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PART ONE MECHANICS

Chapter 1 Introduction and Measurements

1. $555\text{ ft}\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 169\text{ m}$

2. $305\text{ ft}\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 92.96\text{ m} = 93.0\text{ m}$

3. $7\text{ ft}\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 2.13\text{ m}$

4. $144\text{ft}^2(1\text{m}/3.281\text{ ft})^2 = 13.38\text{ m}^2 = 13.4\text{ m}^2$

5. (24 hr/day)(60 min/hr)(60 s/min)
 = 86, 400 s/day
 (86,400 s/day)(30 day/month)
 = 2.59×10^6 s/month
 (86,400 s/day)(365 day/year)
 = 3.154×10^7 s/year

6. Answers will vary.
 Example: height = 6.0 ft
 $6.0\text{ ft}\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 1.829\text{ m} = 1.83\text{ m}$

7. $(60\text{ mi/hr})(5280\text{ ft/mi})\left(\frac{1\text{ hr}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)$
 = 88 ft/s

8. (90 km/hr)(1000 m/km)(3.281 ft/m)
 $\times$ (1 mile/ 5280 ft)
 = 55.93 mph = 55.9 mph

9. 1 km(1000 m/km)(3.281 ft/m) = 3281 ft
 = 3280 ft

10. Using the result from problem 1.5,
 l yr = 3.154×10^7 s
 4.6×10^9 yr(3.154×10^7 s/yr)
 = 1.451×10^{17} s = 1.45×10^{17} s

11. (331 m/s)(3.281 ft/m) = 1086 ft/s =1090 ft/s
 1080 ft/s (3600 s/hr)(1 mi /5280 ft)
 = 736 mph

12. (55 mi/hr)(5280 ft/mi)(1 m/(3.281ft)
 $\times$ (1km/1000 m)
 = 88.51 km/hr = 88.5 km/hr

13. $(1\text{ g/cm}^3)(1\text{kg}/1000\text{ g})(1 \times 10^3\text{ cm}^3/\text{L})$
 = 1 kg/L

14. $50\text{ ft}^3\,(\text{lm}/3.281\text{ ft})^3 = 1.416\text{ m}^3 = 1.42\text{ m}^3$

15. **a.** 75 yr(365 day/yr)(24 hr/day)
 $\times$ (3600 s/hr)
 = 2.365×10^9 s
 b. 75 yr(365 day/yr)(24 hr/day)
 $\times$ (60 min/hr)
 = 3.95×10^7 min
 (3.942×10^9 min/lifetime)(70 pulses/min)
 = 2.76×10^9 pulses/lifetime

16. Cube : a = 50 cm = 0.50 m The cube has six sides. The area of one side
 $= a^2 = (0.50\text{ m})^2 = 0.25\text{ m}^2$
 Total area is $6(0.25\text{ m}^2) = 1.50\text{ m}^2$
 $1.50\text{ m}^2\,(3.281\text{ ft/m})^2 = 16.2\text{ ft}^2$
 Volume $= a^3 = (0.50\text{ m})^3 = 0.125\text{ m}^3$
 $0.125\text{ m}^3\,(3.281\text{ft/m})^3 = 4.42\text{ft}^3$

17. (186,000 mi/s)(60 s/min)(60 min/hr)
 = 6.70×10^8 mph
 (186, 000 mi/s)(5280 ft/mi)[(l m)/(3.281 ft)]
 = 2.99×10^8 m/s

18. 90 ft(1 m/3.281ft) = 27.4 m

19. $10\text{ yd}\left(\frac{1\text{ m}}{1.094\text{ yd}}\right) = 9.14\text{ m}$

$100\text{ yd}\left(\frac{1\text{ m}}{1.094\text{ yd}}\right) = 91.4\text{ m}$

20. Sphere diameter = 6.28 cm
 radius = 1/2 (diameter) = 3.14 cm
 Volume $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(3.14\text{ cm})^3$
 $= 129.7\text{ cm}^3 = 130\text{ cm}^3$
 $129.7\text{ cm}^3(1\text{m}/100\text{ cm}) = 1.297 \times 10^{-4}\text{ m}^3$
 $= 1.30\times10^{-4}\text{ m}^3$
 $129.7\text{ cm}^3(1\text{in}/2.54\text{ cm})^3 = 7.914\text{ in}^3 = 7.91\text{ in}^3$
 $129.7\text{ cm}^3(1\text{ ft}/30.48\text{ cm})^3 = 4.580 \times 10^{-3}\text{ ft}^3$

21. 1245 ft(1 m/3.281 ft) = 379.5 m = 380 m
 1245 ft(1 mi/5280 ft) = 0.236 mi
 1245 ft(12 in./ft) = 1.49×10^4 in.
 1245 ft(30.48 cm/ft)(10 mm/cm)
 = 3.80×10^5 mm

22. ¼ in. = 0.25 in.(2.54 cm/in.) = 0.635 cm
 0.635 cm(10 mm/cm) = 6.35 mm

23. 7927 mi(1.609 km/mi) $=1.275 \times 10^4$ km

24. $\dfrac{132 \text{ m}}{31 \text{ story}}$ = (4.258 m/story)(3.281 ft/m)
= 14.0 ft/story

25. 589 nm = 589×10^{-9} m
a. $589 \times 10^3 \times 10^{-12}$ m = 589,000 pm = 5.89×10^5 pm
b. $589 \times 10^{-6} \times 10^{-3}$ m = 0.000589 mm
= 5.89×10^{-4} mm
c. $589 \times 10^{-7} \times 10^{-2}$ m = 0.0000589 cm
= 5.89×10^{-5} cm
d 589×10^{-9} m/wavelength
The length of a wave
= (589×10^{-9} m/wavelength)(39.37 in./m)
= 2.32×10^{-5} in./wavelength
The number of waves in an inch is the reciprocal of the previous result.
Number of waves = 1/ (2.32×10^{-5} in./ wavelength)
= 4.31×10^4 wavelength/in.

