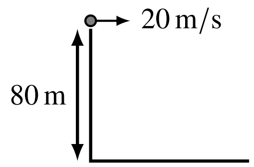
AP PHYSICS C: KINEMATICS

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

Questions 1–2

A ball of mass 0.5 kg is launched horizontally from the top of a cliff 80 m high with a speed of 20 m/s at time $t = 0$.



1. The horizontal distance x traveled by the ball before striking the ground is

   (A) 20 m
   (B) 40 m
   (C) 80 m
   (D) 160 m
   (E) 320 m

2. The speed of the ball just before striking the ground is

   (A) 4 m/s
   (B) 14 m/s
   (C) 20 m/s
   (D) 44 m/s
   (E) 64 m/s

3. A space explorer throws a tool downward on a planet with an initial velocity of 2.0 m/s from a height of 6 m above the surface. The tool strikes the surface in a time of 2 s. The acceleration due to gravity on the planet is

   (A) $1\,\text{m/s}^2$
   (B) $2\,\text{m/s}^2$
   (C) $3\,\text{m/s}^2$
   (D) $4\,\text{m/s}^2$
   (E) $10\,\text{m/s}^2$

Questions 4–5

A sprinter starting from rest runs a 100-meter race on a straight track. The sprinter covers the first 10 meters with a constant acceleration in 2 seconds. The sprinter runs the remaining 90 m with the same velocity he had at the end of 2 s.

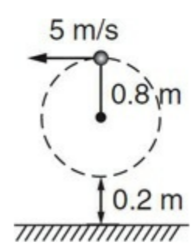
4. The sprinter's velocity at the end of the first 2 s is

   (A) 5 m/s
   (B) 10 m/s
   (C) 20 m/s
   (D) 40 m/s
   (E) 60 m/s

5. The total time it takes for the sprinter to run the full 100 m is

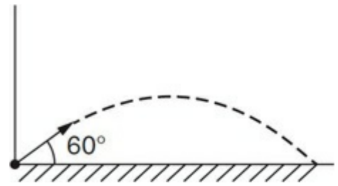
   (A) 2 s
   (B) 9 s
   (C) 10 s
   (D) 11 s
   (E) 12 s

6. A ball is attached to a string of length 0.8 m and is swung in a vertical circle. The bottom of the circle is 0.2 m above the floor. If the string breaks at the top of the circle when the speed of the ball is 5 m/s, the horizontal distance the ball travels before striking the floor is



   (A) 0.8 m
   (B) 2.3 m
   (C) 3.0 m
   (D) 5.0 m
   (E) 13.2 m

7. 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.

Questions 8–9

A particle moves on a horizontal surface with a constant acceleration of $6\,\mathrm{m/s^2}$ in the x-direction and $4\,\mathrm{m/s^2}$ in the y-direction. The initial velocity of the particle is 3 m/s in the x-direction.

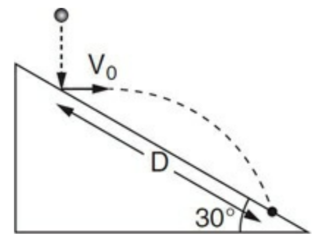
8. The speed of the particle after 4 s is

(A) 16 m/s
(B) 27 m/s
(C) 31 m/s
(D) 44 m/s
(E) 985 m/s

9. The displacement of the particle from its initial position is

(A) 16 m
(B) 32 m
(C) 60 m
(D) 68 m
(E) 92 m

10. A rubber ball is dropped from rest onto a plane angled at $\theta = 30°$ to the horizontal floor and bounces off the plane with a horizontal speed v_0. The ball lands on the plane a distance D along the plane, as shown below. In terms of v_0, D, and g, the speed of the ball just before striking the plane is

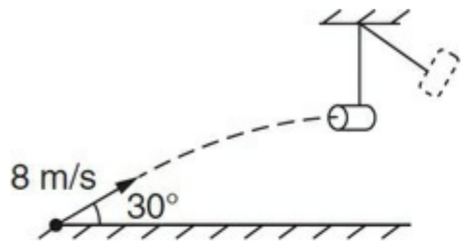


(A) v_0
(B) $\left(v_0^2 + 2D\sin\theta g\right)^{\frac{1}{2}}$
(C) $\left(v_0 + \dfrac{D\sin\theta}{g}\right)^{\frac{1}{2}}$
(D) $\left(v_0^2 + \dfrac{D\sin\theta}{g}\right)^{\frac{1}{2}}$
(E) $(2D\sin\theta g)^{\frac{1}{2}}$

