Physics 23 Problems Chapters 1-4

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Solutions are shown at the end.

Chapter 1 Problems

1. Obtain the direction of the sum of the two displacement vectors, **A** and **B**, below.

   A: 56 km, west
   B: 40 km, 30^o south of east

2. A hiker travels for 500 meters along a heading of 150^o, then 700 meters along a heading of 260^o. Along which heading could a second hiker, starting from the first hiker's initial location, travel to meet the first hiker?

Chapter 2 Problems

Horizontal Motion Problems

1. The velocity of an object traveling along the x-axis changes from -40 m/s to 70 m/s in five seconds. What was the displacement that occurred during this time?

2. An object moving along the x-axis initially has a velocity of 60 m/s and is slowing down at the rate of 4 m/s per second. How far (in meters) will it travel before coming to rest?

3. An accelerating object travels 12 meters from rest in a certain time. How far (in meters) could it have traveled from rest in triple the time?

4. An object's initial velocity is 40 m/s and is accelerating. When the object has traveled 300 m, its velocity is 90 m/s. What is the object's acceleration (in m/s^2)?

5. An object with constant acceleration and traveling horizontally decreases its velocity from 90 m/s to 20 m/s. During this acceleration period it travels 275 meters. What will be its velocity (in m/s) one second later?

6. An automobile moving at 20 m/s accelerates at a rate of 5 m/s^2 for ten seconds. What distance did the automobile travel during the final second of the ten-second period?

7. An object whose initial velocity is 40 m/s travels 300 meters in five seconds. What was the object's final velocity?

8. Two cars initially separated by 900 m are traveling away from each other. Car A is moving to the left at -40 m/s. Car B is moving at 10 m/s to the right and is accelerating at 6 m/s^2. After how many seconds will Car B be 3000 apart ahead of Car A?

Vertical Motion Problems:

9. A bullet is fired straight upward at 100 m/s. What will be its velocity three seconds before reaching maximum height?

10. A ball is thrown at a velocity of -4 m/s straight down from the top of a 40-meter building. After how many seconds will it strike the ground?

11. A ball is thrown straight upward at 20 m/s from the top edge of a tall building, reaches maximum height, then falls towards the ground. When will its velocity be 30 m/s?

12. What maximum height will be reached by a bullet fired straight upward at 100 m/s?

13. A ball is thrown straight upward with an initial velocity of 25 m/s. After how many seconds will it return to the hand of the thrower?

14. At what initial velocity must an arrow be fired straight upward in order that it reach a maximum height of 80 meters?

15. A rock is dropped to the water below from a bridge. It strikes the water 1.8 seconds later. How high above the water is the bridge?

Chapter 3 Problems

1. A stone is thrown from the top of a 50-meter tall building at a speed of 16 m/s and at an angle of 30 degrees below the horizontal. What will be its speed (in m/s) two seconds later?

2. A ball is kicked from level ground and reaches a maximum height of 12 meters. What must have been the ball's initial vertical speed (in m/s)?

3. A bullet is fired at 250 m/s horizontally over level ground at an altitude of 1.9 meters. How far (in meters) horizontally will the bullet travel before striking the ground?

4. A golf ball struck on the ground is given an initial speed of 60 m/s, and initially travels along a line that is inclined 12^{o} above the ground. How far horizontally will it travel, ignoring the effects of air resistance and other factors, such as the ball's spin?

5. A speedboat has a speed of 40 m/s traveling “due” north (zero degrees heading) and is simultaneously accelerating eastward at a rate of 1.4 m/s^2. How far will it travel in the next six seconds?

6. At what firing angle above the horizonal must an arrow, fired at 80 m/s, be aimed to rise to a maximum height of 200 meters?

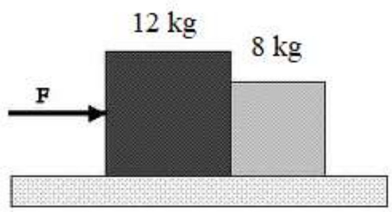
7. A golf ball struck on the ground leaves the ground with speed 90 m/s, traveling initially along an angle of 30 degrees above the horizontal. How far will it be from its starting point three seconds later?

Chapter 4 Part 1 Problems

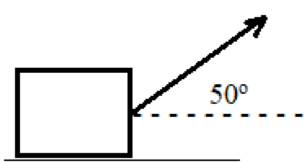
1. At what approximate distance from the center of Earth would a 100-kg object weigh 300 N?

