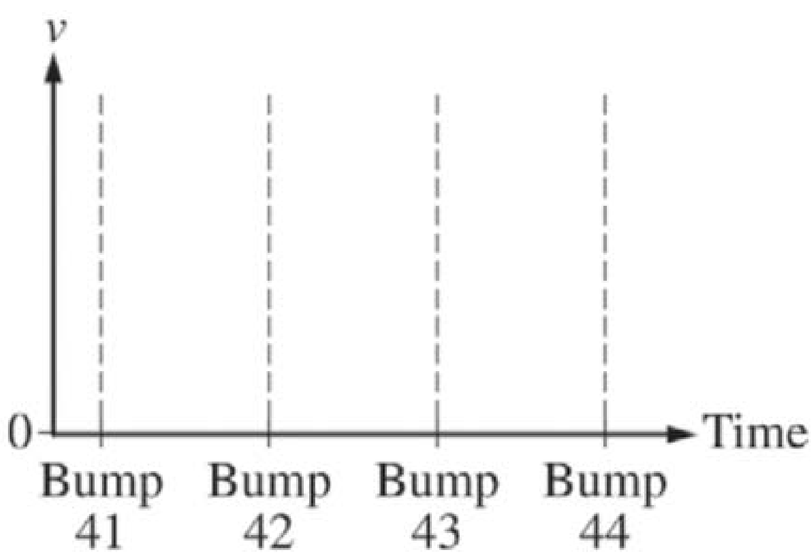
Note: Figure not drawn to scale.

A long track, inclined at an angle θ to the horizontal, has small speed bumps on it. The bumps are evenly spaced a distance d apart, as shown in the figure above. The track is actually much longer than shown, with over 100 bumps. A cart of mass M is released from rest at the top of the track. A student notices that after reaching the 40th bump the cart's average speed between successive bumps no longer increases, reaching a maximum value v_{avg}. This means the time interval taken to move from one bump to the next bump becomes constant.

a. Consider the cart's motion between bump 41 and bump 44.

i. In the figure below, sketch a graph of the cart's velocity v as a function of time from the moment it reaches bump 41 until the moment it reaches bump 44.

ii. Over the same time interval, draw a dashed horizontal line at $v = v_{avg}$. Label the line"v_{avg}"



b. Suppose the distance between the bumps is increased but everything else stays the same. Is the maximum speed of the cart now greater than, less than, or the same as it was with the bumps closer together?

____Greater than ____Less than ____The same as

Briefly explain your reasoning.

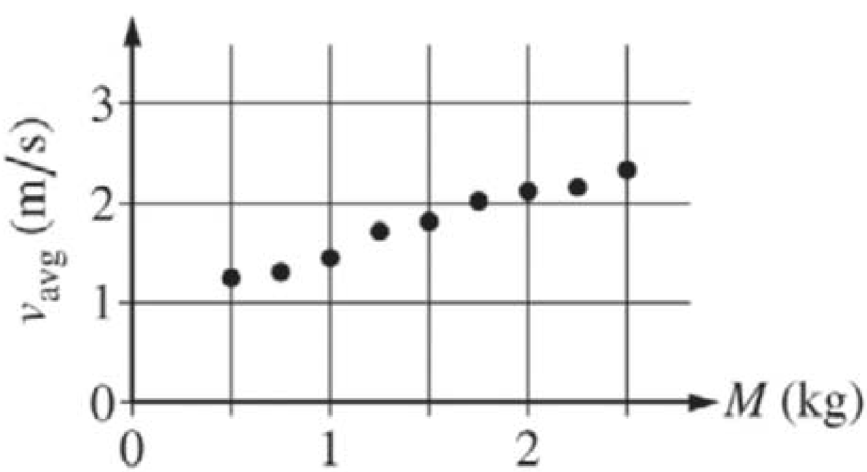
c. With the bumps returned to the original spacing, the track is tilted to a greater ramp angle θ. Is the maximum speed of the cart greater than, less than, or the same as it was when the ramp angle was smaller?

____Greater than ____Less than ____The same as

Briefly explain your reasoning.

d. Before deriving an equation for a quantity such as v_{avg} , it can be useful to come up with an equation that is intuitively expected to be true. That way, the derivation can be checked later to see if it makes sense physically. A student comes up with the following equation for the cart's maximum average speed: $v_{avg} = C\frac{Mg\sin\theta}{d}$, where C is a positive constant.

i. To test the equation, the student rolls a cart down the long track with speed bumps many times in front of a motion detector. The student varies the mass M of the cart with each trial but keeps everything else the same. The graph shown below is the student's plot of the data for v_{avg} as a function of M.



Are these data consistent with the student's equation?

____Yes ____No

Briefly explain your reasoning.

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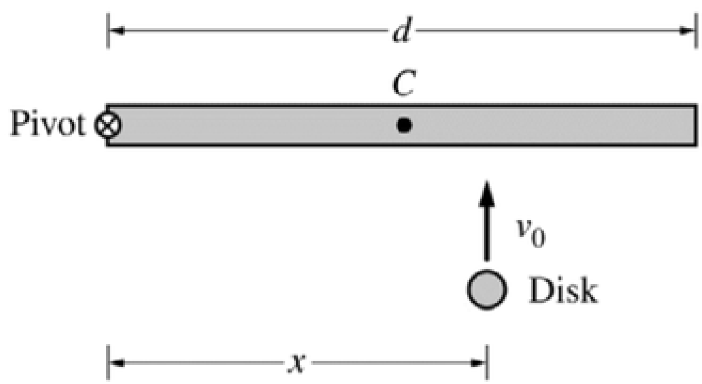
ii. Another student suggests that whether or not the data above are consistent with the equation, the equation could be incorrect for other reasons. Does the equation make physical sense?

____Yes ____No

Briefly explain your reasoning.

Please respond on separate paper, following directions from your teacher.

3.