26. 239,000 mi(1.609 km/mi)(1000 m/km)
= 3.85×10^8 m

27. 1 acre(43,560 ft^2/acre)(1 m/3.281 ft)^2
= 4046 m^2 = 4050 m^2

28. 1.67×10^{-24} g/atom
($1/1.67 \times 10^{-24}$ g/atom) = 5.99×10^{23} atom/g

29. 2.54 cm = 1 in.
(2.54 cm)^3 = (1 in.)^3
16.4 cm^3 = 1 in.^{3}

30. 1 L =1000 cm^3
1 m = 100 cm
(1 m)^3 = (100 cm)^3
1 m^3 = 1×10^6 cm^3
$\left(\dfrac{1 \times 10^6 \text{ cm}^3}{1 \text{ m}^3}\right)\left(\dfrac{1 \text{ L}}{1000 \text{ cm}^3}\right)$ = 1000 L/m^3

31. 10^4 cubic micron(10^{-6} m/micron)^3
= 1×10^{-14} m^3
10^6 cubic micron(10^{-6} m/micron)^3
= 1×10^{-12} m^3
10^4 cubic micron(10^{-6} m/micron)^3 (100 cm/m)^3 $\times$(1 in./ 2.54 cm)^3 = 6.10×10^{-10} in.^{3}
10^6 cubic micron(10^{-6} m/micron)^3 (100 cm/m)^3 $\times$ (1 in./ 2.54 cm)^3 = 6.10×10^{-8} in.^{3}

32. 1 angstrom = 10^{-10} m
20×10^{-10} m = $20 \times 10^2 \times 10^{-12}$ m
= 2000 pm
20×10^{-10} m = $20 \times 10^{-1} \times 10^{-9}$ m
= 2nm
20×10^{-10} m = $20 \times 10^{-4} \times 10^{-6}$ m

= 0.0020×10^{-6} m = 0.002 μm
20×10^{-10} m = $20 \times 10^{-7} \times 10^{-3}$ m
= 20×10^{-7} mm
20×10^{-10} m = $20 \times 10^{-8} \times 10^{-2}$ m
= 20×10^{-8} cm
20×10^{-10} m = 20×10^{-10} m
(20×10^{-8} cm)(1 in./ 2.54 cm)
= 7.87×10^{-8} in.

33. 8.6 angstroms = 8.6×10^{-10} m
$8.6 \times 10^{-7} \times 10^{-3}$ m = 8.6×10^{-7} mm
8.6×10^{-10} m (39.37 in./m) = 3.39×10^{-8}in.

34. 10 micron = 10×10^{-6} m = $10 \times 10^{-4} \times 10^{-2}$ m
= 10×10^{-4} cm = 10^{-3} cm
100 micron = 100×10^{-6} m.
= $100 \times 10^{-4} \times 10^{-2}$ m = 100×10^{-4} cm
= 10^{-2} cm
10^{-2} cm(1 in./2.54 cm) = 3.94×10^{-3} in.
10^{-3} cm(1 in./2.54 cm) = 3.94×10^{-4} in. (
Range: 10^{-3} cm to 10^{-2} cm
3.94×10^{-4} in to 3.94×10^{-3} in.

35. 0.2 micron= 0.2×10^{-6} m
a. $0.2 \times 10^6 \times 10^{-12}$ m = 0.2×10^6 pm
= 200,000 pm = 2.0×10^5 pm
b. $0.2 \times 10^3 \times 10^{-9}$ m = 0.2×10^3 nm
= 200 nm
c. $0.2 \times 10^0 \times 10^{-6}$ m = 0.2 μm
d. $0.2 \times 10^{-3} \times 10^{-3}$ m = 0.2×10^{-3} mm
= 0.0002 mm
e. $0.2 \times 10^{-4} \times 10^{-2}$ m = 0.2×10^{-4} cm
= 2×10^{-5} cm

36. 1454 ft(1m/3.281 ft) = 443.2 m = 443 m

37. 145 g(1 slug /1.459×10^4 g)
= 9.94×10^{-3} slug = 0. 00994 slug

38. 40 ft^3(1m/3.281 ft)^3 = 1.13 m^3

39. 42 gallon/barrel(231 in.^{3}/gallon) $\times$ (2.54 cm/in)^3 $\times$ (1 m/100 cm)^3 = 0.159 m^3/barrel

40. 1298.4 m(3.281 ft/m) = 4.260×10^3 ft
= 4260 ft
1298.4 m (3.281 ft/m)(1 mi/5280 ft)

= 0.807 mi

41. 10,911 m(3.281 ft/m) = 35,798.99 ft
= 3.58×10^4 ft

42. 6194 m(3.281 ft/m) = 20,322.5 ft
= 2.03×10^4 ft

43. 6371 km = 6.371×10^6 m
Surface area of a sphere = $4\pi R^2$
= $4\pi \times (6.371 \times 10^6\ \text{m})^2$
= $5.10 \times 10^{14}\ \text{m}^2$
$5.101 \times 10^{14}\ \text{m}^2\ (3.281\ \text{ft/m})^2$
= $5.49 \times 10^{15}\ \text{ft}^2$
Volume of a sphere = $4/3\ \pi R^3$
= $4/3\ \pi\ (6.371 \times 10^6\text{m})^3$
= $1.08 \times 10^{21}\ \text{m}^3$
$1.083 \times 10^{21}\ \text{m}^3\ (3.281\ \text{ft/m})^3$
= $3.83 \times 10^{22}\ \text{ft}^3$
Density = m/V = (5.97×10^{24} kg/1.083×10^{21} m^3) = 5.51×10^3 kg/m^3