2. The gravitational force two objects of equal mass exert on each other is 6000 N. What would be the new force if the separation is tripled, and the mass of each object is doubled?

3. Two blocks are touching on a frictionless tabletop, as shown in the figure below. A force F = 100 N is applied horizontally to pair. What is the contact force (in newtons) each block exerts on the other?



4. The block on the frictionless table below has a mass of 40 kg, and its acceleration is 2.0 m/s^2. The force F is directed at an angle of 50 degrees above the horizontal. What is the force F?



5. Three forces in a plane act on a 600 kg object. With respect to the positive x-axis, measured counter-clockwise, the forces are

A = 200 N, 40^{o}
B = 160 N, 110^{o}
C = 300 N, 270^{o}

What is the acceleration of the object?

6. A falling object has a mass m = 5 kg, and is subject to an air resistance of 9.0 N. How far will it fall in three seconds, dropped from rest?

7. An object of mass 50 kg is seven meters from an object of mass 120 kg. How far from the lighter object would the net gravitational force due to the two objects be zero on a third object of mass m placed between the two?

8. Equal masses M are at three of the vertices of a square whose side length is L. What is the net gravitational force due to the three masses on a fourth identical mass placed at the center of the square? State your answer in terms of the quantities M, G, and L.

9. An object weighing 500 N is placed in an elevator that is accelerating downward. What would have to be the acceleration of the elevator in order that the object's apparent weight be only 100 N?

10. What would have to be the acceleration of an elevator in order that the "apparent weight" of a passenger be zero?

Chapter 1 Problem Solutions

1.

C = A + B

$C_x = A_x + B_x$
$= -56 + 40 \cos 30$
$= -21.36$

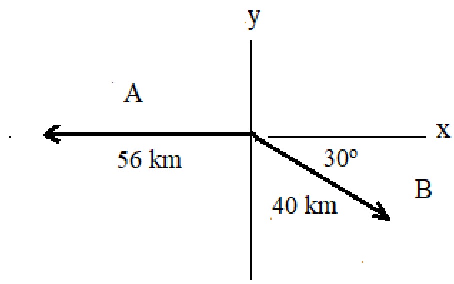
$C_y = A_y + B_y$
$= 0 - 40 \sin 30$
$= -20.00$

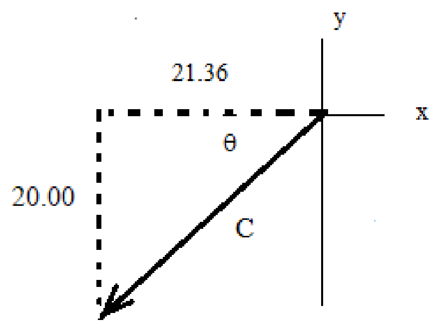
$C = (C_x^2 + C_y^2)^{1/2}$
$= (21.36^2 + 20.00^2)^{1/2}$
$= 29.26$ km

$\theta = \tan^{-1} (20.00/21.36)$
$= 43.12^o$ south of west

Heading:

$270 - 43.12 = 226.88^o$





2.

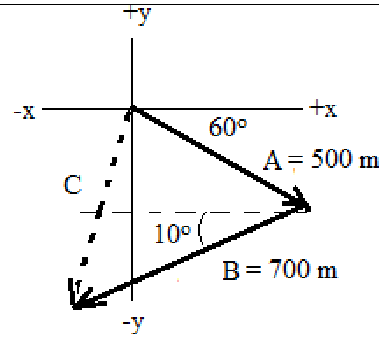
C = A + B

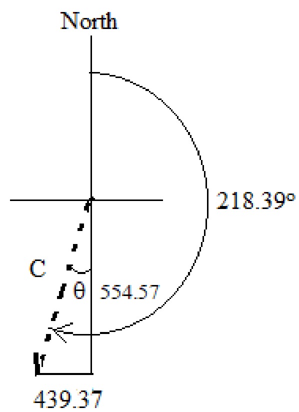
$C_x = A_x + B_x$
$= 500 \cos 60 - 700 \cos 10$
$= -439.36$ m

$C_y = A_y + B_y$
$= -500 \sin 60 - 700 \sin 10$
$= -554.57$ m

$\theta = \tan^{-1} (439.37/554.57)$
$= 38.39^o$

Heading: $180 + 38.39 = 218.39^o$





Chapter 2 Problem Solutions

1. $x = \bar{v}\, t$
$= \frac{1}{2} (v_o + v)\, t$
$= \frac{1}{2} (-40 + 70)\, 5$
$= 75$ m