Top View

The left end of a rod of length d and rotational inertia I is attached to a frictionless horizontal surface by a frictionless pivot, as shown above. Point C marks the center (midpoint) of the rod. The rod is initially motionless but is free to rotate around the pivot. A student will slide a disk of mass m_{disk} toward the rod with velocity v_0 perpendicular to the rod, and the disk will stick to the rod a distance x from the pivot. The student wants the roddisk system to end up with as much angular speed as possible.

a. Suppose the rod is much more massive than the disk. To give the rod as much angular speed as possible, should the student make the disk hit the rod to the left of point C, at point C, or to the right of point C ?

_____To the left of C _____ At C _____ To the right of C

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Briefly explain your reasoning without manipulating equations.

b. On the Internet, a student finds the following equation for the postcollision angular speed ω of the rod in this situation: $\omega = \frac{m_{disk} x v_0}{I}$. Regardless of whether this equation for angular speed is correct, does it agree with your qualitative reasoning in part (a) ? In other words, does this equation for w have the expected dependence as reasoned in part (a) ?

_____Yes _____No

Briefly explain your reasoning without deriving an equation for ω.

c. Another student deriving an equation for the postcollision angular speed ω of the rod makes a mistake and comes up with $\omega = \frac{I x v_0}{m_{disk} d^4}$. Without deriving the correct equation, how can you tell that this equation is not plausible—in other words, that it does not make physical sense? Briefly explain your reasoning.

For parts (d) and (e), do NOT assume that the rod is much more massive than the disk.

d. Immediately before colliding with the rod, the disk's rotational inertia about the pivot is $m_{disk}x^2$ and its angular momentum with respect to the pivot is $m_{disk} v_0 x$. Derive an equation for the postcollision angular speed ω of the rod. Express your answer in terms of d, m_{disk}, I, x, v_0, and physical constants, as appropriate.

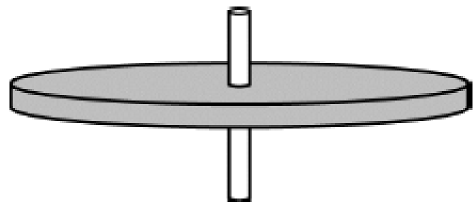
e. Consider the collision for which your equation in part (d) was derived, except now suppose the disk bounces backward off the rod instead of sticking to the rod. Is the postcollision angular speed of the rod when the disk bounces off it greater than, less than, or equal to the postcollision angular speed of the rod when the disk sticks to it?

_____Greater than _____Less than _____Equal to

Briefly explain your reasoning.

Please respond on separate paper, following directions from your teacher.

4.



The disk shown above spins about the axle at its center. A student's experiments reveal that, while the disk is spinning, friction between the axle and the disk exerts a constant torque on the disk.

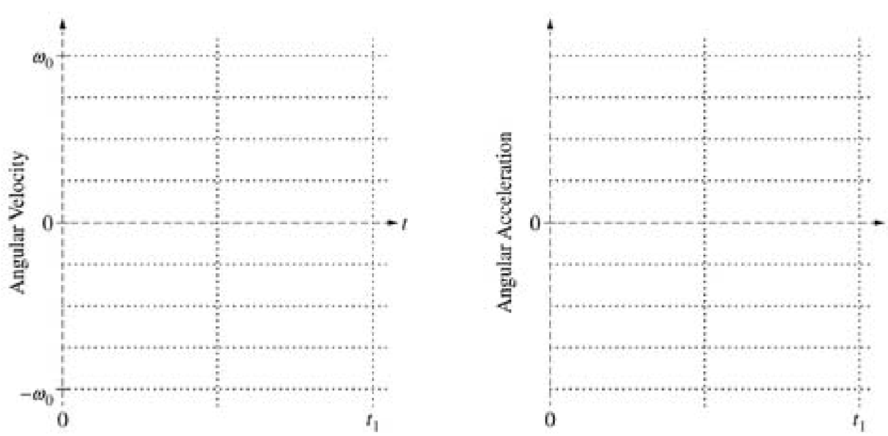
a. At time t = 0 the disk has an initial counterclockwise (positive) angular velocity ω_0.The disk later comes

to rest at time $t = t_1$.

i. On the grid at left below, sketch a graph that could represent the disk's angular velocity as a function of time t from t = 0 until the disk comes to rest at time $t = t_1$.

ii. On the grid at right below, sketch the disk's angular acceleration as a function of time t from t = 0 until the disk comes to rest at time

$t = t_1$.



b. The magnitude of the frictional torque exerted on the disk is τ_0. Derive an equation for the rotational

inertia I of the disk in terms of τ_0, ω_0, t_1, and physical constants, as appropriate.

c. In another experiment, the disk again has an initial positive angular velocity ω_0 at time t = 0. At

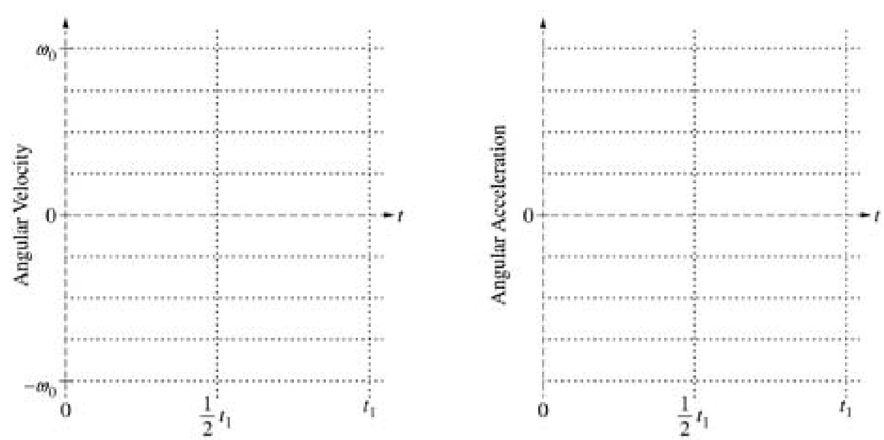
time $t = \frac{1}{2}t_1$, the student starts dripping oil on the contact surface between the axle and the disk to reduce the friction. As time passes, more and more oil reaches that contact surface, reducing the friction even further.

i. On the grid at left below, sketch a graph that could represent the disk's angular velocity as a

function of time from t = 0 to $t = t_1$, which is the time at which the disk came to rest in part (a).

ii. On the grid at right below, sketch the disk's angular acceleration as a function of time from

t = 0 to $t = t_1$.



d. The student is trying to mathematically model the magnitude τ of the torque exerted by the axle on the disk when the oil is present at times $t > \frac{1}{2}t_1$. The student writes down the following two equations, each of which includes a positive constant (C_1 or C_2) with appropriate units.

