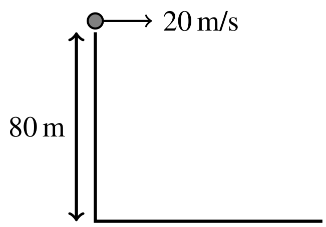
AP PHYSICS 1 & C: KINEMATICS AND DYNAMICS
(Topics 1 & 2)

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 $g = 10\,\mathrm{m/s^2}$ in all problems.

Questions 1-2

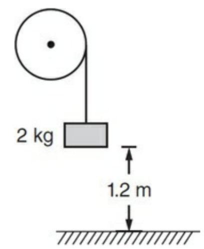
A ball of mass 0.5 kg is launched horizontally from the top of a cliff 80 m high with a speed of 20 m/s at time $t = 0$.



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

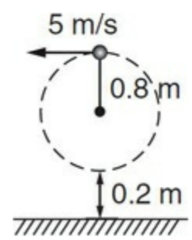
2. The speed of the ball just before striking the ground is
   - (A) 4 m/s
   - (B) 14 m/s
   - (C) 20 m/s
   - (D) 44 m/s
   - (E) 64 m/s

3. A block of mass 2 kg is attached to a string that is wrapped around a pulley of negligible mass and allowed to descend from rest a vertical distance of 1.2 m in a time of 1.5 s. The acceleration of the block is most nearly



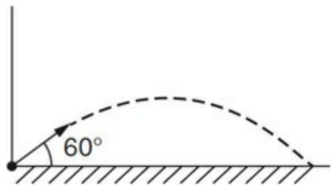
   - (A) 0.2 m/s^2
   - (B) 0.6 m/s^2
   - (C) 1.1 m/s^2
   - (D) 1.4 m/s^2
   - (E) 1.5 m/s^2

4. 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



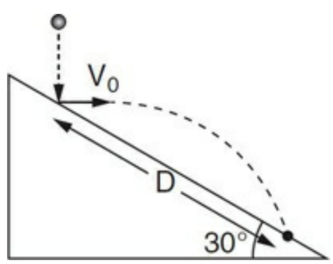
   - (A) 0.8 m
   - (B) 2.3 m
   - (C) 3.0 m
   - (D) 5.0 m
   - (E) 13.2 m

5. 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.

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

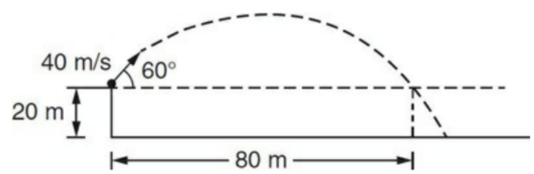


(A) v_o
(B) $\left(v_o^2 + 2D\sin\theta g\right)^{\frac{1}{2}}$
(C) $\left(v_o + \dfrac{D\sin\theta}{g}\right)^{\frac{1}{2}}$
(D) $\left(v_o^2 + \dfrac{D\sin\theta}{g}\right)^{\frac{1}{2}}$
(E) $(2D\sin\theta g)^{\frac{1}{2}}$

7. A space explorer throws a tool downward on a planet with an initial velocity of 2 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 m/s^2
(B) 2 m/s^2
(C) 3 m/s^2
(D) 4 m/s^2
(E) 10 m/s^2

8. A projectile is launched from a platform 20 m high above level ground. The projectile is launched with a velocity of 40 m/s at an angle of 60° above the horizontal. The projectile follows a parabolic path and reaches its original height at a horizontal distance of 80 m, but moves past the height of the cliff to strike the ground below. The total time from the launch until it strikes the ground is



(A) 2 s
(B) 4 s
(C) 6 s
(D) 9 s
(E) 10 s

9. 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}

Questions 10-11

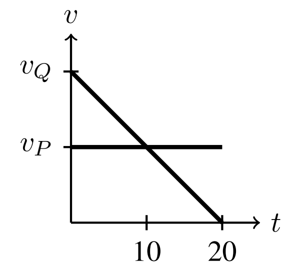
A car of mass m travels along a straight horizontal road. The car begins with a speed v_0^2, but accelerates according to the velocity function $v = \left(v_0^2 + \dfrac{Ct^2}{m}\right)$, where t is time, and C is positive.

