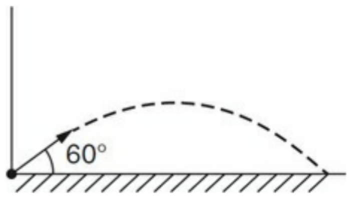
Student #: ____________________ Student Name: ____________________

AP PHYSICS C CLASS 1: KINEMATICS

1. A golf ball is hit from level ground and has a horizontal range of 100 m. The ball leaves the golf club at an angle of 60° to the level ground. At what other angle(s) can the ball be struck at the same initial velocity and still have a range of 100 m?



(A) 30°
(B) 20° and 80°
(C) 10° and 120°
(D) 45° and 135°
(E) There is no other angle other than 60° in which the ball will have a range of 100 m.

2. A stack of coffee filters falls from rest through the air. Due to air resistance, the filters fall with an acceleration proportional to the velocity of fall, that is, $a = -kv$, where k is a positive constant. The velocity of the falling filters as a function of time of fall is

(A) $-kv^2$
(B) $-12kv^2$
(C) $-k$
(D) $\ln(kt)$
(E) $v_0 e^{-kt}$

3. An object starts from rest at $t = 0$ and position $x = 0$, then moves in a straight line with an acceleration described by the equation $a = 4t^2$ in $\mathrm{m/s^2}$. What is the position of the object at $t = 3$ s?

(A) 6 m
(B) 1 m
(C) 27 m
(D) 54 m
(E) 108 m

Questions 4–5: A car of mass m travels along a straight horizontal road. The car begins with a speed v_0, and accelerates according to the velocity function $v(t) = \sqrt{v_0^2 + \frac{Ct^2}{m}}$, where t is time, and C is a positive constant.

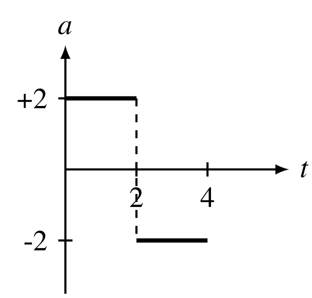
4. The speed of the car is zero at a time t of

(A) zero
(B) $2t$
(C) $4t$
(D) $\sqrt{8t}$
(E) The speed of the car is never zero.

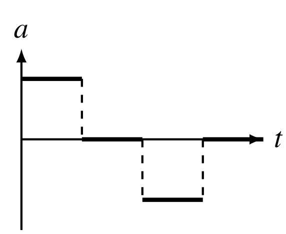
5. The acceleration of the car as a function of time is

(A) $v_0^2 + \frac{Ct^2}{m}$
(B) $v_0^2 + \frac{2Ct^2}{m}$
(C) $v_0 + \frac{Ct}{m}$
(D) $\frac{2Ct}{m}$
(E) $\frac{2Ct^2}{m}$

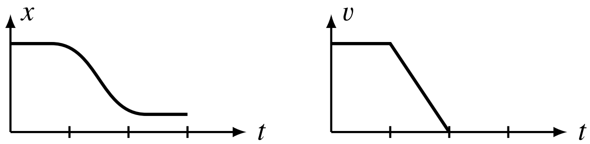
6. The motion of an object is represented by the acceleration vs. time graph below. The object is intially at rest. Which of the following statements is true about the motion of the object?

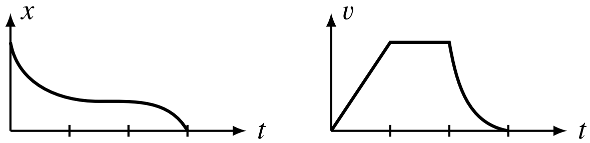


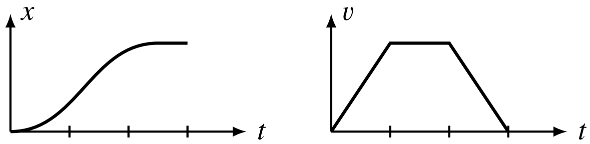
(A) The object returns to its original position.
(B) The velocity of the object is zero at a time of 2 s.
(C) The velocity of the object is zero at a time of 4 s.
(D) The displacement of the object is zero at a time of 4 s.
(E) The acceleration of the object is zero at a time of 2 s.