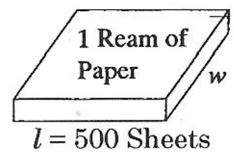
See Conversions: Appendix A
44. To convert from years to other time units, apply dimensional analysis techniques
a. 5.27 yr (12 mo/1 yr) = 63.24 mo
b. 5.27 yr (365.24 d/1 yr) = 1.925×10^3 day
c. 5.27 yr (365.24 d/1 yr)(24 hr/day)
= 4.62×10^4 hr
d. 5.27 yr (365.24 d/1 yr)(86,400 s/day)
= 1.66×10^8 s
e. 5.27 yr (365.24 d/1 yr)(86,400 s/d)
$\times$ (1 millisecond/10^{-3}s)
= 1.66×10^{11} milliseconds = 1.66×10^{11} ms

See Conversions: Appendix A
45. Apply dimensional analysis techniques
v = 40 km/hr(0.621 mi/km) = 24.84 mi/hr

See Conversions: Appendix A
46. Volume = length $\times$ width $\times$ height
h = 6 in. = 0.5 ft
a. V = (100 ft) $\times$ (100 ft)(.5 ft) = 5000 ft^3
b. V = 5000 ft^3(2.83×10^{-2} m^3/ft^3) = 141.5 m^3
c. V = 5000 ft^3(28.3 L/ft^3) = 1.42×10^5 L
d. V = 5000 ft^3(7.48 gal/ft^3) = 3.74×10^4 gal

47. The watch loses 8.5 sec per day or
a. 8.5 sec/day(30 day/month)
= 255 sec/month
or a loss of (255 sec)(1 min/60 sec)
= 4.25 min/month
b. 8.5 sec/day(365.24 day/1 year)
= 3.1045×10^3 sec/year or
(3.1045×10^3 sec/year)(1 min/60 sec)
= 51.74 min/year

48. h = 1 7/8 in. = 1.875 in.
500 sheets



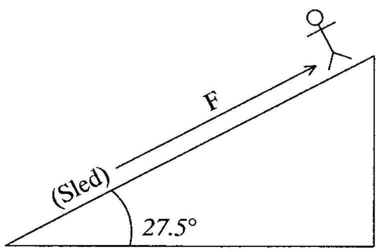
a. Thickness of 1 sheet.
(1.875 in./1 ream)(1 ream/500 sheets)
1 sheet = .00375 in./sheet
(.00375 in./sheet)(2.54 cm/in.)(10 mm/cm)
= 0.0953 mm/sheet
b. l = 11 in.(2.54 cm/in.)(10mm/cm)
= 27.94 mm
w = 8 1/2 in.(2.54 cm/in.)(10 mm/cm)
= 21.59 mm
c. See Conversions: Appendix A
Area = $l \times w$
= (11 in.)(8.5 in.)(6.45×10^{-4}m^2/in.^{2})
= 6.03×10^{-2} m^2
= (11 in.)(8.5 in.)(6.45 cm^2/in.^{2})
$\times$ (10^2 mm^2/cm^2) = 6.03×10^4 mm^2

Chapter 2 Vectors

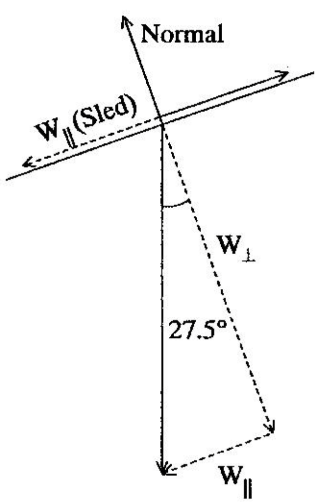
1. $F_x = F\cos 35° = (300\text{ N})\cos 35° = 246\text{ N}$
   $F_y = F\sin 35° = (300\text{ N})\sin 35° = 172\text{ N}$

2. $F = 50$ N at 50° above horizontal
   $F_y = F\sin 50° = (50\text{ N})\sin 50° = 38.3\text{ N}$
   $F_x = F\cos 50° = (50\text{ N})\cos 50° = 32.1\text{ N}$

3.



The normal force is the force the hill exerts on the sled. It is perpendicular to the surface of the hill.
F is the force the boy must apply. The weight of the sled is 68.0 N and is directed downward. See figure 2.13. Draw a diagram showing the forces acting on the sled.

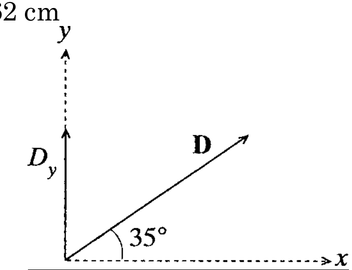


Resolve the weight force into components. One component is perpendicular to the surface, the other is parallel to the hill. In order for the sled to remain at rest, the force the boy exerts must equal the component of the weight acting down the hill. Therefore;

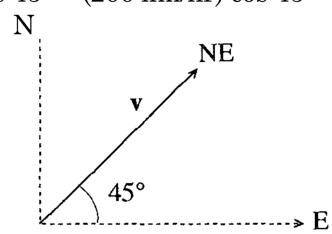
$W_{\|} = W\sin 27.5°$
$F = W\sin 27.5° = 68.0\text{ N}(\sin 27.5°)$
$F = 31.4$ N

The force exerted by the sled perpendicular to the hill is
$W_{\perp} = W\cos 27.5^0 = 68.0\text{ N}(\cos 27.5°)$
$W_{\perp} = 60.32$ N