10. 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.

11. The acceleration of the car as a function of time is
    (A) $\left(v_0^2 + \dfrac{Ct^2}{m}\right)$
    (B) $\left(v_0^2 + \dfrac{2Ct^2}{m}\right)$
    (C) $\left(v_0 + \dfrac{Ct}{m}\right)$
    (D) $\left(\dfrac{2Ct}{m}\right)$
    (E) $\left(\dfrac{2Ct^2}{m}\right)$

Questions 12-13

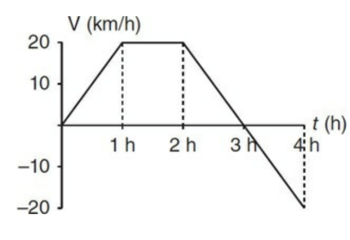
The graph shown below represents the velocity vs. time graphs for two cars, P and Q. Car P begins with a speed v_P, and Car Q begins with a speed v_Q which is twice the velocity of Car P, that is, $v_Q = 2v_P$. Both cars start from the same position.



12. 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.

13. 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.

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

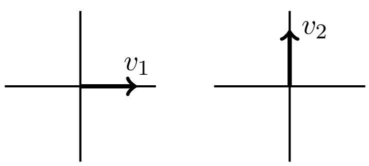


    (A) +10 km
    (B) +20 km
    (C) +30 km
    (D) +40 km
    (E) -10 km

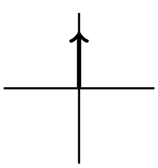
15. A small airplane can fly at 200 km/h with no wind. The pilot of the plane would like to fly to a destination 100 km due north of his present position, but there is a crosswind of 50 km/h east. How much time is required for the plane to fly north to its destination?

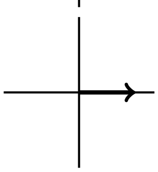
(A) less than 1/2 h
(B) 1/2 h
(C) more than 1/2 h
(D) 1 h
(E) more than 1 h

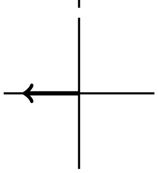
16. Two velocity vectors v_1 and v_2 each have a magnitude of 10 m/s. Graph 1 shows the velocity v_1 at $t = 0$ s, and then the same object has a velocity v_2 at $t = 2$ s, shown in Graph 2. Which of the following vectors best represents the average acceleration vector that causes the object's velocity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

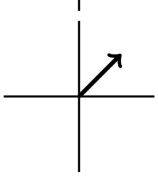


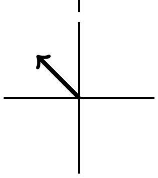
Graph 1 Graph 2

(A) 

(B) 

(C) 

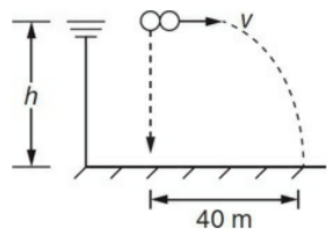
(D) 

(E) 

17. 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 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

18. 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

19. A stone is dropped near the surface of Mars and falls with an acceleration of 3.8 m/s^2. This means that the

(A) distance the stone falls increases 3.8 meters for each second of fall
(B) derivative of the distance fallen with respect to time is 3.8 m/s
(C) derivative of the velocity with respect to time is 3.8 m/s^2
(D) velocity is constant at 3.8 m/s
(E) derivative of the acceleration is 3.8 m/s^2

20. A passenger on a train moving horizontally at a constant speed relative to the ground drops a ball from his window. A stationary observer on the ground sees the ball falling with a speed v_1 at an angle to the vertical at the instant it is dropped from the train window, but the ball appears to be falling vertically with a speed v_2 at the same instant as viewed by the train passenger. What is the speed (magnitude of velocity) of the train relative to the ground after the ball is dropped? Neglect air resistance.