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$(1)\ \tau = C_1\left(t - \frac{1}{2}t_1\right)\ \left(for\, t > \frac{1}{2}t_1\right)$

$(2)\ \tau = \frac{C_2}{\left(t + \frac{1}{2}t_1\right)}\ \left(for\, t > \frac{1}{2}t_1\right)$

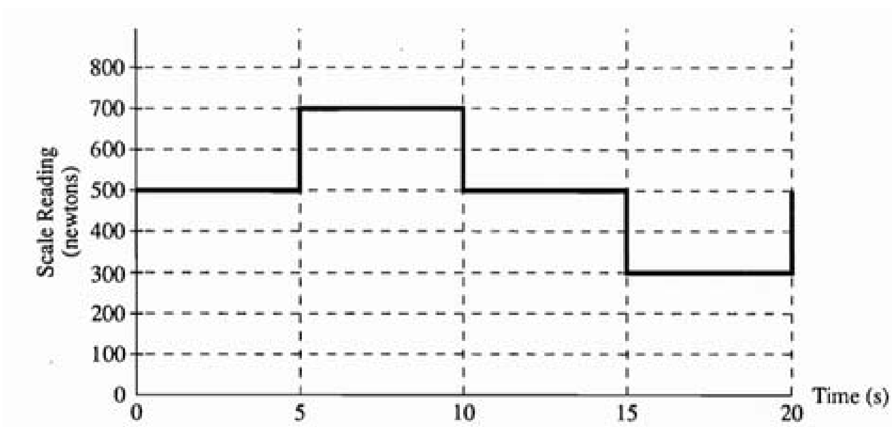
Which equation better mathematically models this experiment?

____Equation (1) ____Equation (2)

Briefly explain why the equation you selected is plausible and why the other equation is not plausible.

Please respond on separate paper, following directions from your teacher.

5.



A student whose normal weight is 500 newtons stands on a scale in an elevator and records the scale reading as a function of time. The data are shown in the graph above. At time t = 0, the elevator is at displacement x = 0 with velocity v = 0. Assume that the positive directions for displacement, velocity, and acceleration are upward.

(a) On the diagram to the right,draw and label of the forces on the student at *t* = 8 seconds.

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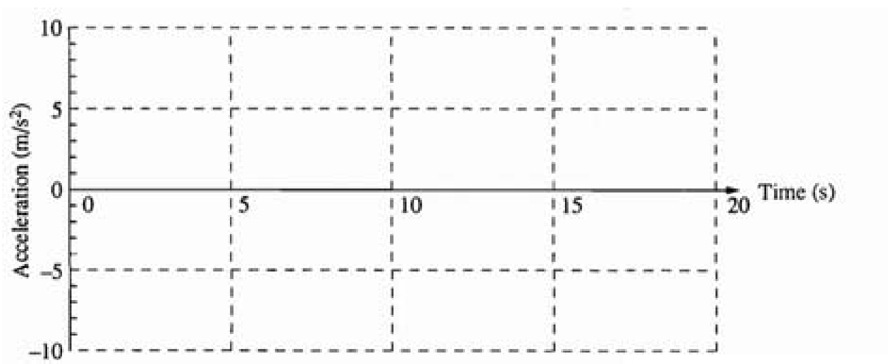
(b) Calculate the acceleration *a* of the elevator for each 5-second interval.

i. Indicate your results by completing the following table.

Time interval(s)	0-5	5-10	10-15	15-20
$a(m/s^2)$	____	____	____	____

ii. Plot the acceleration as a function of time on the following graph



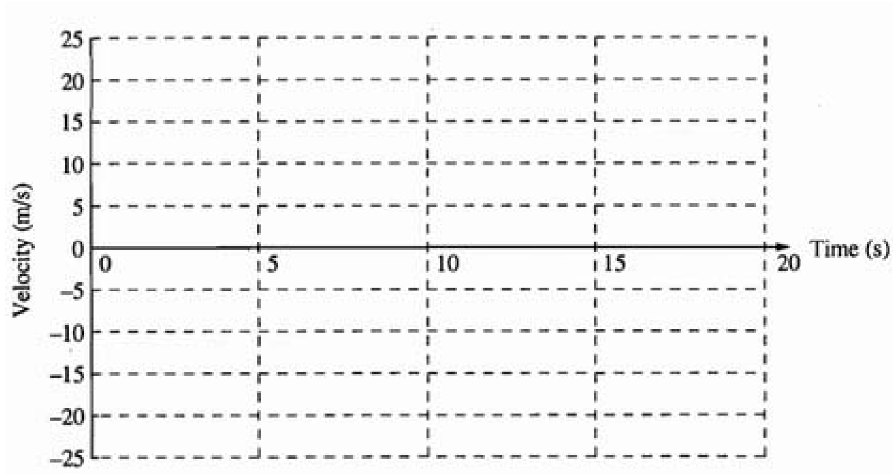
(c) Determine the velocity *v* of the elevator at the end of each 5-second interval.

i. Indicate your results by completing the following table

Time interval(s)	5	10	15	20
v(m/s)	____	____	____	____

ii. Plot the velocity as a function of time on the following graph.