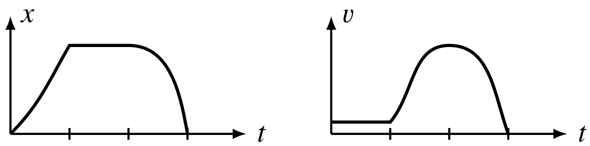


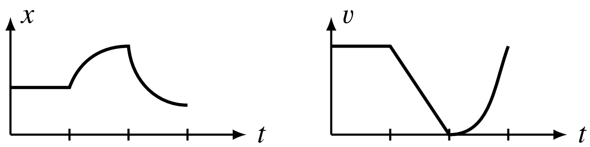
7. Which of the following pairs of graphs could show the position vs. time and velocity vs. time graphs for the acceleration vs. time graph shown above? Assume $v = 0$ and $x = 0$ at $t = 0$.

(A) 

(B) 

(C) 

(D) 

(E) 

Questions 8–9: An object is released from rest and falls through a resistive medium. The resistance causes the velocity of the object to change according to the equation $v = 16t - \frac{1}{2}t^4$, where v is in m/s, and time is in seconds.

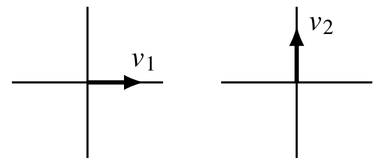
8. Which of the following is a possible equation for the acceleration of the object as a function of time?

(A) $16 - 2t^2$
(B) $16 - 2t^3$
(C) $16 - 2t$
(D) $8t^3 - 2t^2$
(E) $32t^3 - 2t^5$

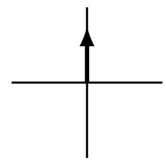
9. What is the terminal velocity of the object as it falls?

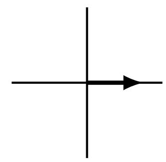
(A) 5 m/s
(B) 10 m/s
(C) 24 m/s
(D) 32 m/s
(E) The object never reaches a terminal velocity.

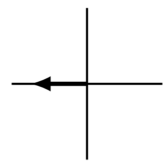
10. Two velocity vectors v_1 and v_2 each have a magnitude of 10 m/s. Graph 1 shows the velocity v_1 at $t = 0$ s, and then the same object has a velocity v_2 at $t = 2$ s, shown in Graph 2. Which of the following vectors best represents the average acceleration vector that causes the object's velocity to change from v_1 to v_2 ?



Graph 1 Graph 2


(A)


(B)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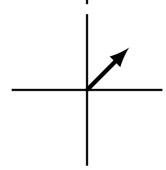
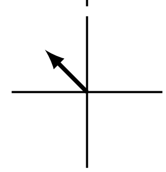
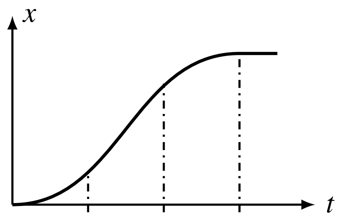

(D)

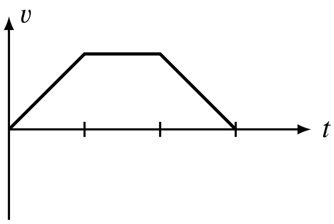

(E)

11. A toy dart gun fires a dart at an angle of 45° to the horizontal and the dart reaches a maximum height of 1 meter. If the dart were fired straight up into the air along the vertical, the dart would reach a height of

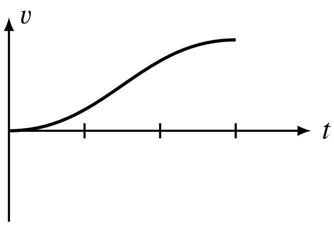
(A) 1 m
(B) 2 m
(C) 3 m
(D) 4 m
(E) 5 m

12. The graph below shows the displacement as a function of time for a car moving in a straight line. Which of the following graphs shows the velocity vs. time graph for the same time intervals?