(A) $v_1 + v_2$
(B) $v_1 - v_2$
(C) $v_1^2 + v_2^2$
(D) $v_1^2 - v_2^2$
(E) $\sqrt{v_1^2 - v_2^2}$

21. 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

Questions 22-23

22. 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) $32t^3 - 2t^5$

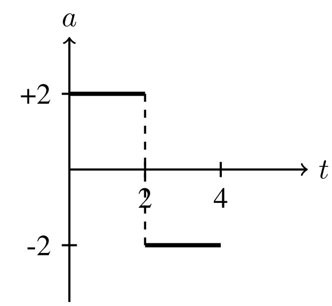
23. What is the terminal velocity of the object as it falls?

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

24. 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

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

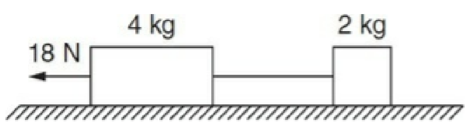


(A) The object returns to its original position.
(B) The velocity of the object is zero at a time of 2 s.
(C) The velocity of the object is zero at a time of 4 s.
(D) The displacement of the object is zero at a time of 4 s.
(E) The acceleration of the object is zero at a time of 2 s.

26. A small moving block collides with a large block at rest. Which of the following is true of the forces the blocks apply to each other
    (A) The small block exerts twice the force on the large block compared to the force the large block exerts on the small block.
    (B) The small block exerts half the force on the large block compared to the force the large block exerts on the small block.
    (C) The small block exerts exactly the same amount of force on the large block that the large block exerts on the small block.
    (D) The large block exerts a force on the small block, but the small block does not exert a force on the large block.
    (E) The small block exerts a force on the large block, but the large block does not exert a force on the small block.

Questions 27-28

Two blocks, 4.0 kg and 2.0 kg, are connected by a string. An applied force F of magnitude 18 N pulls the blocks to the left.

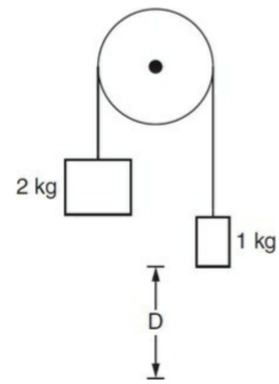


27. The acceleration of the 4.0 kg block is
    (A) $2.0\,\text{m/s}^2$
    (B) $3.0\,\text{m/s}^2$
    (C) $4.0\,\text{m/s}^2$
    (D) $4.5\,\text{m/s}^2$
    (E) $6.0\,\text{m/s}^2$

28. The tension in the string between the blocks is
    (A) 4.0 N
    (B) 6.0 N
    (C) 12 N
    (D) 16 N
    (E) 18 N

Questions 29-30

A system consists of two blocks having masses of 2 kg and 1 kg. The blocks are connected by a string of negligible mass and hung over a light pulley, and then released from rest.

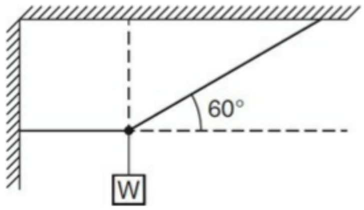


29. The acceleration of the 2 kg block is most nearly
    (A) $\frac{2}{9}g$
    (B) $\frac{1}{3}g$
    (C) $\frac{1}{2}g$
    (D) $\frac{2}{3}g$
    (E) g

30. The speed of the 2 kg block after it has descended a distance D is most nearly
    (A) $\sqrt{\frac{4gD}{3}}$
    (B) $\sqrt{\frac{2gD}{3}}$
    (C) $\sqrt{\frac{gD}{3}}$
    (D) $\sqrt{\frac{gD}{2}}$
    (E) $\sqrt{\frac{4gD}{6}}$

Questions 31-32

A weight of magnitude W is suspended in equilibrium by two cords, one horizontal and one slanted at an angle of $60°$ from the horizontal, as shown.



