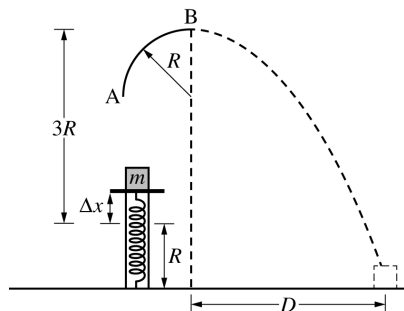
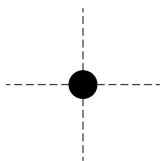


Begin your response to QUESTION 3 on this page.

Note: Figure not drawn to scale.

3. A block of mass m is placed on top of an ideal spring of spring constant k . The block is pushed against the spring, compressing the spring a distance Δx . The block is released from rest, leaves the spring at the position shown in the figure, travels upward, and enters a track with a constant radius of curvature R that has negligible friction. The block enters the track at point A, maintains contact with the track, and exits horizontally at point B, a distance $3R$ above the point the block was released. The block then falls to the ground and lands a horizontal distance D from the end of the track. Express all algebraic answers in terms of m , k , Δx , R , and physical constants, as appropriate. The size of the block is much smaller than the radius of curvature of the track.

- (a) On the dot below, which represents the block, draw and label the forces (not components) that act on the block while still in contact with the track at point B. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.



Justify your choice of vectors.

GO ON TO THE NEXT PAGE.

Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

(b)

- i. Derive an expression for the speed v of the block at point B.

- ii. Derive an expression for the magnitude of the net force F on the block at point B.

- (c) Derive an expression for the minimum value of $\Delta x_{\min}$ required in order for the block to maintain contact with the track through point B.

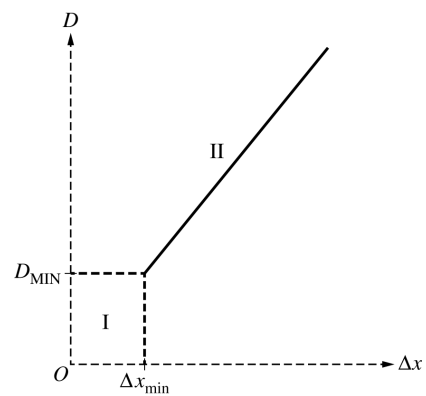
The procedure is repeated several times with the distance $\Delta x > \Delta x_{\min}$.

- (d) Calculate the distance D that the block travels.

GO ON TO THE NEXT PAGE.

Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

(e) The graph below shows the best-fit line drawn by the students through their data of D as a function of Δx .



i. Explain why there are no data for section I of the graph.

ii. Explain the reason for the shape and minimum value of section II on the graph.

GO ON TO THE NEXT PAGE.

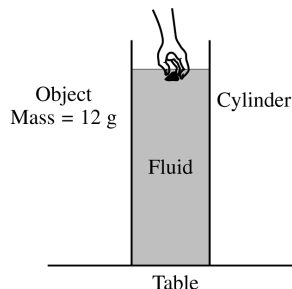
Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

STOP

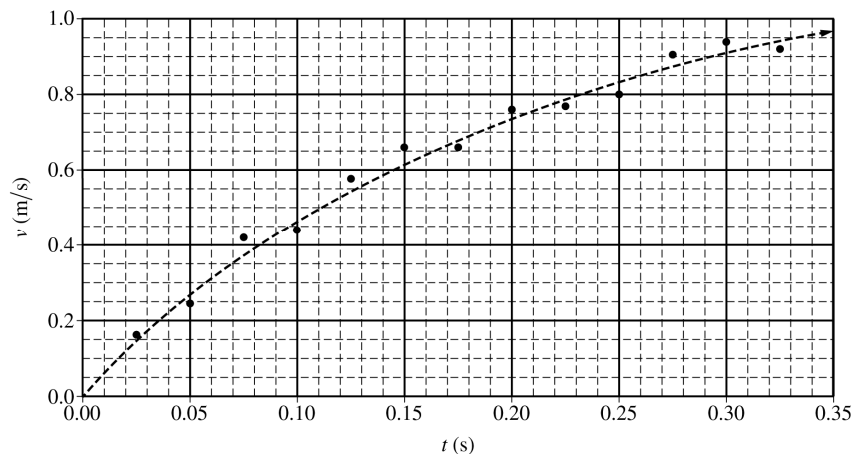
END OF EXAM

PHYSICS C: MECHANICS**SECTION II****Time—45 minutes****3 Questions**

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



1. In an experiment, students used video analysis to track the motion of an object falling vertically through a fluid in a glass cylinder. The object of $m = 12\text{ g}$ is released from rest at the top of the column of fluid, as shown above. The data for the speed v of the falling object as a function of time t are graphed on the grid below. The dashed curve represents the best fit chosen by the students for these data.