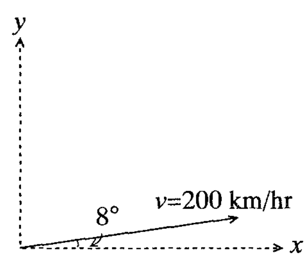
4. Set up a horizontal axis (y) and vertical axis (x)
   $D_y = D\sin 35°$
   $150\text{ cm} = D\sin 35°$
   $(150\text{ cm}/\sin 35^0) = D$
   $D = 262$ cm



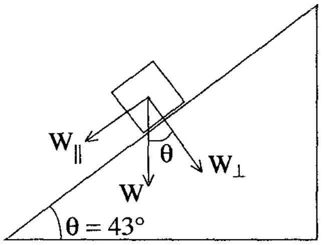
5. It is assumed that a direction of northeast is at 45°as shown
   a. $v_N = v\sin 45° = (200\text{ km/hr})\sin 45° = 141\text{ km/hr}$
   b. $v_E = v\cos 45° = (200\text{ km/hr})\cos 45° = 141\text{ km/hr}$



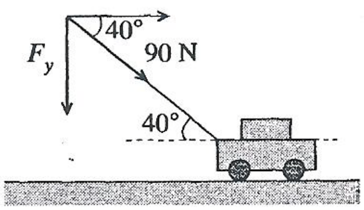
6. $v_x = (200\text{ km/hr})\cos 8° = 198\text{ km/hr}$
   $v_y = (200\text{ km/hr})\sin 8° = 27.8\text{ km/hr}$



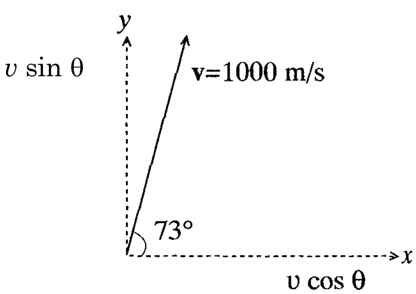
7. See figure 2.13
   $W = 8900$ N
   $W_{\perp} = W\cos\theta = 8900\text{ N}\cos 43°$
   $W_{\perp} = 6510$ N
   $W_{\|} = W\sin\theta = 8900\text{ N}\sin 43°$
   $W_{\|} = 6070$ N



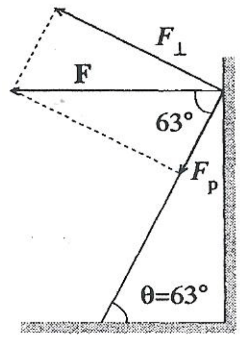
8. Draw a line parallel to the ground that contacts the arm of the lawn mower and identify the given angle.
F_x = (90 N) cos 40° = 68.9 N (horizontal)
F_y = –(90 N) sin 40° = –57.9 N (vertical)
The component in the y-direction is downward and may be given a negative sign. The vertical component pushes down on the mower making it harder to push along the ground. By raising the handle to 50°, the horizontal component is decreased and the contact force (vertical component) is increased, making it harder still to push the lawn mower.



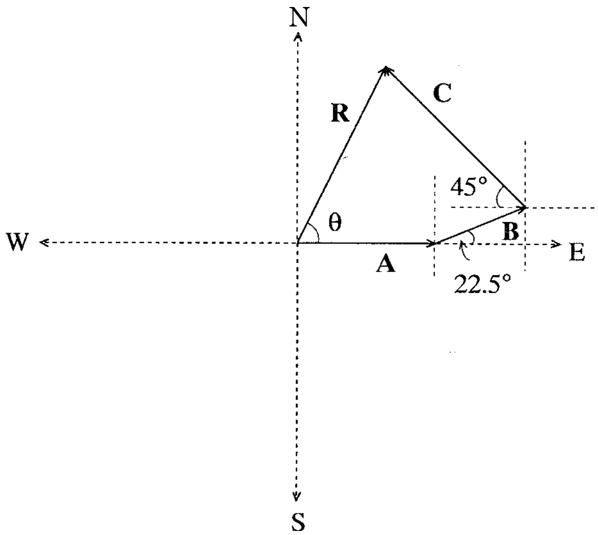
9. v_x = (1000 m/s) cos 73° = 292 m/s
v_y = (1000 m/s) sin 73° = 956 m/s



10. Use the theorem - two parallel lines cut by a transversal have equal alternate interior angles to find the necessary angle θ.
$F_p = F \cos \theta$ = (50 N) cos 63° = 22.7 N
$F_1 = F \sin \theta$ = (50 N) sin 63° = 44.6 N



11. It is assumed that the directions east-northeast and northwest correspond to angles of 22.5°and 45° respectively.
A = 3 km due east
B = 6 km east-northeast
C = 7 km northwest
Find the x- and y-components for each vector.
A_x = 3 km
B_x = (6 km) cos 22.5° = 5.54 km
C_x = –(7 km) cos 45° = –4.95 km
Sum the x-components, the westerly direction is negative.
$R_x = A_x + B_x + C_x$ = 3 km + 5.54 km –4.95 km
= 3.59 km
A_y = 0
B_y = (6 km) sin 22.5° = 2.30 km
C_y = (7 km) sin 45° = 4.95 km
Sum the y-components, south is negative.
$R_y = A_y + B_y + C_y$ = 0 + 2.30 km + 4.95 km
= 7.25 km
Now R_x and R_y are the components of R and form a right triangle.
The magnitude = $|\mathbf{R}| = (R_x^2 + Ry^2)^{1/2}$
$= \sqrt{(3.59 \text{ km})^2 + (7.25 \text{ km})^2} = 8.09 \text{ km}$
The direction is determined from
$\tan\theta = \dfrac{R_y}{R_x} \quad \theta = \tan^{-1}\dfrac{7.25 \text{ km}}{3.59 \text{ km}} = 63.7^0$
Resultant displacement **R** = 8.09 km at 63.7° north of east