31. Which of the following statements is true?
    - (A) The tension in the horizontal cord must be greater than the tension in the slanted cord.
    - (B) The tension in the slanted cord must be greater than the tension in the horizontal cord.
    - (C) The tension is the same in both cords.
    - (D) The tension in the horizontal cord equals the weight W.
    - (E) The tension in the slanted cord equals the weight W.

32. The tension in the horizontal cord is
    - (A) equal to the tension in the slanted cord
    - (B) one-third as much as the tension in the slanted cord
    - (C) one-half as much as the tension in the slanted cord
    - (D) twice as much as the tension in the slanted cord
    - (E) three times as much as the tension in the slanted cord

Questions 33-34

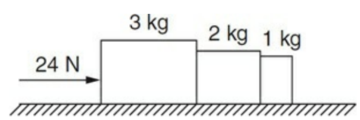
An object of mass m moves along a straight line with a speed described by the equation $v = c + bt^3$.

33. The initial velocity of the mass is
    - (A) c
    - (B) $ct + bt^3$
    - (C) $ct + bt^4$
    - (D) bt^2
    - (E) bt

34. The net force acting on the mass at time T is
    - (A) $3mbT$
    - (B) $3mbT^2$
    - (C) $3mbT^3$
    - (D) $mc + 2mbT^2$
    - (E) $mc^2 + 4mbT^4$

Questions 35-36

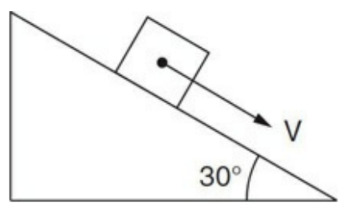
Three blocks of mass 3 kg, 2 kg, and 1 kg are pushed along a horizontal frictionless plane by a force of 24 N to the right, as shown.



35. The acceleration of the 2 kg block is
    - (A) 144 m/s^2
    - (B) 72 m/s^2
    - (C) 12 m/s^2
    - (D) 6 m/s^2
    - (E) 4 m/s^2

36. The force that the 2 kg block exerts on the 1 kg block is
    - (A) 2 N
    - (B) 4 N
    - (C) 6 N
    - (D) 24 N
    - (E) 144 N

37. A block of mass 4 kg slides down a rough incline with a constant speed. The angle the incline makes with the horizontal is 30°. The coefficient of friction acting between the block and incline is most nearly



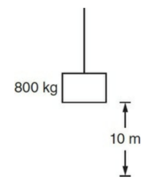
(A) 0.1
(B) 0.2
(C) 0.3
(D) 0.4
(E) 0.6

38. A ball is thrown straight up into the air, encountering air resistance as it rises. What forces, if any, act on the ball as it rises?

(A) A decreasing gravitational force and an increasing force of air resistance
(B) An increasing gravitational force and an increasing force of air resistance
(C) A decreasing gravitational force and a decreasing force of air resistance
(D) A constant gravitational force and an increasing force of air resistance
(E) A constant gravitational force and a decreasing force of air resistance

Questions 39-40

An 800 kg elevator is supported by a vertical cable.