Practice FRQ's

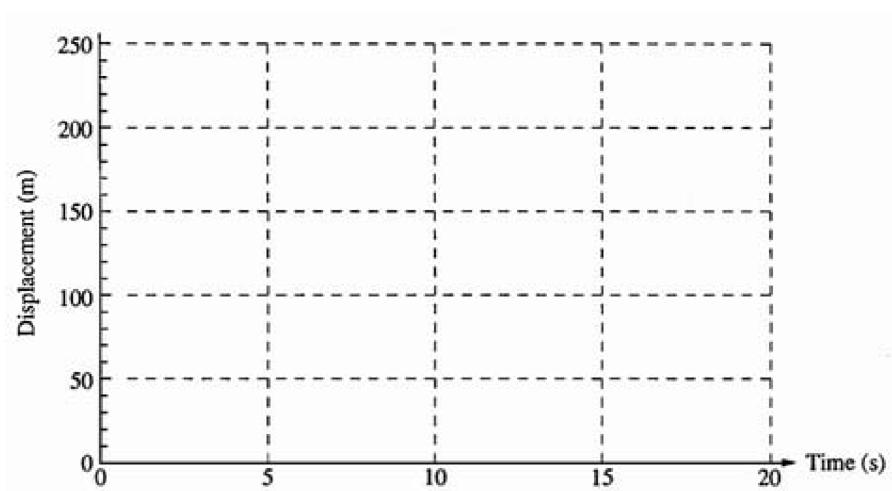


(d) Determine the displacement *x* of the elevator above the starting point at the end of each 5-second interval.

i. Indicate your results by completing the following table

Time interval(s)	5	10	15	20
x(m)	____	____	____	____

ii. Plot the displacement as a function of time on the following graph.



Please respond on separate paper, following directions from your teacher.

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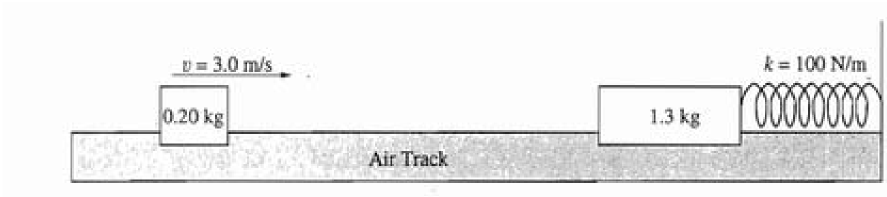
6.



As shown above, a 0.20-kilogram mass is sliding on a horizontal friction less air track with a speed of 3.0 meters per second when it instantaneously hits and sticks to a 1.3-kilogram mass initially at rest on the track. The 1.3-kilogram mass is connected to one end of a mass less spring, which has a spring constant of 100 newtons per meter. The other end of the spring is fixed.

(a) Determine the following for the 0.20-kilogram mass immediately before the impact.

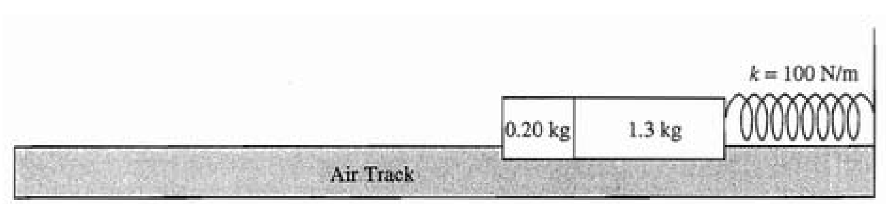
i. Its linear momentum

ii. Its kinetic energy

(b) Determine the following for the combined masses immediately after the impact

i. The linear momentum

ii. The kinetic energy



After the collision, the two masses undergo simple harmonic motion about their position at impact.

(c) Determine the amplitude of the harmonic motion.

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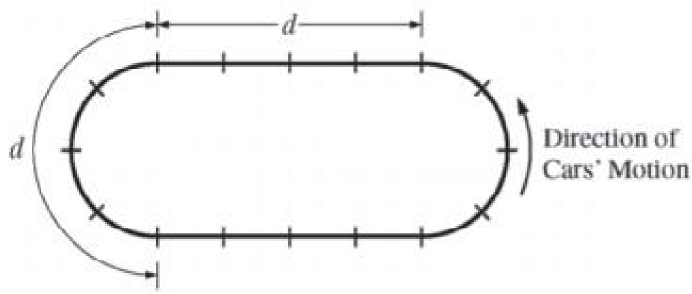
(d) Determine the period of the harmonic motion.

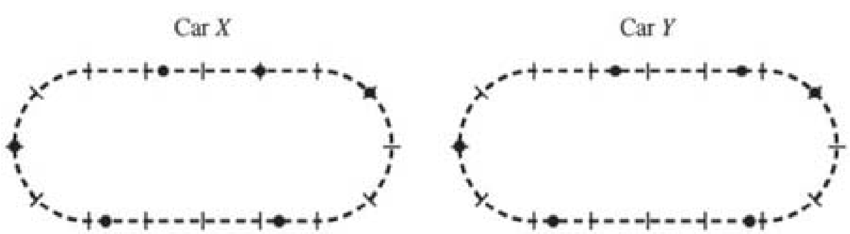
Please respond on separate paper, following directions from your teacher.

7.



The figure above represents a racetrack with semicircular sections connected by straight sections. Each section has length d, and markers along the track are spaced $d/4$ apart. Two people drive cars counterclockwise around the track, as shown. Car X goes around the curves at constant speed v_c, increases speed at constant acceleration for half of each straight section to reach a maximum speed of $2v_c$, then brakes at constant acceleration for the other half of each straight section to return to speed v_c. Car Y also goes around the curves at constant speed v_c, increases speed at constant acceleration for one-fourth of each straight section to reach the same maximum speed $2v_c$, stays at that speed for half of each straight section, then brakes at constant acceleration for the remaining fourth of each straight section to return to speed v_c.