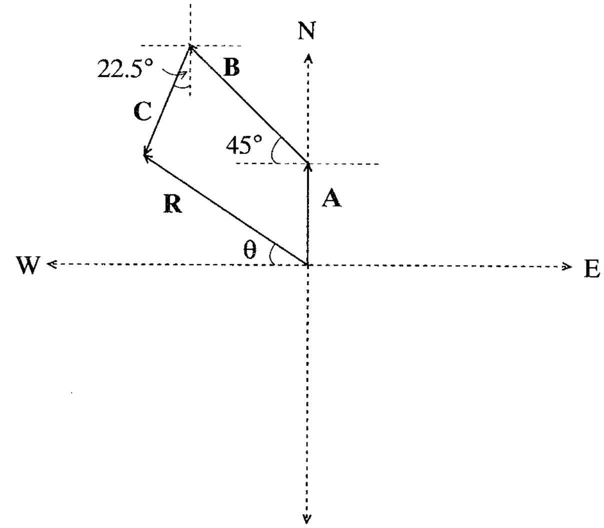
12. The directions northwest and south-southwest are taken to be 45° and 22.5°, respectively, as shown.
A = 3 km north
B =12 km northwest
C = 5 km south-southwest
Determine the x-components.
$A_x = 0$
$B_x = -(12\text{ km})\cos 45° = -8.49\text{ km}$
$C_x = -(5\text{ km})\sin 22.5° = -1.91\text{ km}$
Sum the x-components, west is negative.
$R_x = A_x + B_x + C_x = -8.49\text{ km} - 1.91\text{ km}$
$= -10.4\text{ km}$
Determine the y-components.
$A_y = 3\text{ km}$
$B_y = (12\text{ km})\sin 45° = 8.49\text{ km}$
$C_y = -(5\text{ km})\cos 22.5° = -4.62\text{ km}$
Sum the y-components, south is negative.
$R_y = A_y + B_y + C_y = 3\text{ km} + 8.49\text{ km} - 4.62\text{ km}$
$= 6.87\text{ km}$

Distance traveled = 3 km + 12 km + 5 km = 20 km

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-10.4)^2 + (6.87)^2} = 12.5\text{ km}$$

$$\tan\theta = \frac{R_y}{R_x} = \frac{6.87\text{ km}}{-10.4\text{ km}} = 0.661$$

θ = – 33.5° (See note) = 146.5° from the positive x-axis. Direction = 33.5° north of west
Magnitude = 12.5 km
Note: In determining the direction, the negative sign for R_x implies that **R** is in the second or third quadrant. But since R_y is positive, the vector **R** must be in the second quadrant..



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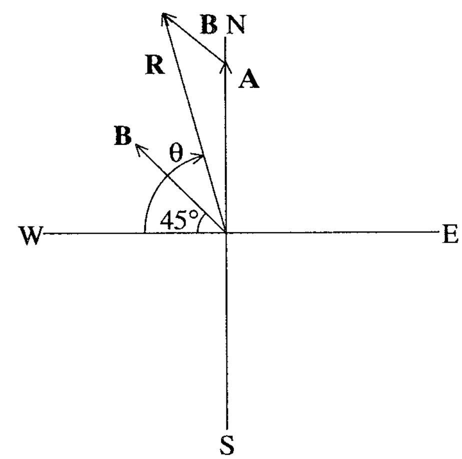


A = Velocity of Airplane
= 380 km/hr due North
B = Velocity of wind
= 75 km/hr from SE
R = Resultant Velocity of Airplane
Determine the x-components of the velocity of the airplane and wind, west is negative.
$A_x = 0$
$B_x = -B\cos 45° = -(75\text{ km/hr})\cos 45° = -53.0\text{ km/hr}$
$R_x = A_x + B_x = 0 + -53.0\text{ km/hr}$
$R_x = -53\text{ km/hr}$
Determine the y-components of the airplane and wind, south is negative.
$A_y = 380\text{ km/hr}$
$B_y = B\sin 45° = 75\text{ km/hr}\sin 45° = 53.0\text{ km/hr}$
$R_y = A_y + B_y = 380\text{ km/hr} + 53.0\text{ km/hr} = 433.0\text{ km/hr}$
The magnitude of R:

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-53.0)^2 + (433)^2} = 436\text{ km}$$

To determine the direction, look at the diagram

$$\tan\theta = \frac{R_y}{R_x} = \frac{433.0 \text{ km/hr}}{53.0 \text{ km/hr}} = 8.17$$

$\theta = 83.0^0$

Magnitude 436 km/hr; direction 83.0° north of west.

* The negative sign for R_x is ignored using the second quadrant right triangle with angle θ and sides R_x and R_y.

14. Find the x-components of each force. fig(a)

a_x = (30 N) cos 40° = 23 N

b_x =(120 N)cos135° = –84.9 N

c_x = (60 N) cos 260° = –10.4 N

Sum the x-components.

$Rx = a_x + b_x + c_x$ = 23 N –84.9 N –10.4 N = –72.3 N

Find the y-components of each force.

a_y = (30 N) sin 40° = 19.3 N

b_y = (120 N)sin 135°= 84.9 N

c_y = (60 N) sin 260° = –59.1 N

Sum the y-components.