(a)

- i. Does the speed of the object increase, decrease, or remain the same?

____ Increase ____ Decrease ____ Remain the same

- ii. In a brief statement, describe the direction of the object's acceleration and how the magnitude of this acceleration changed as the object fell.

- iii. Using the graph, calculate an approximate value for the magnitude of the acceleration of the object at $t = 0.20\text{ s}$.

The students use the equation $v = A(1 - e^{-Bt})$ to model the speed of the falling object and find the best fit coefficients to be $A = 1.18\text{ m/s}$ and $B = 5\text{ s}^{-1}$.

(b) Use the above equation to:

- i. Derive an expression for the magnitude of the vertical displacement $y(t)$ of the falling object as a function of time t .
- ii. Derive an expression for the magnitude of the net force $F(t)$ exerted on the object as it falls through the fluid as a function of time t .

The students repeat the experiment with a taller glass cylinder that is filled with the same fluid. The cylinder is tall enough so that the object reaches a constant speed.

(c)

- i. Determine the constant speed of the object.

Justify your answer.

- ii. Determine the force exerted by the fluid on the object at this time.

Justify your answer.

PHYSICS C: MECHANICS

SECTION II

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.

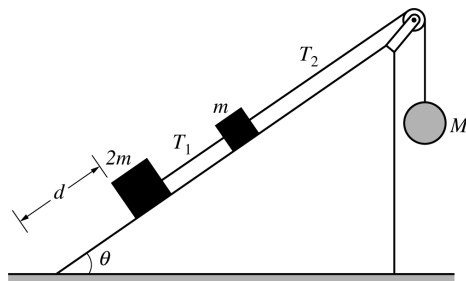


Figure 1

1. Blocks of mass m and $2m$ are connected by a light string and placed on a frictionless inclined plane that makes an angle θ with the horizontal, as shown in Figure 1 above. Another light string connecting the block of mass m to a hanging sphere of mass M passes over a pulley of negligible mass and negligible friction. The entire system is initially at rest and in equilibrium.
 - (a) On the dots below that represent the block of mass m and the sphere of mass M , draw and label the forces (not components) that act on each of the objects shown. Each force must be represented by a distinct arrow starting on and pointing away from the dot.



- (b) Derive expressions for the magnitude of each of the following. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figures in part (a).
 - i. The force T_2 exerted on the block of mass m by the string. Express your answers in terms of m , θ , and physical constants, as appropriate.
 - ii. The mass M for which the system can remain in equilibrium. Express your answers in terms of m , θ , and physical constants, as appropriate.
- (c) Now suppose that mass M is large enough to descend and that the sphere reaches the floor before the blocks reach the pulley. Answer the following for the moment immediately after the sphere reaches the floor.
 - i. Does the tension T_1 increase, decrease to a nonzero value, decrease to zero, or stay the same?

___ Increase	___ Decrease to a nonzero value
___ Decrease to zero	___ Stay the same
 - ii. Is the velocity of the block of mass m up the ramp, down the ramp, or zero?

___ Up the ramp	___ Down the ramp	___ Zero
-----------------	-------------------	----------
 - iii. Is the acceleration of the block of mass m up the ramp, down the ramp, or zero?

___ Up the ramp	___ Down the ramp	___ Zero
-----------------	-------------------	----------
- (d) Consider the initial setup in Figure 1. Now suppose the surface of the incline is rough and the coefficient of static friction between the blocks and the inclined plane is μ_s . Derive an expression for the minimum possible value of M that will keep the blocks from moving down the incline. Express your answer in terms of m , μ_s , θ , and fundamental constants, as appropriate.
- (e) The string connecting block m and the sphere of mass M then breaks, and the blocks begin to move from rest down the incline. The lower block starts a distance d from the bottom of the incline, as shown in Figure 1. The coefficient of kinetic friction between the blocks and the inclined plane is μ_k . Derive an expression for the speed of the blocks when the lower block reaches the bottom of the incline. Express your answer in terms of m , d , μ_k , θ , and fundamental constants, as appropriate.