11. 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

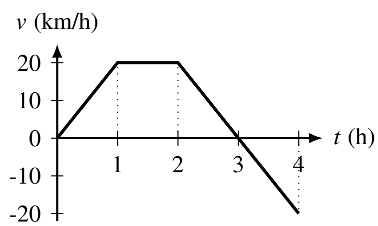
(A) $-kv^2$
(B) $-12kv^2$
(C) $-k$
(D) $\ln(kt)$
(E) v_0e^{-kt}

12. A small ball is launched with a speed of 8 m/s at an angle of 30° from the horizontal. A cup is hung so that it is in position to catch the ball when it reaches its maximum height. How far above the floor should the cup be hung to catch the ball?



(A) 2.4 m
(B) 1.6 m
(C) 1.0 m
(D) 0.8 m
(E) 0.4 m

13. The velocity vs. time graph below represents the motion of a bicycle rider. The displacement of the rider between 0 and 4 h is



(A) +10 km
(B) +20 km
(C) +30 km
(D) +40 km
(E) −10 km

Questions 14–15
A car of mass m travels along a straight horizontal road. The car begins with a speed v_0, but accelerates according to the velocity function $v = \left(v_0^2 + \frac{Ct^2}{m}\right)$, where t is time.

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

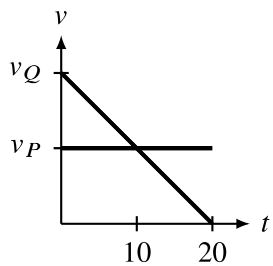
(A) zero
(B) $2t$
(C) $4t$
(D) $\sqrt{8t}$
(E) The speed of the car is never zero.

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

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

Questions 16–17

The graph shown below represents the velocity vs. time graphs for two cars, P and Q. Car P begins with a speed v_P, and Car Q begins with a speed v_Q which is twice the velocity of Car P, that is, $v_Q = 2v_P$. Both car starts at the same position at $t = 0$.



16. Which of the following is true at a time of 10 s?

(A) The cars occupy the same position.
(B) Car P is at rest.
(C) $v_Q > v_P$
(D) $v_P > v_Q$
(E) Car Q is ahead of Car P.

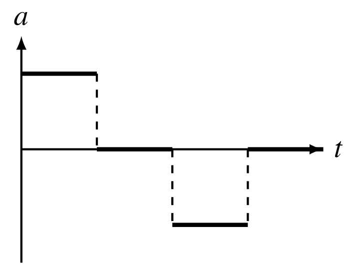
17. Which of the following is true at a time of 20 s?

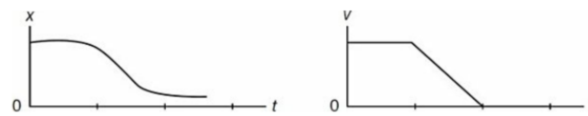
(A) The cars occupy the same position.
(B) Car P is at rest.
(C) $v_Q > v_P$
(D) $a_P = a_Q$
(E) Car P is ahead of Car Q.

18. A car is initially moving with a positive velocity of 20 m/s when it passes the origin at time $t = 0$. The car continues to move at 20 m/s between $t = 0$ and $t = 2$ s. At $t = 2$ s, the driver presses the brake, giving the car an acceleration of $-4\ \text{m/s}^2$. The displacement of the car at $t = 6$ s is

(A) 40 m
(B) 32 m
(C) 48 m
(D) 64 m
(E) 88 m

19. 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)


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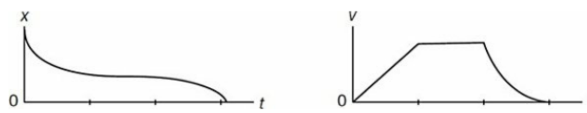

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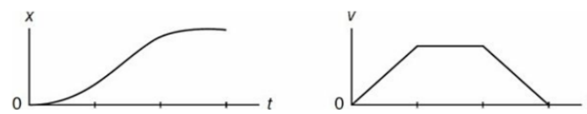

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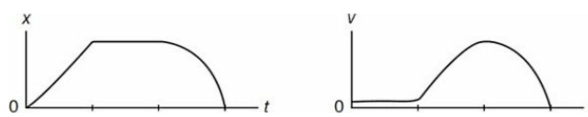
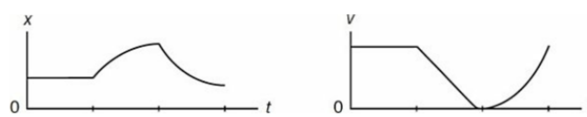
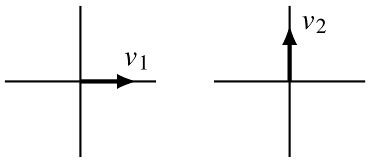


(E)


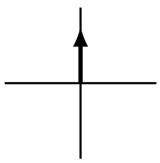
20. A small airplane can fly at 200 km/h with no wind. The pilot of the plane would like to fly to a destination 100 km due north of his present position, but there is a crosswind of 50 km/h east. How much time is required for the plane to fly north to its destination?