$R_y = a_y + b_y + c_y$ = 19.3 N + 84.9 N – 59.1 N = 45.1 N

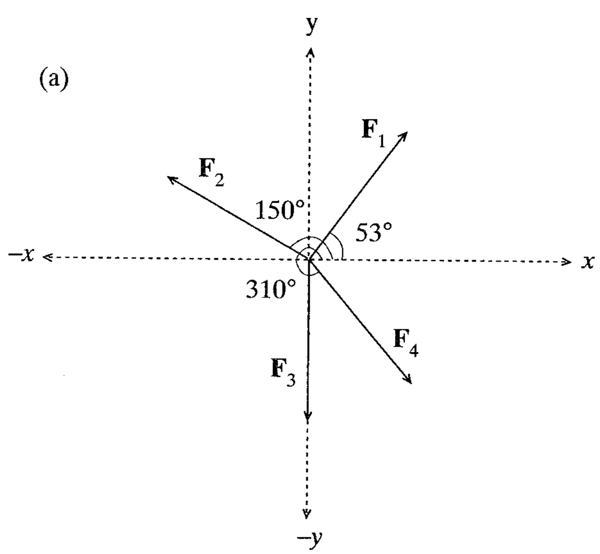
The magnitude of the resultant is determined from the Pythagorean theorem. fig. (b)

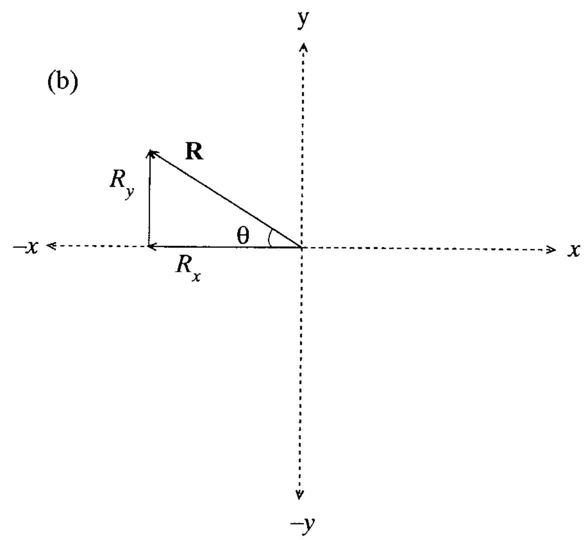
$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-72.3)^2 + (45.1)^2} = 85.2 \text{ N}$$

$$\tan\theta = \frac{R_y}{R_x} = \frac{45.1 \text{ N}}{72.3 \text{ N}} = 0.624$$

θ = 32°

R: magnitude of 85.2 N
direction = 32° above – x-axis
or 148° from + x-axis





15. Find the x-component of each force. fig. (a)

F_{1x} = (200N)cos 53° = 120 N

F_{2x} = (300 N) cos 150° = –260 N

F_{3x} = 0

F_{4x} = (350 N) cos 310° = 225 N

Sum the x-components.

$R_x = F_{1x} + F_{2x} + F_{3x} + F_{4x}$

R_x = 120 N + –260 N + 0 + 225 N = 85 N

Find the y-components for each force.

F_{1y} = (200 N) sin 53° = 160 N

F_{2y} = (300 N) sin 150° = 150 N

F_{3y} = –200 N

F_{4y} = (350 N) sin 310° = –268 N

Sum the y-components

$R_y = F_{1y} + F_{2y} + F_{3y} + F_{4y}$

R_y = 160 N + 150 N – 200 N – 268 N = –158 N

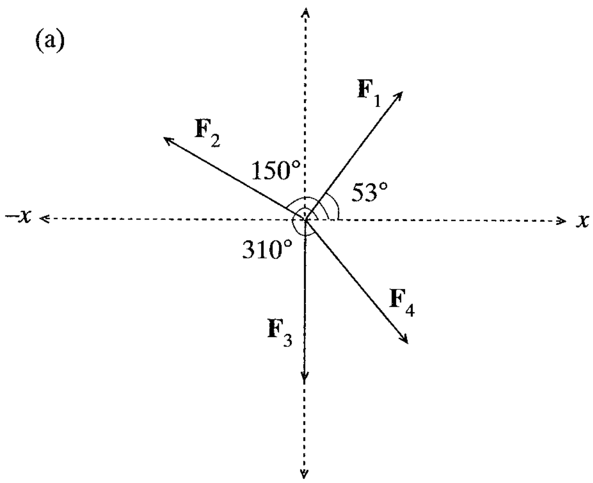
The resultant is determined from the Pythagorean theorem. fig. (b)

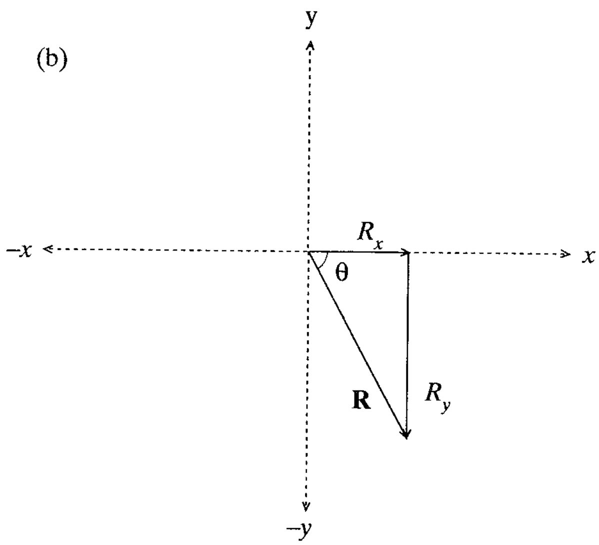
$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(85)^2 + (158)^2} = 179 \text{ N (magnitude)}$$

$$\tan\theta = \frac{R_y}{R_x} = \frac{-158 \text{ N}}{85 \text{ N}} = -1.86 \text{ ; } \theta = -61.7°$$