39. The cable has a tension of 10,000 N as it accelerates the elevator upward from rest to a height of 10 m. The acceleration of the elevator is most nearly

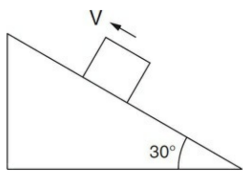
(A) 1.0 m/s^2
(B) 2.0 m/s^2
(C) 2.5 m/s^2
(D) 3.5 m/s^2
(E) 4.0 m/s^2

40. The elevator passes the 10 m height on the way up, stops, then begins its descent downward, having an initial velocity as it passes the 10 m height on the way down. If the tension in the cable is now 6000 N, and it comes to rest just before reaching the ground, the initial velocity at the 10 m height must have been most nearly

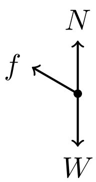
(A) 5.0 m/s
(B) 7.0 m/s
(C) 29.5 m/s
(D) 12.5 m/s
(E) 16.0 m/s

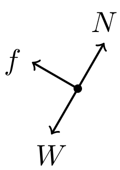
Questions 41-42

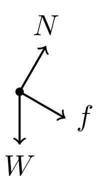
A 1 kg block is sliding up a rough 30° incline and is slowing down with an acceleration of −6 m/s^2. The mass has a weight **W**, and encounters a frictional force **f** and a normal force **N**.

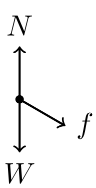


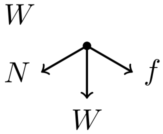
41. Which of the following free body diagrams best represents the forces acting on the block as it slides up the plane?

(A) 

(B) 

(C) 

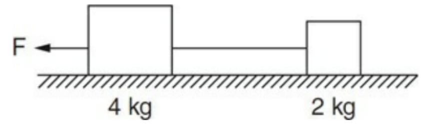
(D) 

(E) 

42. The magnitude of the frictional force f between the block and the plane is most nearly

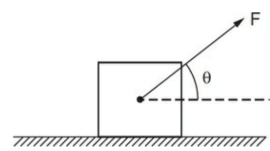
(A) 1 N
(B) 2 N
(C) 3 N
(D) 4 N
(E) 5 N

43. Two blocks are pulled by a force of magnitude F along a level surface with negligible friction as shown. The tension in the string between the blocks is



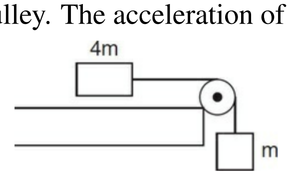
(A) $\frac{1}{4}F$
(B) $\frac{1}{2}F$
(C) $\frac{1}{3}F$
(D) F
(E) $2F$

44. A force of magnitude F pulls up at an angle θ to the horizontal on a block of mass m. The mass remains in contact with the level floor and the coefficient of friction between the block and the floor is μ. The frictional force between the floor and the block is



(A) μmg
(B) $\mu(mg - F\sin\theta)$
(C) $\mu(mg + F\sin\theta)$
(D) $\mu(mg - F\cos\theta)$
(E) $\mu(mg + F\cos\theta)$

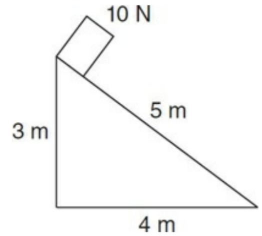
45. A block of mass $4m$ can move without friction on a horizontal surface. Another block of mass m is attached to the larger block by a string that is passed over a light pulley. The acceleration of the system is



(A) $\frac{1}{5}g$
(B) $\frac{1}{2}g$
(C) $\frac{2}{3}g$
(D) g
(E) $5g$

Questions 46-47

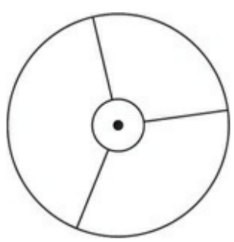
A 10 N block sits atop an inclined plane in the shape of a right triangle of sides 3 m, 4 m, and 5 m, as shown. The block is allowed to slide down the plane with negligible friction.