(a) On the figures below, draw an arrow showing the direction of the net force on each of the cars at the positions noted by the dots. If the net force is zero at any position, label the dot with 0.



(b)

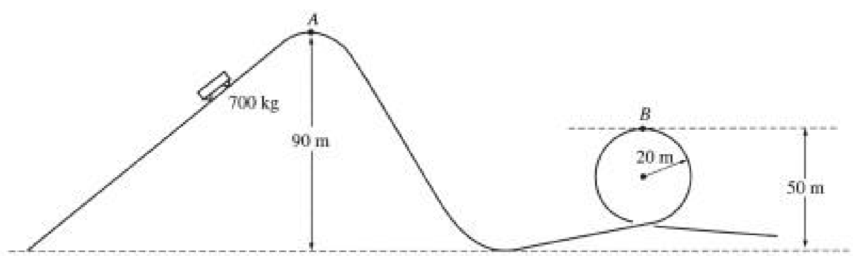
i. Indicate which car, if either, completes one trip around the track in less time. and justify your answer quantitatively with appropriate equations.

ii. Justify your answer about which car, if either, completes one trip around the track in less time quantitatively with appropriate equations.

(c) Explain how your equations in part (b) ii reexpress your reasoning in part (b) i. Do not simply refer to any final results of your calculations, but instead indicate how terms in your equations correspond to concepts in your qualitative explanation.

Please respond on separate paper, following directions from your teacher.

8.



A roller coaster ride at an amusement park lifts a car of mass 700 kg to point *A* at a height of 90 m above the lowest point on the track, as shown above. The car starts from rest at point *A*, rolls with negligible friction down the incline and follows the track around a loop of radius 20 m. Point *B*, the highest point on the loop, is at a height of 50 m above the lowest point on the track.

(a)

i. Indicate on the figure the point *P* at which the maximum speed of the car is attained.

ii. Calculate the value v_{max} of this maximum speed.

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(b) Calculate the speed v_B of the car at point *B*.

(c)

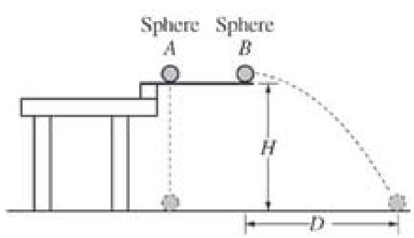
i. On the figure of the car below, draw and label vectors to represent the forces acting on the car when it is upside down at point *B.*

ii. Calculate the magnitude of all the forces identified in (c)i.

(d) Now suppose that friction is not negligible. How could the loop be modified to maintain the same speed at the top of the loop as found in (b)? Justify your answer.

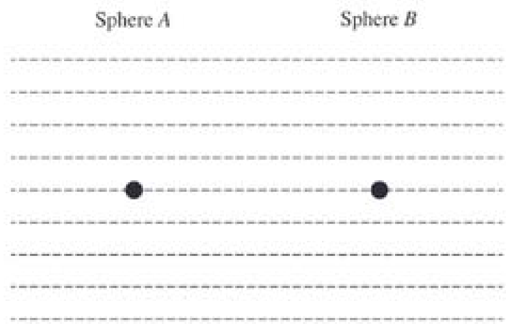
Please respond on separate paper, following directions from your teacher.

9.

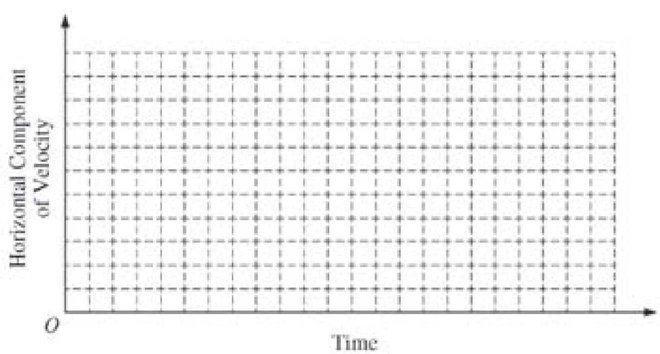


Two identical spheres are released from a device at time t = 0 from the same height H, as shown above. Sphere A has no initial velocity and falls straight down. Sphere B is given an initial horizontal velocity of magnitude v_0 and travels a horizontal distance D before it reaches the ground. The spheres reach the ground at the same time t_f , even though sphere B has more distance to cover before landing. Air resistance is negligible.

(a) The dots below represent spheres A and B. Draw a free-body diagram showing and labeling the forces (not components) exerted on each sphere at time $\frac{t_f}{2}$.



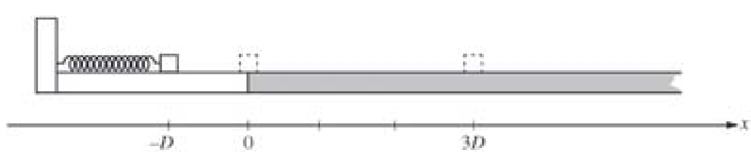
(b) On the axes below, sketch and label a graph of the horizontal component of the velocity of sphere A and of sphere B as a function of time.



(c) In a clear, coherent, paragraph-length response, explain why the spheres reach the ground at the same time even though they travel different distances. Include references to your answers to parts (a) and (b).

Please respond on separate paper, following directions from your teacher.

10.