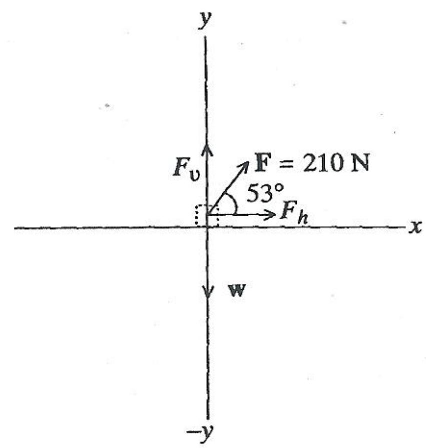
Direction: 61.7° below + x-axis or 298.3° counterclockwise from + x-axis

x





16. **a.** $F_h = F\cos 53° = 210\text{ N}\cos 53^0$
$F_h = 126.4$ N
b. $F_v = F\sin 53° = 210\text{ N}\sin 53°$
$F_v = 167.7$ N
c. The resultant downward force includes the verticle component of F (upward) and the weight of the trunk (taken to be negative downward)
$R_{\text{down}} = F_v - w = 167.7\text{ N} - 800\text{ N}$
$R_{\text{down}} = -632$ N



17. Since the problem only asks for multiples and combinations of vector **A**, the direction of the resultant will be along a line 50° north of east in the first quadrant (+**A**) to 50° south of west in the third quadrant (–**A**).

a. $|2\mathbf{A}| = 2(15.0\text{ m}) = 30.0$ m;
direction: 50° north of east

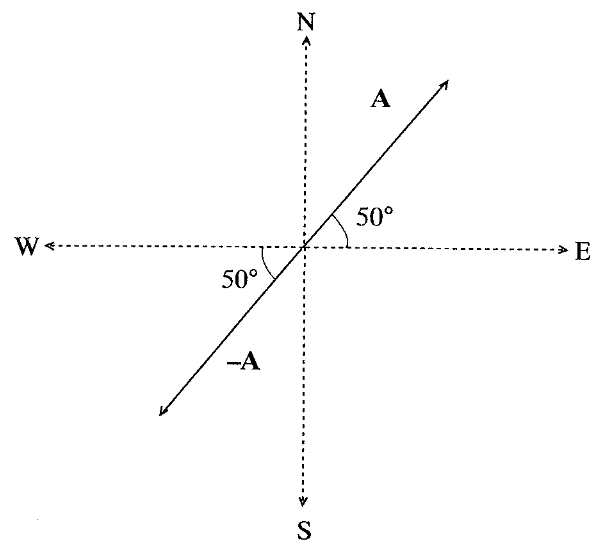
b. $|0.5\mathbf{A}| = 0.5(15.0\text{ m}) = 7.50$ m;
direction: 50° north of east

c. $|-\mathbf{A}| = 15.0$ m;
direction: 50° south of west
d. e. f.

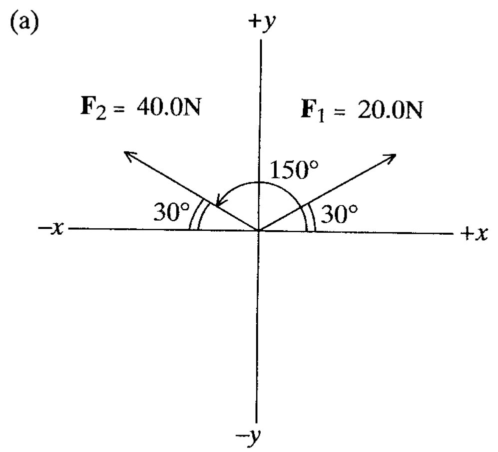
d. $|-5\mathbf{A}| = 5(15.0\text{ m}) = 75.0$ m;
direction: 50° south of west

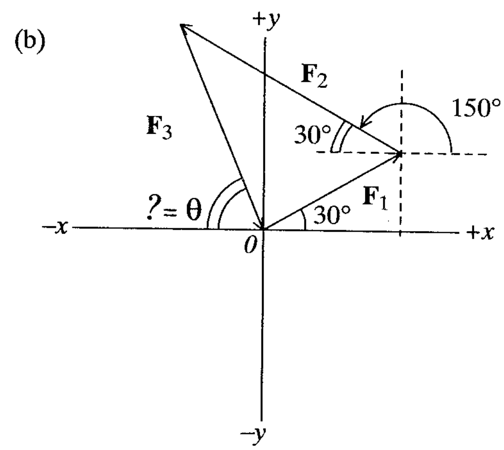
e. $|\mathbf{A} + 4\mathbf{A}| = |5\mathbf{A}| = 5(15.0\text{ m}) = 75.0$ m;
direction: 50° north of east

f. $|\mathbf{A} - 4\mathbf{A}| = |-3\mathbf{A}| = 3(15.0\text{ m}) = 45.0$ m;
direction: 50° south of west



18.





To determine a third force that results in a summation that equals zero, resolve the three forces (as seen in figure b), into their x- and y-components and solve for F_{3x} and F_{3y}. Then proceed to determine the magnitude and direction of F_3.