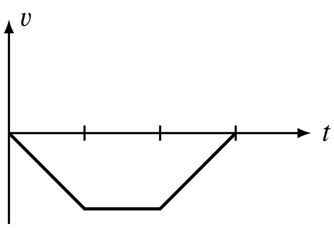




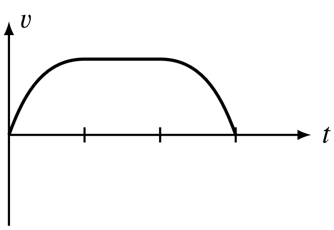
(A)



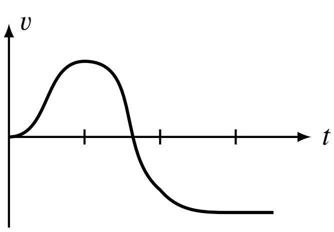
(B)



(C)



(D)



(E)

13. The position x of an object is described with respect to time t by the following equation: $x = 2t^3 - 15t^2 + 36t - 8$, where x is in meters and t in seconds. Answer the following questions.

(a) Find its displacement between $t = 3$ and $5\,\mathrm{s}$.

(b) Write out an expression for the velocity of the object with respect to time.

(c) Write out an expression for the acceleration of the object with respect to time.

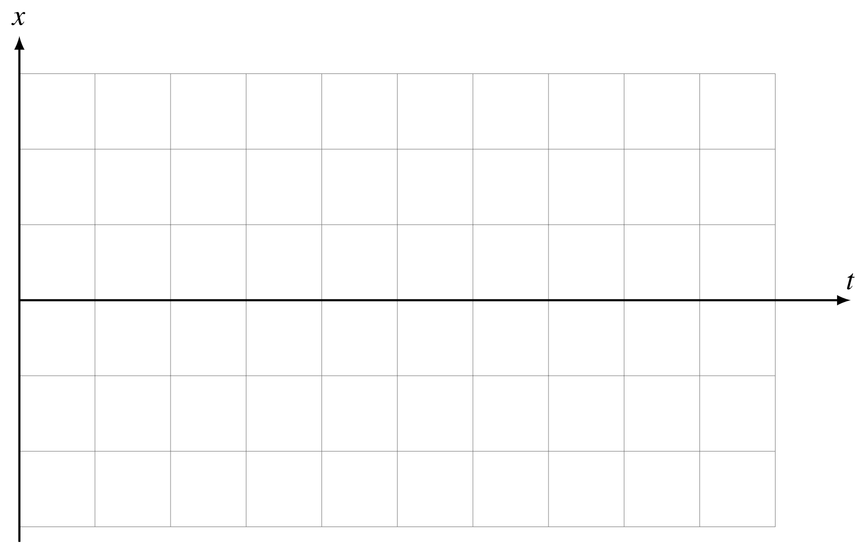
(d) At what point(s) in time is the velocity of the object zero?

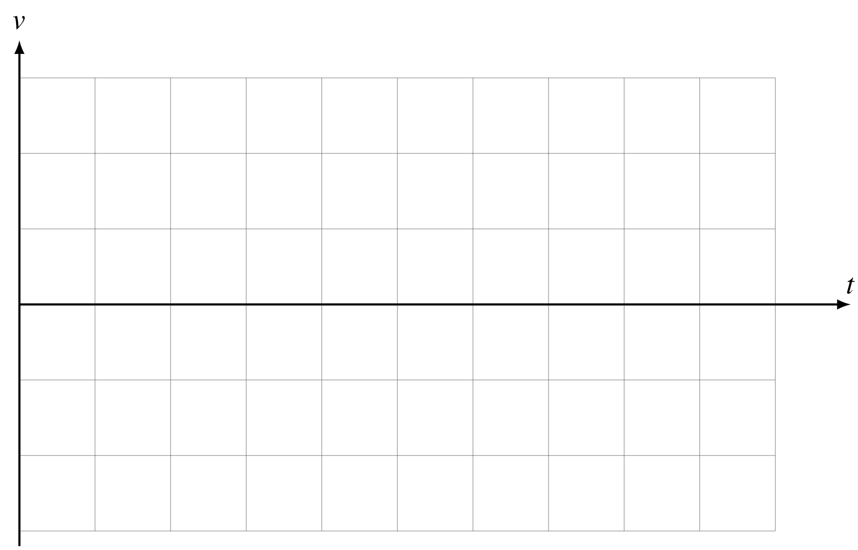
(e) At each of those points (from d above), is the acceleration positive, negative, or zero?