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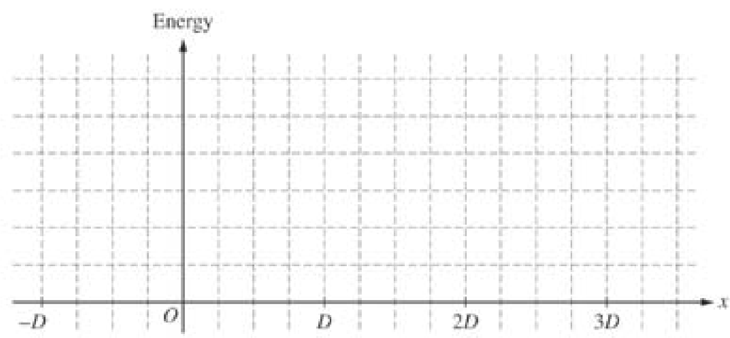
A block is initially at position x = 0 and in contact with an uncompressed spring of negligible mass. The block is pushed back along a frictionless surface from position *x = 0 to x = -D*, as shown above, compressing the spring by an amount $\Delta x = D.$. The block is then released. At *x = 0* the block enters a rough part of the track and eventually comes to rest at position *x = D*. The coefficient of kinetic friction between the block and the rough track is μ.

(a) On the axes below, sketch and label graphs of the following two quantities as a function of the position of the block between x = -D and x = 3D. You do not need to calculate values for the vertical axis, but the same vertical scale should be used for both quantities.

i. The kinetic energy *K* of the block

ii. The potential energy *U* of the block-spring system



The spring is now compressed twice as much, to $\Delta x = 2D.$ A student is asked to predict whether the final position of the block will be twice as far at *x = 6D*. The student reasons that since the spring will be compressed twice as much as before, the block will have more energy when it leaves the spring, so it will slide farther along the track before stopping at position *x = 6D.*

b)

i. Which aspects of the student's reasoning, if any, are correct? Explain how you arrived at your answer.

ii. Which aspects of the student's reasoning, if any, are incorrect? Explain how you arrived at your answer.

(c) Use quantitative reasoning, including equations as needed, to develop an expression for

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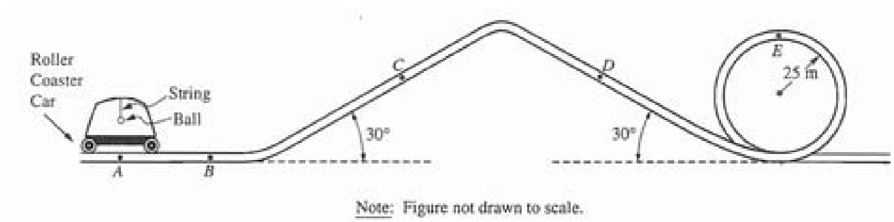
the new final position of the block. Express your answer in terms of D.

(d) Explain how any correct aspects of the student's reasoning identified in part (b) are expressed by your mathematical relationships in part (c). Explain how your relationships in part (c) correct any incorrect aspects of the student's reasoning identified in part (b). Refer to the relationships you wrote in part (c), not just the final answer you obtained by manipulating those relationships.

Please respond on separate paper, following directions from your teacher.

11.



Part of the track of an amusement park roller coaster is shaped as shown above. A safety bar is oriented length-wise along the top of each car. In one roller coaster car, a small 0.10-kilogram ball is suspended from this bar by a short length of light, inextensible string.

(a) Initially, the car is at rest a point A.

i. On the diagram to the right, draw and label all the forces acting on the 0.10-kilogram ball.

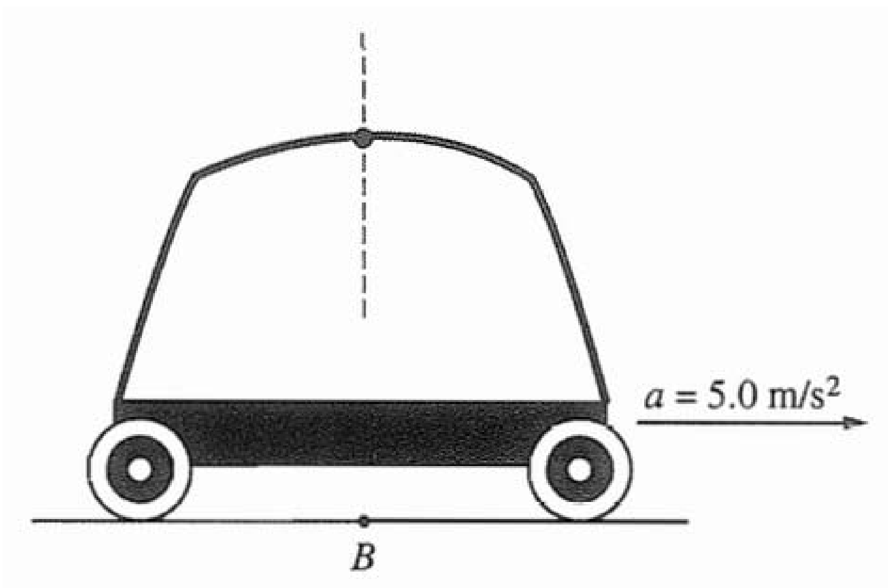
ii. Calculate the tension in the string.

The car is then accelerated horizontally, goes up a 30° incline, goes down a 30° incline, and then goes around a vertical circular loop of radius 25 meters. For each of the four situations described in parts (b) to (e), do all three of the following. In each situation, assume that the ball has stopped swinging back and forth.

• Determine the horizontal component T_h of the tension in the string in newtons and record your answer in the space provided.

• Determine the vertical component T_v of the tension in the string in newtons and record your answer in the space provided.

• Show on the adjacent diagram the approximate direction of the string with respect to the vertical. The dashed line shows the vertical in each situation.



(b) The car is at point B moving horizontally to the right with an acceleration of 5.0 m/s^2.