2. $v = v_o + at$
$0 = 60 - 4t$
$t = 15$ s

$x = v_o t + \frac{1}{2} at^2$
$= 60 (15) - \frac{1}{2} (4) 15^2$
$= 450$ m

3. $x = v_o t + \frac{1}{2} at^2$
$= 0 + \frac{1}{2} at^2$

Original $x = \frac{1}{2} at^2$
$= 12$ m

New $x = \frac{1}{2} a (3t)^2$
$= \frac{1}{2} a (9t^2)$
$= 9 [\frac{1}{2} at^2]$
$= 9 (12)$
$= 108$ m

4. $v^2 = v_o^2 + 2ax$ $90^2 = 40^2 + 2a\,(300)$ $a = 10.83\ m/s^2$	5. $v^2 = v_o^2 + 2ax$ $20^2 = 90^2 + 2a\,(275)$ $a = -14\ m/s^2$ $v = v_o + at$ $= 20 + (-14)(1)$ $= 6\ m/s$

6.

After nine seconds: $x = 20\,(9) + \frac{1}{2}\,(5)\,9^2$
$= 382.5$ m

After ten seconds: $x = 20\,(10) + \frac{1}{2}\,(5)\,10^2$
$= 450.0$ m

The distance traveled is the difference between the two x-coordinates:

Distance = 450.0 - 382.5
= 67.5 m

7.

Two ways to calculate average velocity:

First Way:
$\bar{v} = y/t$
$= 300/5$
$= 60$ m/s

Second Way:
$\bar{v} = 60$ m/s
$= \frac{1}{2}\,(v_o + v)$
$= \frac{1}{2}\,(40 + v)$

Equate the two expression for $\bar{v}$:

$\frac{1}{2}\,(40 + v) = 60$
$v = 80$ m/s

8. <u>Car A:</u> Let the reference zero be at the starting location of Car A: $x = x_o + v_o t + \frac{1}{2} at^2$ $= 0 - 40\ t + 0$ $= -40\ t$ <u>Car B:</u> Initiallly, Car B is 900 meters to the right of Car A: $x_o = 900$ m $x = x_o + v_o\ t + \frac{1}{2} at^2$ $= 900 + 10t + \frac{1}{2} (6)t^2$ Car B x-coordinate = Car A x-coordinate + 3000 $900 + 10t + \frac{1}{2} (6)t^2 = -40t + 3000$ $t = 19.41$ s	9. $v = v_o + at$ $0 = v_o - 9.8(3)$ $v_o = 29.4$ m/s

10.	11.
Recall: When only one object is in motion, the reference zero mark is most conveniently chosen to be wherever the object was when the observation began--in this case, at the top of the building. The y = 0 mark is at the top of the building, so the y-coordinate of the bottom of the 40-meter building is $y = -40$ m. $y = v_o t + \frac{1}{2} at^2$ $-40 = -4t - \frac{1}{2}(9.8)t^2$ $t = 2.48$ s	Recall: Speed is the magnitude (absolute value) of the velocity. A velocity of 30 m/s (speed = 30 m/s) is not achievable moving upward, because the initial upward velocity is only 20 m/s, and on its way up from the top of the building it's losing velocity, stops, then heads back down. However, after it passes the top of the building on its way back down a velocity of -30 m/s (speed = 30 m/s) is obtainable: $v = v_o + at$ $-30 = 20 - 9.8t$ $t = 5.10$ s

12.
Maximum height is reached when the vertical velocity is reduced to zero: $v = v_o + at$ $0 = 100 - 9.8\,t$ $t = 10.20$ s <u>First Method</u> $y = v_o t + \frac{1}{2} at^2$ $= 100(10.20) - \frac{1}{2}(9.8)\,10.20^2$ $= 510$ m <u>Second Method</u> $y = \bar{v}\,t$ $= \frac{1}{2}(100 + 0)(10.20)$ $= 510$ m

13.	14.
Recall: The point from which motion begins is the "zero" location. So, in returning to the point from which it started, the object's y-coordinate is zero: $y = v_o t + ½ at^2$ $0 = 25 t - ½ (9.8)t^2$ $t = 5.10$ s	$v^2 = v_o^2 + 2ay$ $0^2 = v_o^2 + 2(-9.8)80$ $v_o = 39.60$ m/s