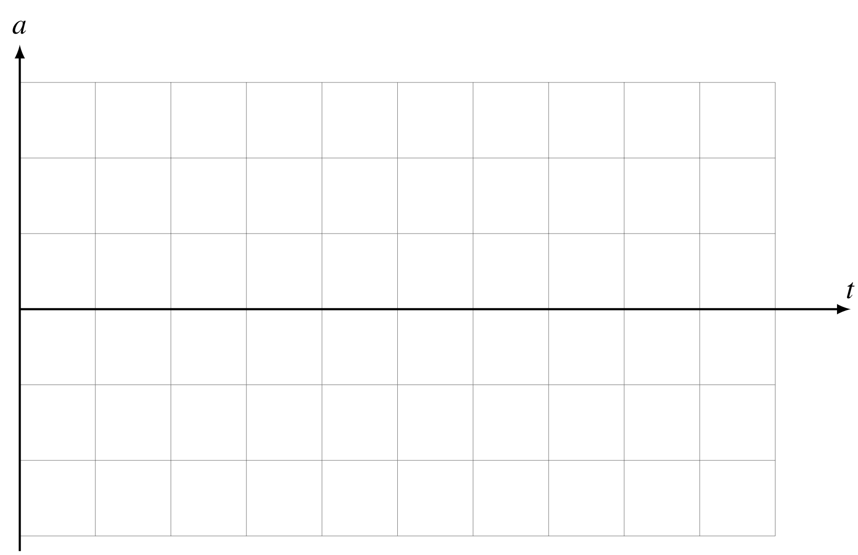
(f) During what intervals of time is the velocity of the object positive?

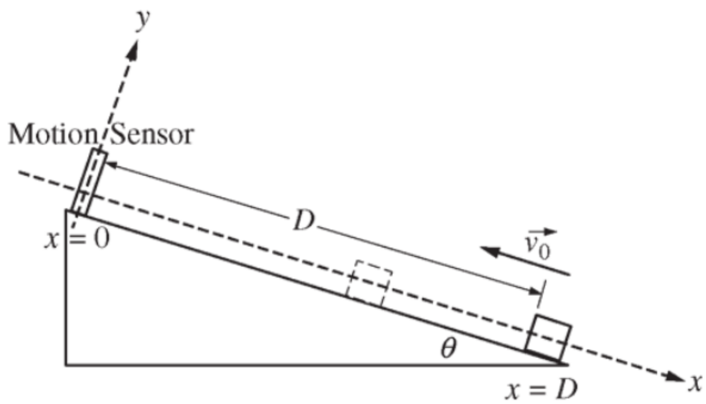
(g) During what intervals of time is the acceleration of the object positive?

(h) On the graph (on the next page), sketch position x, velocity v and acceleration a as functions of time.









14. 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.