46. The acceleration of the block is most nearly
    - (A) $2\,m/s^2$
    - (B) $4\,m/s^2$
    - (C) $6\,m/s^2$
    - (D) $10\,m/s^2$
    - (E) $12\,m/s^2$

47. The normal force exerted on the block by the plane is most nearly
    - (A) 2 N
    - (B) 4 N
    - (C) 6 N
    - (D) 8 N
    - (E) 10 N

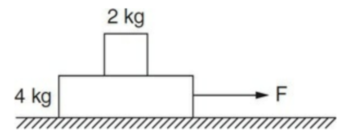
48. Three strings are attached to a ring in the center of a force table. The top view of the force table is shown. For the ring to remain in the center of the table, which of the following must be true?



- (A) The vector sum of the three forces must equal zero.
- (B) The lengths of the strings must be equal.
- (C) The strings must form an angle of 90° relative to each other.
- (D) The magnitudes of two of the tensions in the strings must equal the tension in the third string.
- (E) The tension in each string must be equal to each other.

Questions 49-50

A block of mass 2 kg rests on top of a larger block of mass 4 kg. The larger block slides without friction on a table, but the surface between the two blocks is not frictionless. The coefficient of friction between the two blocks is 0.2. A horizontal force **F** is applied to the 4 kg mass.



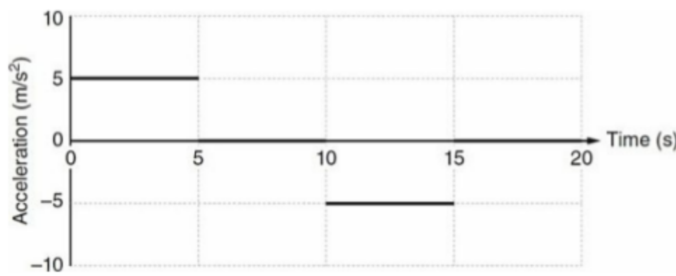
49. What is the maximum force that can be applied such that there is no relative motion between the two blocks?
    - (A) zero
    - (B) 1 N
    - (C) 2 N
    - (D) 4 N
    - (E) 12 N

50. What is the acceleration of the 2 kg block relative to the 4 kg block if a force is applied to the 4 kg block that causes the 4 kg block to accelerate at $3\,m/s^2$ to the right?
    - (A) $1\,m/s^2$ to the right
    - (B) $1\,m/s^2$ to the left
    - (C) $2\,m/s^2$ to the right
    - (D) $2\,m/s^2$ to the left
    - (E) zero

AP PHYSICS 1 & C: KINEMATICS & DYNAMICS
SECTION II
8 Questions

Directions: Answer all questions. The suggested time is about 10 minutes for answering each of the 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.

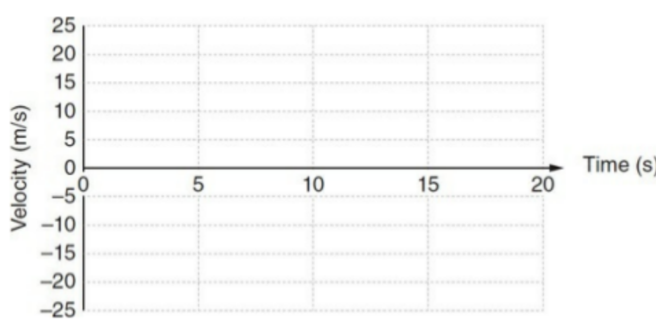
1. The acceleration vs. time graph shows the motion of an elevator during a 20-second time interval. The elevator starts from rest at time $t = 0$.



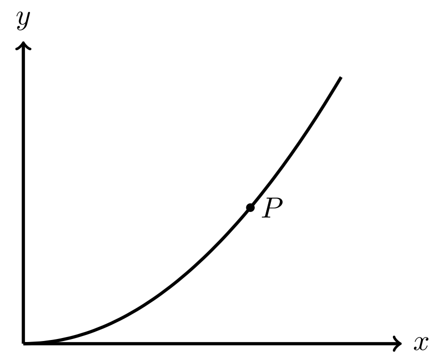
(a) Determine the instantaneous velocity of the elevator at the end of 10 s.