(A) less than 1/2 h
(B) 1/2 h
(C) more than 1/2 h
(D) 1 h
(E) more than 1 h

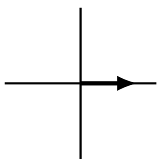
21. Two velocity vectors v_1 and v_2 each have a magnitude of 10 m/s. Graph 1 shows the velocity v_1 at $t = 0$ s, and then the same object has a velocity v_2 at $t = 2$ s, shown in Graph 2. Which of the following vectors best represents the average acceleration vector that causes the object's velocity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



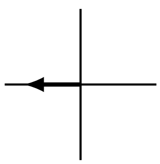
Graph 1 Graph 2



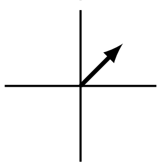
(A)



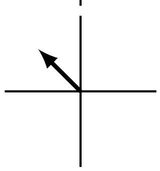
(B)



(C)



(D)

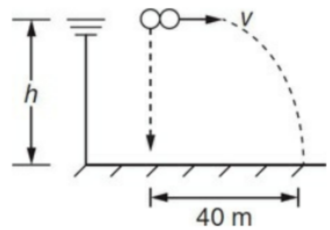


(E)

22. 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

23. A ball is dropped from rest from the top of a cliff 80 meters high. At the same time, a rock is thrown horizontally from the top of the same cliff. The rock and ball hit the level ground below a distance of 40 m apart. The horizontal velocity of the rock that was thrown was most nearly



(A) 5 m/s
(B) 10 m/s
(C) 20 m/s
(D) 40 m/s
(E) 80 m/s

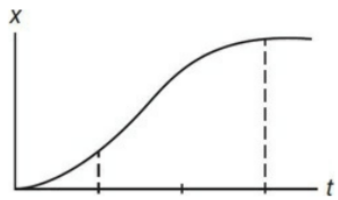
24. A ball is hit straight up into the air with an upward positive velocity. Wich of the following describes the velocity and acceleration of the ball at the instant it reaches the top of its flight?

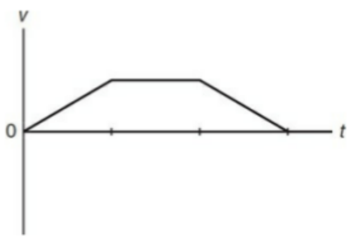
	Velocity	Acceleration
(A)	0	0
(B)	0	g
(C)	$2v_0$	g
(D)	$\frac{1}{2}v_0$	0
(E)	0	$\frac{1}{2}g$

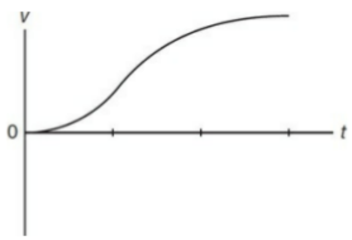
25. A toy dart gun fires a dart at an angle of 45° to the horizontal and the dart reaches a maximum height of 1 meter. If the dart were fired straight up into the air along the vertical, the dart would reach a height of

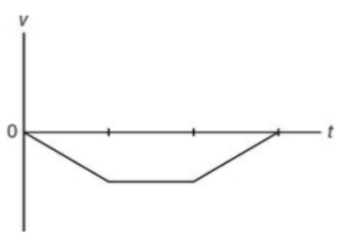
(A) 1 m
(B) 2 m
(C) 3 m
(D) 4 m
(E) 5 m

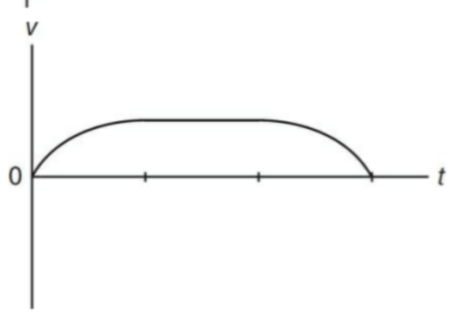
26. The graph below shows the displacement as a function of time for a car moving in a straight line. Which of the following graphs shows the velocity vs. time graph for the same time intervals?

