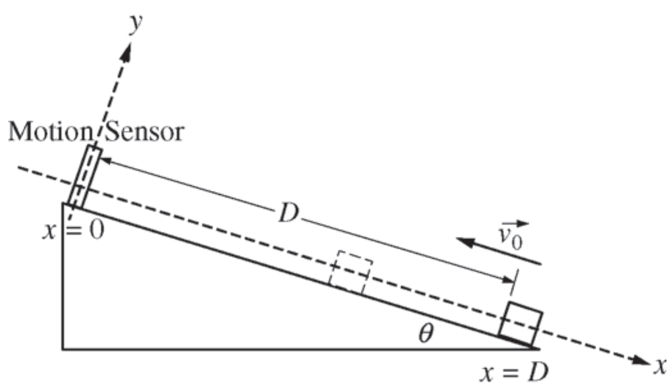
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

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.



Mech.1.

A block of mass m is projected up from the bottom of an inclined ramp with an initial velocity of magnitude v_0. The ramp has negligible friction and makes an angle θ with the horizontal. A motion sensor aimed down the ramp is mounted at the top of the incline so that the positive direction is down the ramp. The block starts a distance D from the motion sensor, as shown above. The block slides partway up the ramp, stops before reaching the sensor, and then slides back down.

(a) Consider the motion of the block at some time t after it has been projected up the ramp. Express your answers in terms of m, D, v_0, t, θ and physical constants, as appropriate.

i. Determine the acceleration a of the block.

ii. Determine an expression for the velocity v of the block.

iii. Determine an expression for the position x of the block.

(b) Derive an expression for the position x_{min} of the block when it is closest to the motion sensor. Express your answer in terms of m, D, v_0, θ, and physical constants, as appropriate.

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Question 1

15 points total | **Distribution of points**

(a)

i. 1 points

Using Newton's second law with down the incline as the positive direction

$F_{net} = ma$

$mg\sin\theta = ma$

For a correct expression of a positive acceleration — 1 point

$a = g\sin\theta$

ii. 2 points

Using a correct kinematics equation to solve for velocity

$v_2 = v_1 + at$

For substitution into a correct kinematics equation consistent with the acceleration from part (a)i — 1 point

For having a negative sign on v_0 — 1 point

$v = -v_0 + (g\sin\theta)t$

iii. 1 points

Using a correct kinematics equation to solve for position

$x = x_0 + v_1 t + \frac{1}{2}at^2$

For substitution into a correct kinematics equation consistent with expressions from parts (a)i and (a)ii — 1 point

$x = D - v_0 t + \frac{1}{2}(g\sin\theta)t^2$

(b) 2 points

Using an equation that can be solved for the closest position to the sensor

$v_2^2 = v_1^2 + 2ad$

For substitution into a correct kinematic equation consistent with part (a) — 1 point

For setting v_2 to zero and using D for the initial position — 1 point

$0 = v_0^2 + 2(g\sin\theta)(x - D)$

$x = D - \frac{v_0^2}{2g\sin\theta}$

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Question 1 (continued)

Distribution of points

(b) (continued)

Alternate solution: *Alternate points*

Using a conservation of energy approach to find the highest point the cart moves along the incline

$$K_1 + U_{g1} = K_2 + U_{g2}$$

$$K_1 = U_{g2}$$

$$\frac{1}{2}mv_0^2 = mgh_2$$

For using the correct energy statement with the correct initial velocity *1 point*

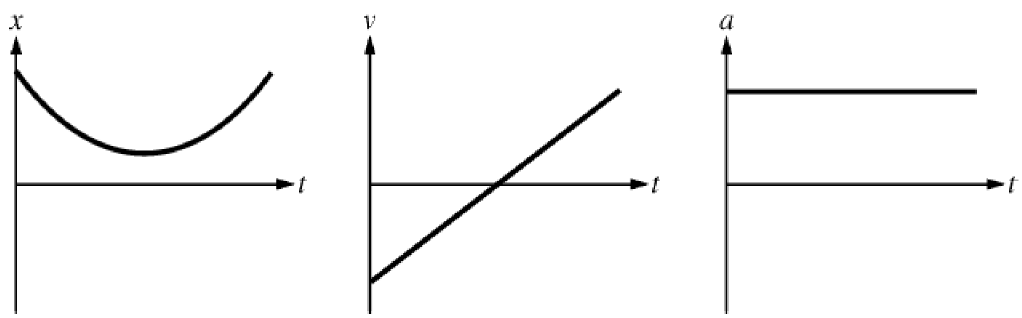
For a correct statement of the height of the cart along the incline *1 point*

$$h = (D - x)\sin\theta$$

$$\frac{1}{2}v_0^2 = g(D - x)(\sin\theta)$$

$$x = D - \frac{v_0^2}{2g\sin\theta}$$

(c) 4 points



For a position graph that is a parabola that does not cross the t-axis and has a vertex that does not touch the t-axis 1 point

For a velocity graph that is a straight line and crosses the t-axis 1 point

For an acceleration graph that is a horizontal line 1 point

For a set of graphs that are consistent with each other 1 point

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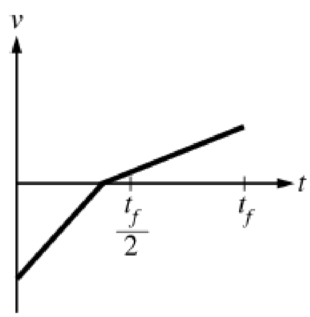
Question 1 (continued)

		Distribution of points
(d)	2 points	
	Using an equation that can be solved for the distance	
	$v_2^2 = v_1^2 + 2ad$	
	For a correct expression of the frictional force	1 point
	$f = -\mu_k mg = ma$	
	$a = -\mu_k g$	
	$0 = v_0^2 - 2\mu_k gd$	
	For a correct answer	1 point
	$d = \dfrac{v_0^2}{2\mu_k g}$	
	Alternate solution:	*Alternate points*
	Using an equation that can be solved for the distance	
	$Fd = \frac{1}{2}m\left(v_2^2 - v_1^2\right)$	
	For a correct expression of the frictional force	*1 point*
	$-\mu_k mgd = \frac{1}{2}m\left(0 - v_0^2\right)$	
	For a correct answer	*1 point*
	$d = \dfrac{v_0^2}{2\mu_k g}$	

(e) 3 points



The graph has two straight line portions.

For having a change in slope at $v = 0$	1 point
For having slope values of each segment that have the same sign and the correct relative magnitudes (segment I slope magnitude greater than segment II slope magnitude, as shown in the graph above)	1 point
For having a graph that crosses the t-axis earlier than $t_f/2$ and extends to t_f	1 point

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