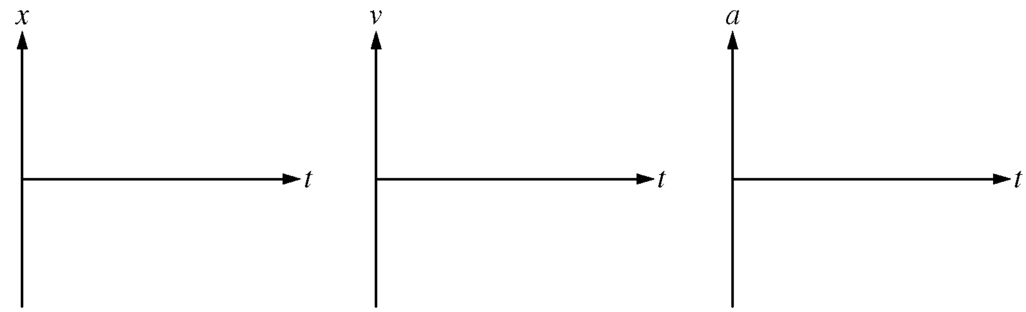
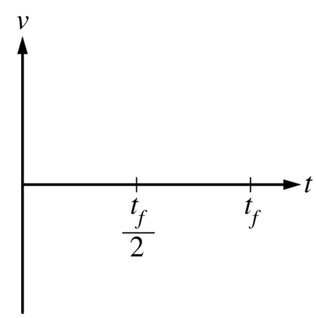
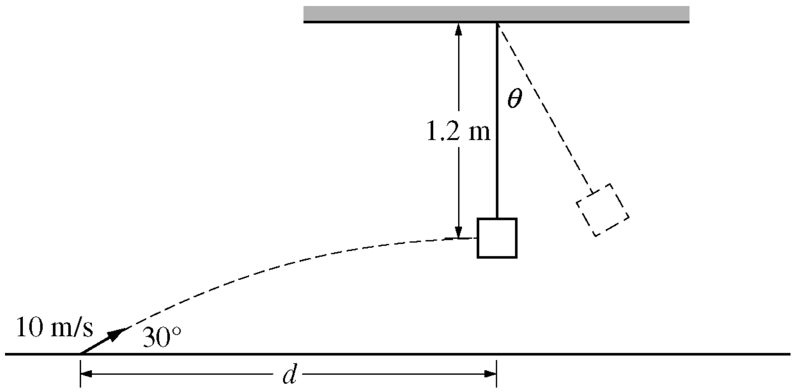
(c) On the axes provided below, sketch graphs of position x, velocity v, and acceleration a as functions of time t for the motion of the block while it goes up and back down the ramp. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



(d) After the block slides back down and leaves the bottom of the ramp, it slides on a horizontal surface with a coefficient of friction given by μ_k. Derive an expression for the distance the block slides before stopping. Express your answer in terms of m, D, v_0, θ, μ_k, and physical constants, as appropriate.

(e) Suppose the ramp now has friction. The same block is projected up with the same initial speed v_0 and comes back down the ramp. On the axes provided below, sketch a graph of the velocity v as a function of time t for the motion of the block while it goes up and back down the ramp, arriving at the bottom of the ramp at time t_f. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.





Mech.2.

A small dart of mass 0.020 kg is launched at an angle of 30° above the horizontal with an initial speed of 10 m/s. At the moment it reaches the highest point in its path and is moving horizontally, it collides with and sticks to a wooden block of mass 0.10 kg that is suspended at the end of a massless string. The center of mass of the block is 1.2 m below the pivot point of the string. The block and dart then swing up until the string makes an angle θ with the vertical, as shown above. Air resistance is negligible.

(a) Determine the speed of the dart just before it strikes the block.

(b) Calculate the horizontal distance d between the launching point of the dart and a point on the floor directly below the block.

(c) Calculate the speed of the block just after the dart strikes.