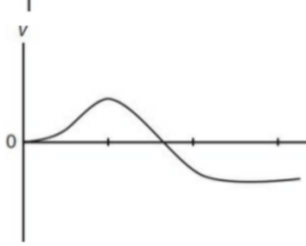


(A)


(B)


(C)


(D)


(E)


Questions 27–28

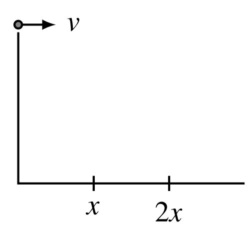
27. An object is released from rest and falls through a resistive medium. The resistance causes the velocity of the object to change according to the equation $v = 16t - \frac{1}{2}t^4$, where v is in m/s and time is in s. Which of the following is a possible equation for the acceleration of the object as a function of time?

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

28. 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.

29. A student jumps off a cliff with an initial horizontal velocity v and lands in a lake below at a distance of x from the base of the cliff. In terms of his initial velocity v, how fast would he have had to jump to land a distance $2x$ from the base of the cliff?



(A) $\sqrt{2}v$
(B) $2v$
(C) $4v$
(D) $8v$
(E) $16v$

30. An astronaut drops a hammer on a moon with no atmosphere. The hammer falls a distance of 2 meters in the first second. What is the acceleration due to gravity on this moon?

(A) $1\,m/s^2$
(B) $2\,m/s^2$
(C) $3\,m/s^2$
(D) $4\,m/s^2$
(E) $8\,m/s^2$

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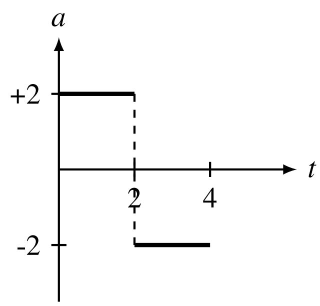
31. The motion of an object is represented by the acceleration vs. time graph below. The object begins from rest. Which of the following statements is true about the motion of the object?



(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.

AP PHYSICS C: KINEMATICS
SECTION II
5 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

1. An object has a position vector given by $\mathbf{r} = 30t\hat{\imath} + (40t - 5t^2)\hat{\jmath}$. Find
   (a) its intantaneous velocity and acceleration vectors as functions of time
   (b) its displacement after $t = 3$ s. → from $t=0 \to 3$

a) $\vec{v} = \frac{d\vec{r}}{dt} = 30\hat{\imath} + (40 - 10t)\hat{\jmath}$

$\vec{a} = \frac{d\vec{v}}{dt} = -10\hat{\jmath}$

b) $\Delta\vec{r} = \vec{r}(3) - \vec{r}(0) = \vec{r}(3)$

2. The position x of an object is described with respect to time t by the following equation: $x = 2t^3 - 15t^2 + 36t - 8$. Answer the following questions.
   (a) Find its displacement between $t = 3$ and 5 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 2d 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.

1D

$x(5) = 2(5^3) - 15(5^2) + 36(5) - \cancel{8}$
$- \; x(3) = 2(3^3) - 15(3^2) + 36(3) - \cancel{8}$
$2(5^3 - 3^3) - 15(5^2 - 3^2) + 36(5-3)$