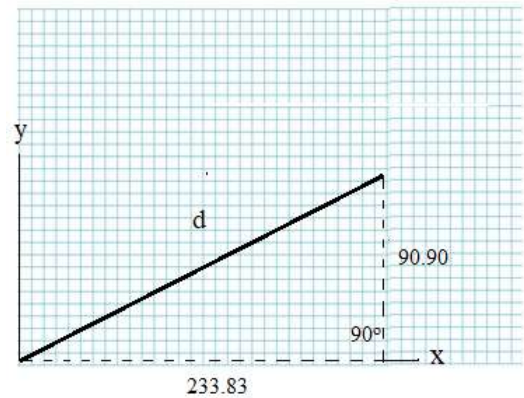
15.
$y = v_o t + ½ at^2$ $= 0 + ½ (-9.8)1.8^2$ $= -15.88$ m 2 The negative sign affirms what we expected: The water is 15.88 m below the bridge. Therefore, the bridge is 15.88 m above the water.

Chapter 3 Problem Solutions

1. <u>Horizontal:</u> $v = v_o + at$ $= 16 \cos 30 + 0$ $= 13.86$ m/s <u>Vertical</u>: $v = v_o + at$ $= -16 \sin 30 - 9.8(2)$ $= -27.6$ m/s <u>Speed</u>: $v = (v_x^2 + v_y^2)^{1/2}$ $v = (13.86^2 + 27.60^2)^{1/2}$ $= 30.88$ m/s	2. <u>Vertical</u>: $v^2 = v_o^2 + 2ay$ $0^2 = v_o^2 + 2(-9.8)12$ $v_o = 15.34$ m/s

3. <u>Vertical</u>: $y = v_o\, t + ½\, at^2$ $-1.9 = 0 + ½\,(-9.8)t^2$ $t = 0.623$ s <u>Horizontal</u>: $x = v_o\, t + ½\, at^2$ $= 250\,(0.623) + 0$ $= 156$ m	4. Rise time = (60 sin 12) /9.8 = 1.27 s Fall time = 1.27 s Total = 2.54 s x = (60 cos 12) (2.54) = 149 m

5. $y = 40(6)$ $= 240$ m $x = ½ (1.4)6^2$ $= 25.2$ m $d = (240^2 + 25.2^2)^{1/2}$ $= 241.32$ m	6. $v_o = 80 \sin \theta$ $v = 0$ $\bar{v} = ½ (80 \sin \theta + 0)$ $= 40 \sin \theta$ Rise Time $= 80 \sin \theta/9.8$ $y = \bar{v}\, t$ $200 = (40 \sin \theta)(80 \sin \theta)/9.8$ $\theta = 51.5^o$

7. $x = (90 \cos 30)\, 3$ $= 233.83$ m $y = (90 \sin 30)3 - ½ (9.8)3^2$ $= 90.90$ m $d = (233.83^2 + 90.90^2)^{1/2}$ $= 250.88$ m	

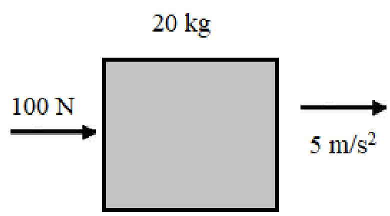
Chapter 4 Part 1 Problem Solutions

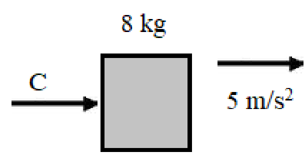
1. $M = 5.98 \times 10^{24}$ kg $m = 100$ kg $G = 6.67 \times 10^{-11}$ N-m^2/kg^2 $GMm/r^2 = F$ $6.67 \times 10^{-11} (5.98 \times 10^{24})(100)/r^2 = 300$ $r = 1.15 \times 10^7$ m	2. $F = Gmm/r^2$ $= Gm^2/r^2$ $= 6000$ N Solve this problem in two steps. First, get the new force based on the change in m, then use the new force as the starting point for the change in the separation r. First, if m is doubled, m^2 is quadrupled, which quadruples the numerator, which quadruples F to 24,000 N. Second, if r is tripled, the r^2 becomes nine times greater denominator becomes nine times greater, which means the force will decrease to one-ninth of its previous value of 24,000 N. The new force therefore is 24,000/9 = 2667 N.