(b) Determine the displacement of the elevator after 5 s.

(c) On the axes below, sketch the graph that represents the velocity vs. time graph for the elevator for the 20-second time interval.



2. A particle follows a parabolic path with the equation $y = 2x^2$ as shown. The x-component of the particle's position is given by $x = 3t^2$.



(a) Determine the y-component of the particle's velocity v_y as a function of time.
(b) On the diagram above, sketch arrows to represent the horizontal and vertical components of the particle's acceleration at point P.

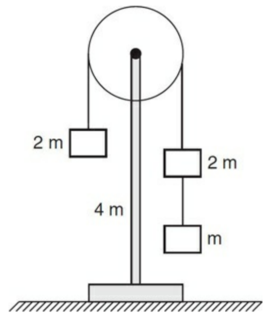
3. Given an object whose displacement is given by $x(t) = 2t^2 - 3t^3$, find

(a) Its average velocity between $t = 2\,\text{s}$ and $t = 5\,\text{s}$.
(b) Its instantaneous velocity at $t = 2\,\text{s}$.
(c) Its acceleration at $t = 2\,\text{s}$.
(d) If its mass is $2\,\text{kg}$, find the net force on this object as a function of time.

4. An object moves on a plane as $\mathbf{d}(t) = 2t^2\hat{\boldsymbol{\imath}} + \dfrac{1}{t}\hat{\boldsymbol{\jmath}}$ for $t \geq 2\,\mathrm{s}$. Find
   (a) its displacement at $t = 3\,\mathrm{s}$.
   (b) its velocity and speed at $t = 3\,\mathrm{s}$.
   (c) its acceleration as a function of time and the magnitude of the acceleration.

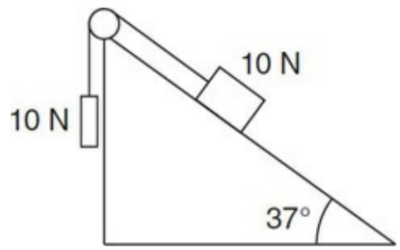
5. An object has velocity $v(t) = t^2 - 2t$ for $t \geq 0$:
   (a) Describe its motion.
   (b) Find its displacement in 5 s.
   (c) Find its displacement between 3 and 5 s.

6. Three masses are connected by two strings as shown. One of the strings is passed over a pulley of negligible mass and friction. The pulley is attached to a stand that rests on a table. The smallest mass is m, the other two masses each have a mass of $2m$, and the mass of the stand is $4m$.



   (a) If the small mass m is removed, the other two masses hang in equilibrium. Determine the normal force the table exerts on the stand when the system is in equilibrium.
   (b) The small mass m is once again hung below one of the masses of mass $2m$. Determine the acceleration of the system.
   (c) Determine the tension in the string between the block of mass $2m$ and the attached block of mass m while the system is accelerating.
   (d) While the system is accelerating, is the normal force exerted by the table on the stand greater than, equal to, or less than $8mg$? Justify your answer.

7. Two blocks weighing 10 N each are connected by a light string that is passed over a light pulley. One of the blocks rests on an inclined plane at an angle of 37° to the horizontal. The friction between the inclined plane and the block is such that the system remains at rest. The length of the ramp is 5 m.



(a) Determine the tension in the string while the system is at rest.

(b) Determine the frictional force between the block and the inclined plane while the system is at rest.

(c) If the string is suddenly cut, what is the speed of the block when it reaches the bottom of the plane?

8. Two blocks of mass m and M are connected via pulley with a configuration as shown on the right. The coefficient of static friction between the left block and the surface is $\mu_{s,1}$, and the coefficient of static friction between the right block and the surface is $\mu_{s,2}$. Formulate a mathematical inequality for the condition that no sliding occurs. There may be more than one inequality.