a) $x(5) - x(3) = \_\_\_$

b) $v = \frac{dx}{dt} = 6t^2 - 30t + 36$

c) $a = \frac{dv}{dt} = 12t - 30$

d) $6t^2 - 30t + 36 = 0 \to t = t_1, t_2$

e) $12t - 30 = \_\_\_$

f) $-\; | \; - \; | \; -$
$t_1 \quad t_2$

g) $12t - 30 = 0$
$t = \_\_\_$

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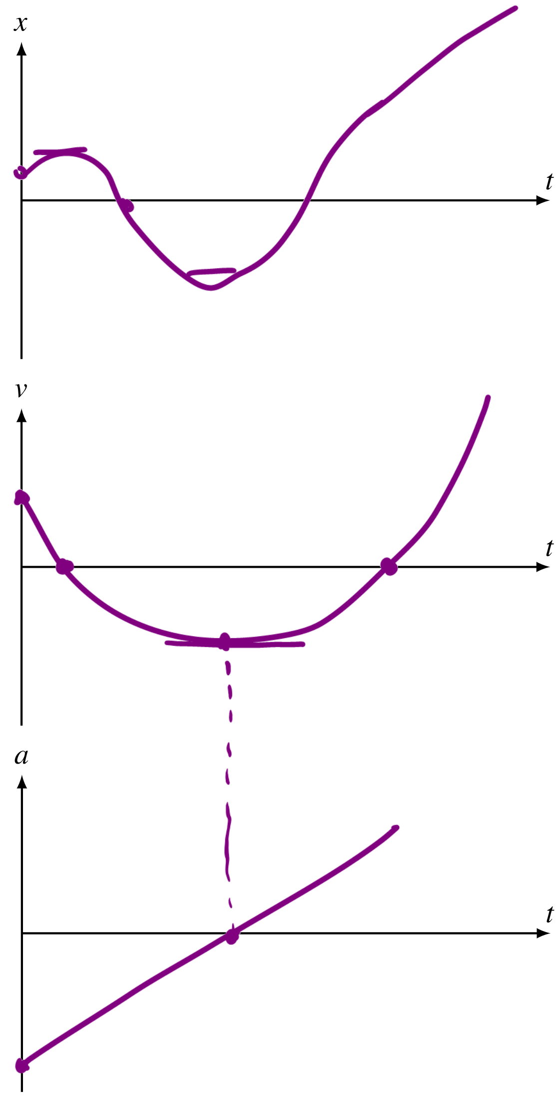
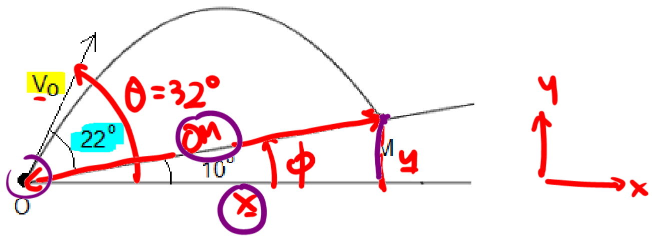


intercepts ?

3. A projectile is launched from point O at an angle of 22° with an initial velocity of 15 m/s up an incline plane that makes an angle of 10° with the horizontal. The projectile hits the incline plane at point M.

accel. due to gravity
$-g = -10\,m/s^2$ or 9.81



(a) Find the time it takes for the projectile to hit the incline plane.
(b) Find the distance OM.

a) $x = V_0 \cos\theta\, t$

$y = V_0 \sin\theta\, t - \frac{1}{2} g t^2$

$\frac{y}{x} = \tan\phi$

$t = \frac{x}{V_0 \cos\theta}$

$\cancel{x} \tan\phi = \cancel{V_0} \sin\theta \frac{\cancel{x}}{\cancel{V_0} \cos\theta} - \frac{1}{2} g \left(\frac{x^2}{V_0^2 \cos^2\theta}\right)$

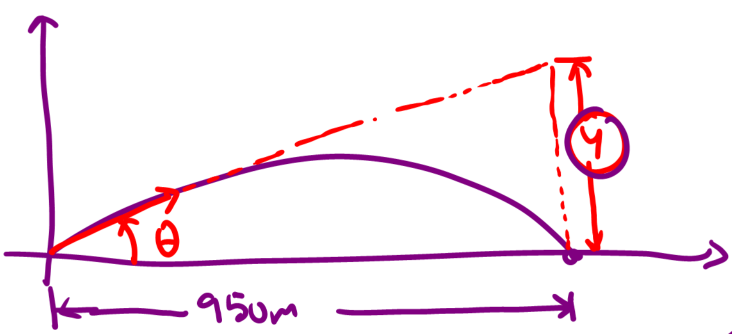
$\tan\phi = \tan\phi - \frac{g}{V_0^2 \cos^2\theta} x$

$x =$ ___ $\longrightarrow t = \frac{x}{V_0 \cos\theta} =$ ___

b) $OM \cos\phi = x$

$OM = \frac{x}{\cos\phi} =$ ___

4. A high-powered rifle shoots bullets that leave the muzzle at 1.1×10^3 m/s. If a bullet is to hit a target 950 m away at the level, the gun must be aimed at a point above the target. Neglecting air resistance, how far above the target is this point?



$\boxed{R = \frac{V_0^2 \sin 2\theta}{g}}$

$\theta_1 = \frac{1}{2} \sin^{-1}\left(\frac{Rg}{V_0^2}\right) = 0.22°$??