3.

The pair of blocks accelerate as if they were one block of mass 20 kg; the acceleration of the pair is

$$a = F/m$$
$$= 100/20$$
$$= 5 \text{ m/s}^2$$

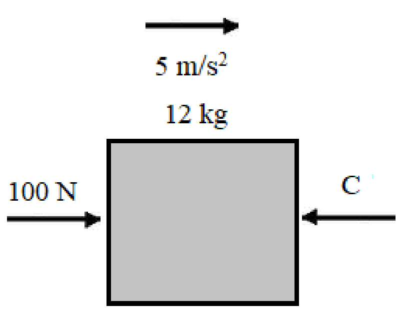




The only force the 8-kg block experiences is the contact force, C.

$$F = ma$$
$$C = (8)(5)$$
$$= 40 \text{ N}$$

Get the same result by isolating the 12-kg block:

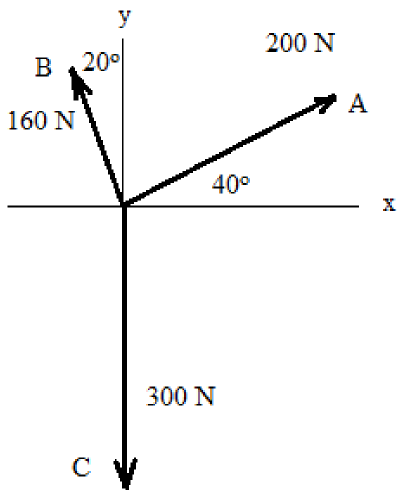


$$F = m$$
$$100 - C = 12(5)$$
$$C = 40 \text{ N}$$

4.

$$F_x = ma_x$$
$$F \cos 50 = 40(2)$$
$$F = 124.46 \text{ N}$$

5. **D = A + B + C**



$D_x = A_x + B_x + C_x$

$D_x = 200 \cos 40 - 160 \sin 20 + 0$
$= 98.49$ N

$D_y = A_y + B_y + C_y$
$= 200 \sin 40 + 160 \cos 20 - 300$
$= -21.09$ N

$D = (D_x^2 + D_y^2)^{1/2}$
$D = (98.49^2 + 21.09^2)^{1/2}$
$= 100.72$ N

$a = 100.72/600$
$= 0.17\ m/s^2$

6.

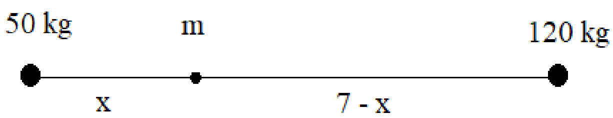
$F = -(5)(9.8) + 9.0$
$= -40$ N

$a = F/m$
$= -40/5$
$= -8.0\ m/s^2$

$y = v_o t + ½ at^2$
$= 0 + ½ (-8.0)(3)^2$
$= -36$ m

Object falls 36 meters.

7.



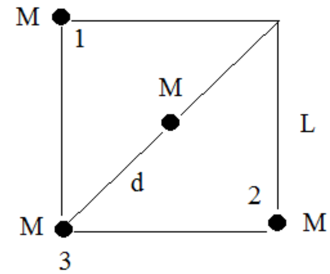
$G\,(50)(m)/x^2 = G\,(120)(m)/(7 - x)^2$

Divide by Gm:

$50/x^2 = 120/(7 - x)^2$

$x = 2.75$ m

8.



D = Diagonal length

$D^2 = L^2 + L^2$

$D = \sqrt{2}\,L$

Half-Diagonal: $d = \frac{1}{2} D$

$= \frac{1}{2} \sqrt{2}\,L$

$d^2 = \frac{1}{2} L^2$

Opposing attractions by objects at vertices 1 and 2 cancel. Only the force due to the pull by the mass at vertex 3 is unbalanced.

$F = GM^2/d^2$

$= GM^2/(\frac{1}{2} L^2)$

$= 2\,GM^2/L^2$

9.

$m = 500/9.8$

$= 51.02$ kg

$C = 100$ N

$F = -mg + C$

$= -500 + 100$

$= -400$ N

$F = ma$

$-400 = 51.02\,a$

$a = -7.84$ m/s^2

10.

If C = 0, the only force acting is the weight force, -mg.

$F = ma$

$-mg = ma$

$a = -g$

$= -9.8$ m/s^2