T_h =________N T_v =________N

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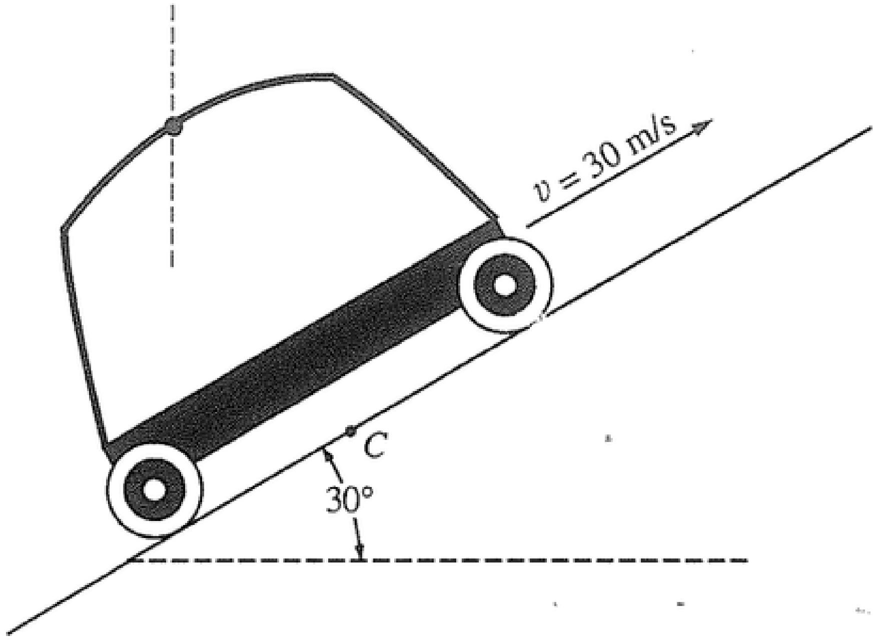

(c) The car is at point C and is being pulled up the 30° incline with a constant speed of 30 m/s

T_h =________N T_v =________N

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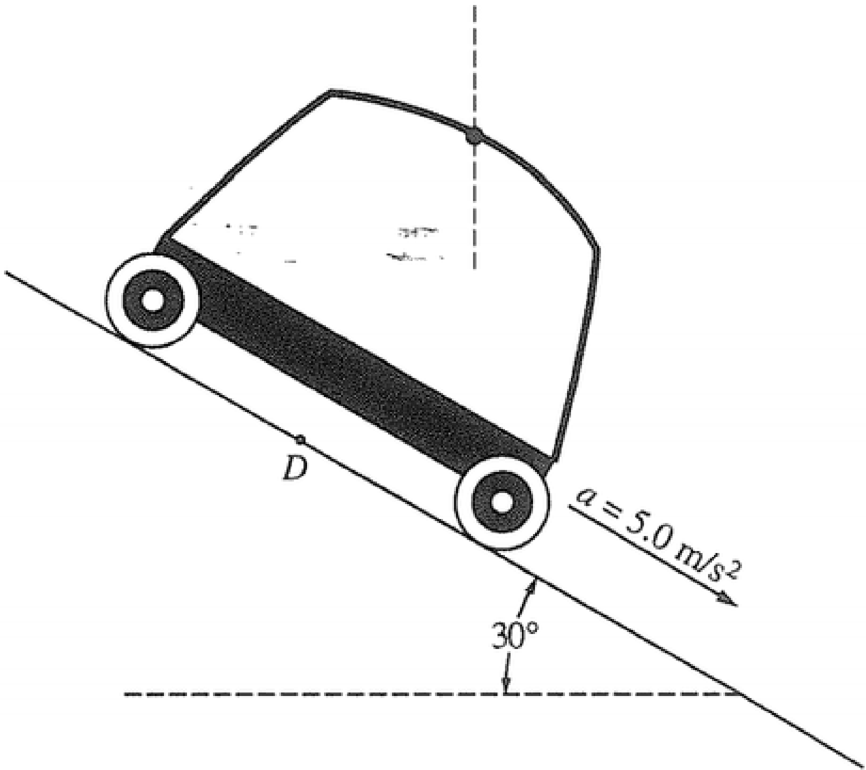
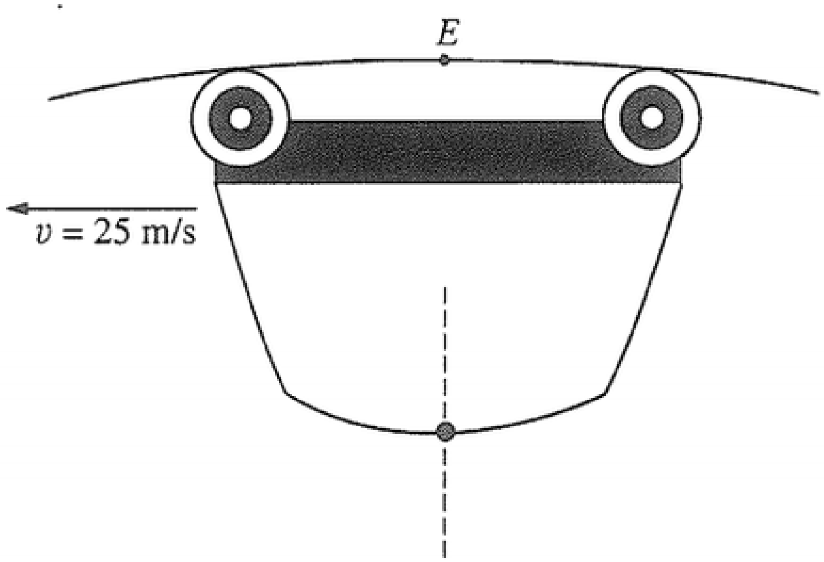


(d) The car is at point D moving down the 30° incline with an acceleration of 5.0 m/s².

T_h =________N T_v =________N



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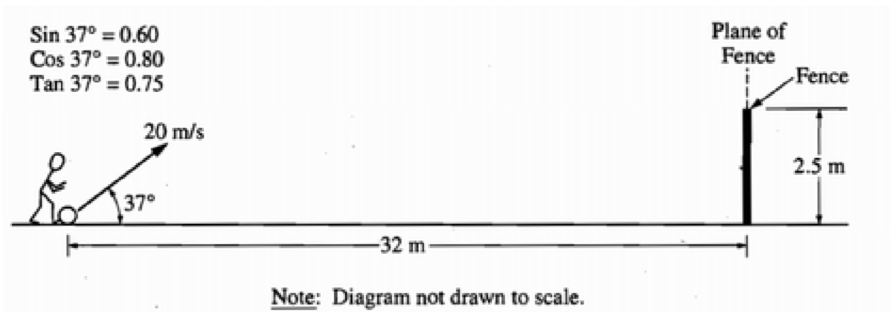
(e) The car is at point E moving upside down with an instantaneous speed of 25 m/s and no tangential acceleration at the top of the vertical loop of radius 25 meters.