$\theta_2 = 90 - \theta_1 =$ ___ ✗

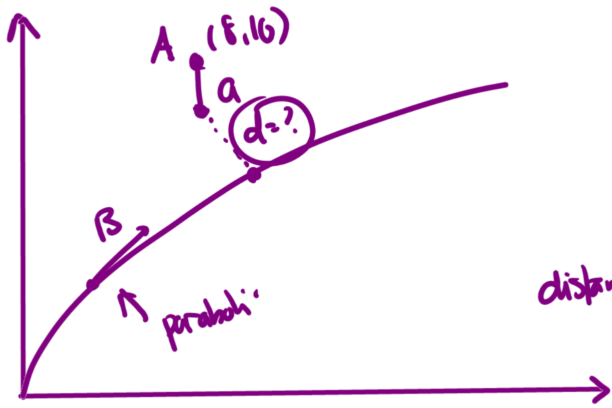
not practical

$\tan\theta = \frac{y}{950}$ $y = 950 \tan\theta =$ ___

5. A steel ball is dropped from a point with (x, y) coordinate of $(8\,\text{m}, 16\,\text{m})$. At the same time, another ball is launched from the origin with a speed of $20\,\text{m/s}$ at an angle of $30°$.

   (a) Find the minimum distance of separation occur of the two balls.
   (b) At what time does this separation occur?
   (c) Give the coordinates of the two balls for the minimum separation.

$g = 10\,\text{m/s}^2$

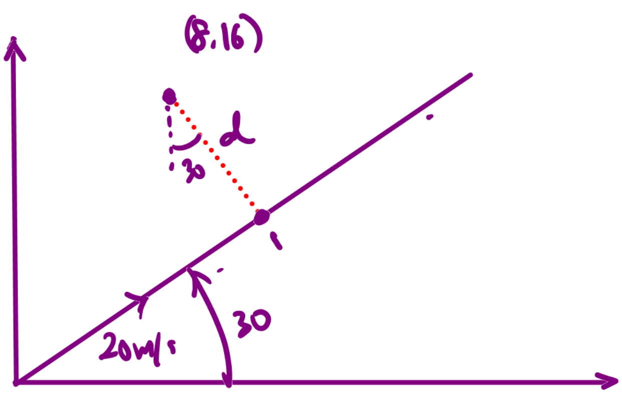


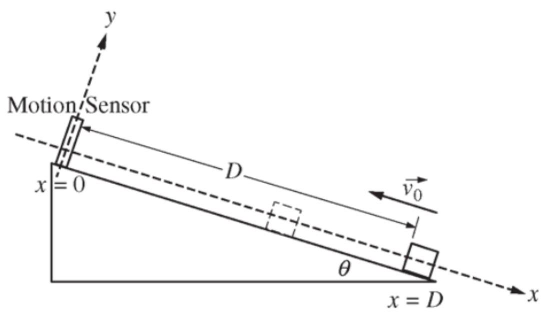
$$\vec{x}_A(t) = 8\hat{i} + (16 - 5t^2)\hat{j}$$

$$\vec{x}_B(t) = (20\cos 30° t)\hat{i} + (20\sin 30° t - 5t^2)\hat{j}$$

distance → $F(t) = |x_B(t) - x_A(t)|^2 =$

$\frac{dF}{dt} = 0 \to t,\ F(t) =$





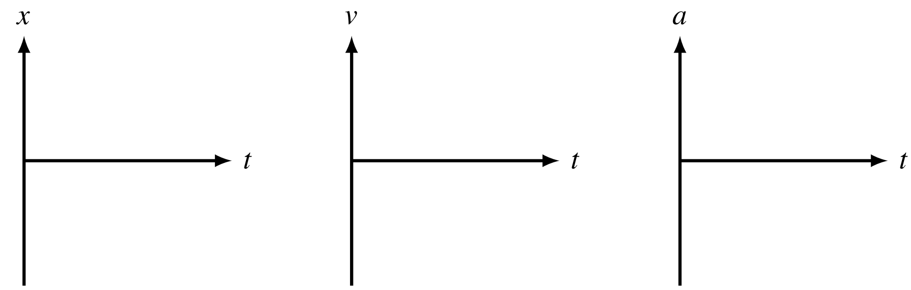
6. A block of mass m is projected up from the bottom of an inclined ramp with an initial velocity of magnitude v_0. The ramp has negligible friction and makes an angle θ with the horizontal. A motion sensor aimed down the ramp is mounted at the top of the incline so that the positive direction is down 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.