(d) Calculate the angle θ through which the dart and block on the string will rise before coming momentarily to rest.

(e) The block then continues to swing as a simple pendulum. Calculate the time between when the dart collides with the block and when the block first returns to its original position.

(f) In a second experiment, a dart with more mass is launched at the same speed and angle. The dart collides with and sticks to the same wooden block.

i. Would the angle θ that the dart and block swing to increase, decrease, or stay the same?

______ Increase   ______ Decrease   ______ Stay the same

Justify your answer.

ii. Would the period of oscillation after the collision increase, decrease, or stay the same?

______ Increase   ______ Decrease   ______ Stay the same

Justify your answer.

Question 2

15 points total | **Distribution of points**

(a) 1 point

Writing an equation to solve for the speed when the dart is at its maximum height

$v = v_x = v_0(\cos\theta)$

$v = (10\ \text{m/s})(\cos 30°)$

For a correct answer — 1 point

$v = 8.7\ \text{m/s}$

(b) 2 points

Writing an equation to solve for time using motion in the vertical direction

$v_y = v_{y0} + a_y t$

$0 = (10\ \text{m/s})(\sin 30) + \left(-9.8\ \text{m/s}^2\right)t$

For a correct value for the time — 1 point

$t = 0.51\ \text{s}$ (or $t = 0.50\ \text{s}$ if using $g = 10\ \text{m/s}^2$)

For substituting into an equation for the horizontal motion consistent with the speed from part (a), or for determining the correct answer — 1 point

$x = v_x t$

$x = (8.7\ \text{m/s})(0.51\ \text{s})$

$x = 4.4\ \text{m}$

(c) 3 points

For a correct expression of conservation of momentum — 1 point

$p_i = p_f$

For a correct expression that represents a totally inelastic collision between the dart and the block — 1 point

$m_1 v_{1i} = (m_1 + m_2)v_f$

$(0.020\ \text{kg})(8.66\ \text{m/s}) = (0.020\ \text{kg} + 0.10\ \text{kg})v_f$

For an answer consistent with the speed from part (a) and correct mass substitutions — 1 point

$v = 1.4\ \text{m/s}$

Question 2 (continued)

	Distribution of points
(d) 3 points	
For a correct expression of conservation of energy	1 point
$K_1 + U_{g1} = K_2 + U_{g2}$	
$\frac{1}{2}mv_1^2 = mgh_2$	
For a correct expression for the height reached by the block	1 point
$h = L - L(\cos\theta)$	
For substituting the speed value from part (c) into a correct conservation of energy equation	1 point
$\frac{1}{2}mv_1^2 = mgL(1-\cos\theta)$	
$\cos\theta = 1 - \frac{v_1^2}{2gL}$	
$\cos\theta = 1 - \frac{(1.44\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)(1.2\ \text{m})}$	
$\theta = 24°$	
(e) 2 points	
For substituting the correct length into the correct equation for the period	1 point
$T = 2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{(1.2\ \text{m})}{\left(9.8\ \text{m/s}^2\right)}} = 2.2\ \text{s}$	
For correctly dividing the period in half to solve for the time	1 point
$t = T/2 = (2.2\ \text{s})/2$	
$t = 1.1\ \text{s}$	
(f) i. 2 points	
For selecting "Increase"	1 point
For a correct justification of the larger angle for the block-dart system	1 point
Example: A more massive dart would cause the speed after the collision with the block to increase. A greater speed after the collision would cause the block to reach a greater height and thus the angle θ would increase.	

Question 2 (continued)

Distribution of points

(f) (continued)

ii. 2 points

For selecting "Stay the same"	1 point
For a correct justification	1 point

Example: A more massive dart would not affect the period of the pendulum. Only changing the length of the string would change the period.

Note: If the student correctly points out the changes to the simple pendulum could be outside the small angle approximation, then the student's entire answer will be considered (both check box and justification are consistent and physically correct).