T_h =________N T_v =________N

Please respond on separate paper, following directions from your teacher.

12.



A ball of mass 0.5 kilogram, initially at rest, is kicked directly toward a fence from a point 32 meters away, as shown above. The velocity of the ball as it leaves the kicker's foot is 20 meters per second at a angle of 37° above the horizontal. The top of the fence is 2.5 meters high. The kicker's foot is in contact with the ball for 0.05 second. The ball hits nothing while in flight and air resistance is negligible.

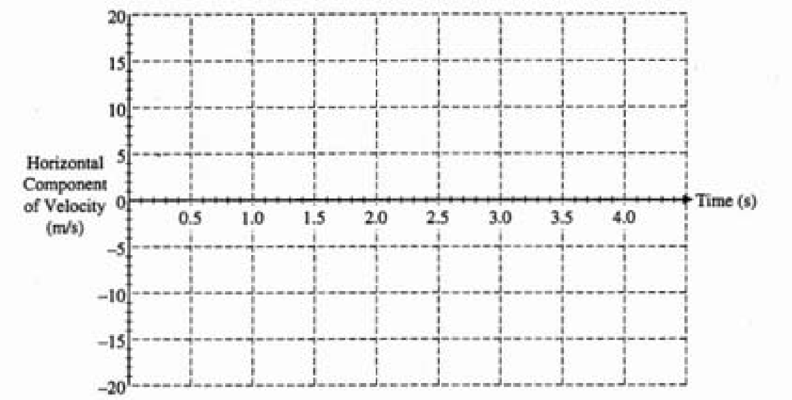
(a) Determine the magnitude of the average net force exerted on the ball during the kick.

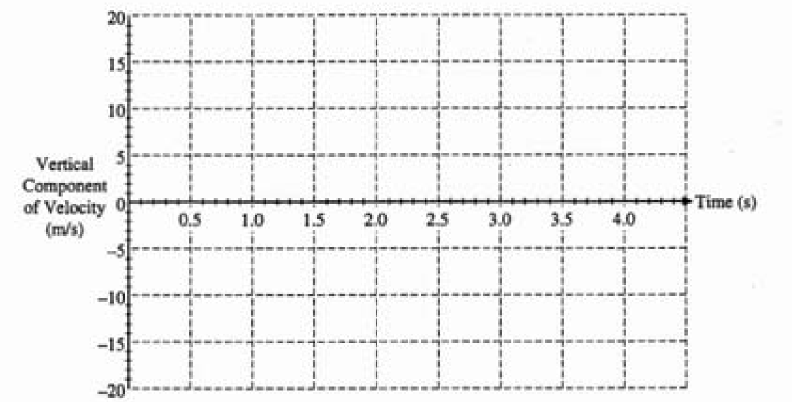
(b) Determine the time it takes for the ball to reach the plane of the fence.

(c) Will the ball hit the fence? If so, how far below the top of the fence will it hit? If not, how far above the top of the fence will it pass?

(d) On the axes below, sketch the horizontal and vertical components of the velocity of the ball as functions of time until the ball reaches the plane of the fence.

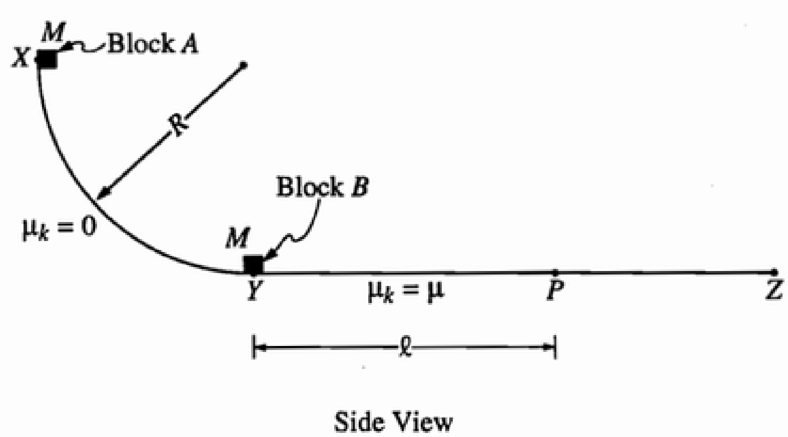
Practice FRQ's





Please respond on separate paper, following directions from your teacher.

13.



Practice FRQ's

A track consists of a frictionless arc *XY*, which is a quarter-circle of radius *R*, and a rough horizontal section *YZ*. Block *A* of mass *M* is released from rest at point *X,* slides down the curved section of the track, and collides instantaneously and in elastically with identical block *B* at point *Y*. The two blocks move together to the right, sliding past point *P*, which is a distance *L* from point *Y*. The coefficient of kinetic friction between the blocks and the horizontal part of the track is μ. Express your answers in terms of *M*, *L*, μ, *R*, and *g*.

(a) Determine the speed of block *A* just before it hits block *B*.

(b) Determine the speed of the combined blocks immediately after the collision.

(c) Determine the amount of kinetic energy lost due to the collision.

(d) The specific heat of the material used to make the blocks is *c*. Determine the temperature rise that results from the collision in terms of *c* and the other given quantities. (Assume that no energy is transferred to the track or to the air surrounding the blocks.)

(e) Determine the additional thermal energy that is generated as the blocks move from *Y* to *P*.

Please respond on separate paper, following directions from your teacher.