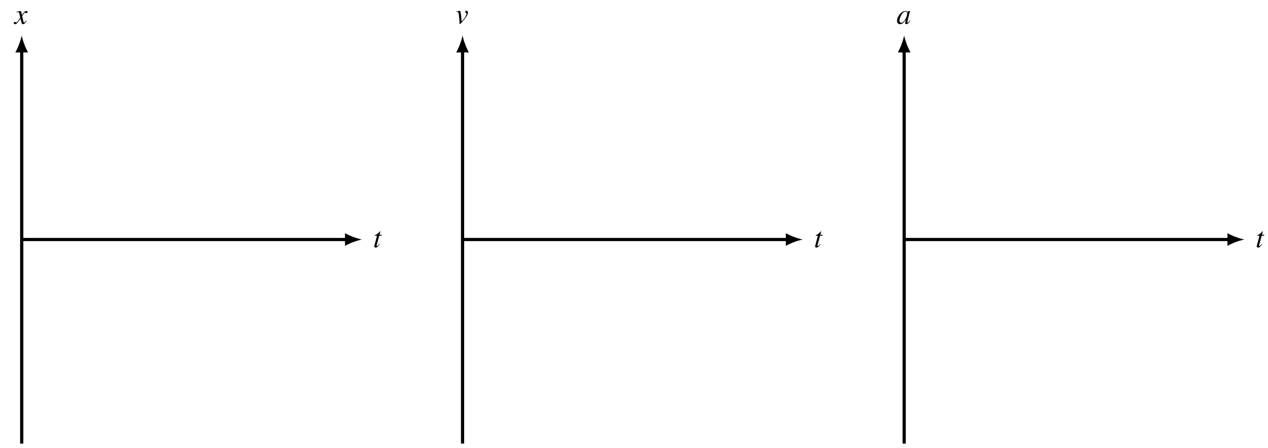
    i. Determine the acceleration a of the block.

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

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

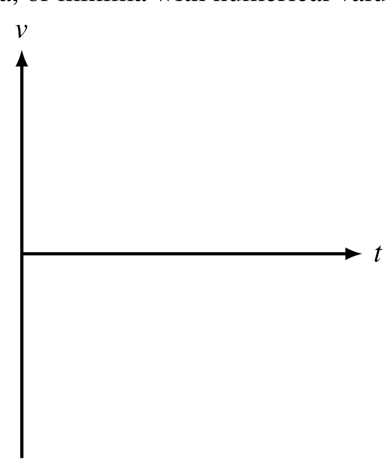
    (b) Derive an expression for the position x_{min} of the block when it is closest to the motion sensor. Express your answer in terms of m, D, v_0, θ, and physical constants, as appropriate.

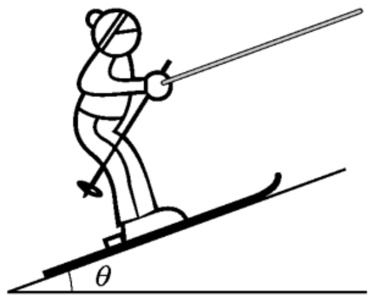
(c) On the axes provided below, sketch graphs of position x, velocity v, and acceleration a as functions of time t for the motion of the block while it goes up and back down the ramp. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



(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.





15. A skier of mass m will be pulled up a hill by a rope, as shown above. The magnitude of the acceleration of the skier as a function of time t can be modeled by the equations

$$a = a_{\text{max}} \sin\left(\frac{\pi t}{T}\right) \qquad (0 < t < T)$$
$$= 0 \qquad (t \geq T)$$

where a_{max} and T are constants. The hill is inclined at an angle θ above the horizontal, and friction between the skis and the snow is negligible. Express your answers in terms of given quantities and fundamental constants.

(a) Derive an expression for the velocity of the skier as a function of time during the acceleration. Assume the skier starts from rest.

(b) Derive an expression for the work done by the net force on the skier from rest until terminal speed is reached.

(c) Determine the magnitude of the force exerted by the rope on the skier at terminal speed.

(d) Derive an expression for the total impulse imparted to the skier during the acceleration.

(e) Suppose that the magnitude of the acceleration is instead modeled as $a = a_{max}e^{-\pi t/2T}$ for all $t > 0$, where a_{max} and T are the same as in the original model. On the axes below, sketch the graphs of the force exerted by the rope on the skier for the two models, from $t = 0$ to a time $t > T$. Label the original model F_1 and the new model F_2.