We need $\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = 0$

Therefore

$F_{1x} + F_{2x} + F_{3x} = 0$

and

$F_{1y} + F_{2y} + F_{3y} = 0$

$F_{1x} = F_1 \cos 30°$

$F_{1y} = F_1 \sin 30°$

$F_{2x} = F_2 \cos 30°$ or $F_2 \cos 150°$

$F_{2y} = F_2 \sin 30°$ or $F_2 \sin 150°$

x-component:

$(20.0 \text{ N}) \cos 30° - (40.0 \text{ N}) \cos 30° + F_{3x} = 0$

$F_{3x} = (40.0 \text{ N}) \cos 30° - (20.0 \text{ N}) \cos 30° = 17.3 \text{ N}$

y-component:

$(20.0 \text{ N}) \sin 30° + (40.0 \text{ N}) \sin 30° + F_{3y} = 0$

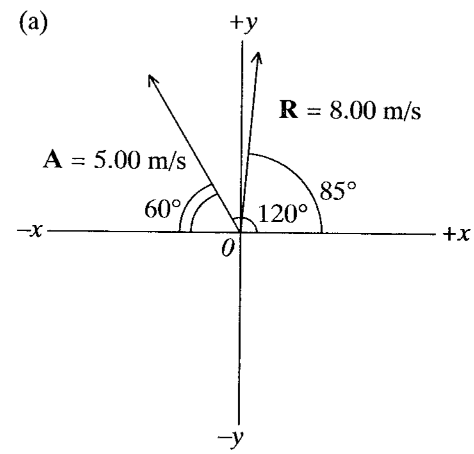
$F_{3y} = -(20.0 \text{ N}) \sin 30° - (40.0 \text{ N}) \sin 30° = -30.0 \text{ N}$

$$|\mathbf{F}| = \sqrt{F_{3x}^2 + F_{3y}^2} = \sqrt{(17.3 \text{ N})^2 + (30.1 \text{ N})^2} = 34.6 \text{ N}$$

Direction: $\theta = \tan^{-1}\dfrac{F_{3y}}{F_{3x}} = \tan^{-1}\dfrac{30.0 \text{ N}}{17.3 \text{ N}} = 60.0^0$

The vector $\mathbf{F}_3$ points toward the origin. Therefore the direction of this vector would be 60°0 below the positive x-axis. The magnitude is 34.6 N

19.



We want $\mathbf{B} + \mathbf{A} = \mathbf{R}$

Therefore

$B_x + A_x = R_x$

$B_y + A_y = R_y$

$B_x + (-5.00 \text{ m/s}) \cos 60° = (8.00 \text{ m/s}) \cos 85°$

$B_x = 3.20 \text{ m/s}$

$B_y + (5.00 \text{ m/s}) \sin 60° = (8.00 \text{ m/s}) \sin 85°$

$B_y = 3.64 \text{ m/s}$

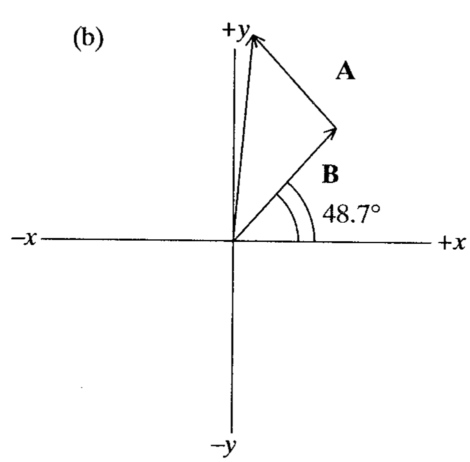
$$|\mathbf{B}| = \sqrt{B_x^2 + B_y^2} = \sqrt{(3.20 \text{ m/s})^2 + (3.64 \text{ m/s})^2} = 4.85 \text{ m/s}$$

Since B_x and B_y are both postive, θ is in the 1st Quadrant.

$$\theta = \tan^{-1}\frac{B_y}{B_x} = \tan^{-1}\frac{3.64 \text{ m/s}}{3.20 \text{ m/s}} = 48.7^0$$

Direction: θ = 48.7° above the + x-axis

$\mathbf{B} + \mathbf{A} = \mathbf{R}$

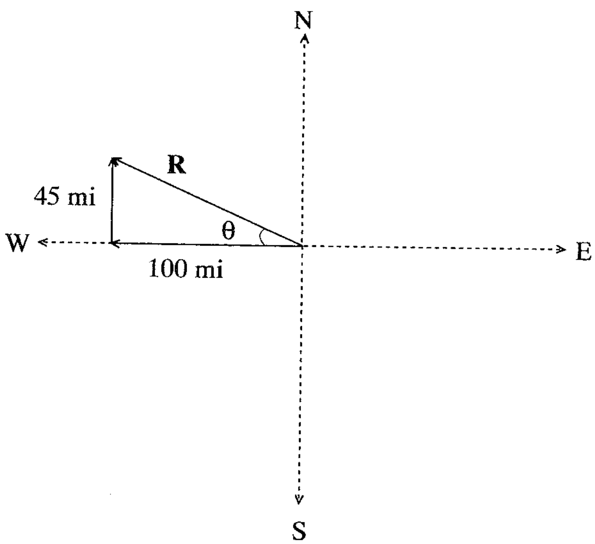


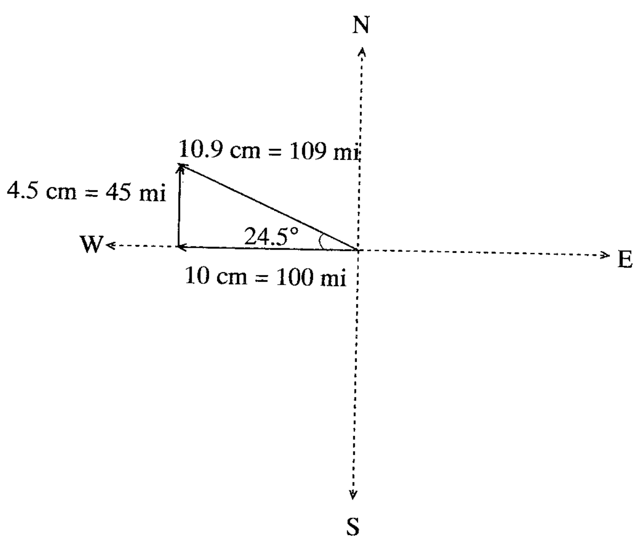
20.

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(100\text{ km})^2 + (45.0\text{ km})^2} = 110\text{ km}$$

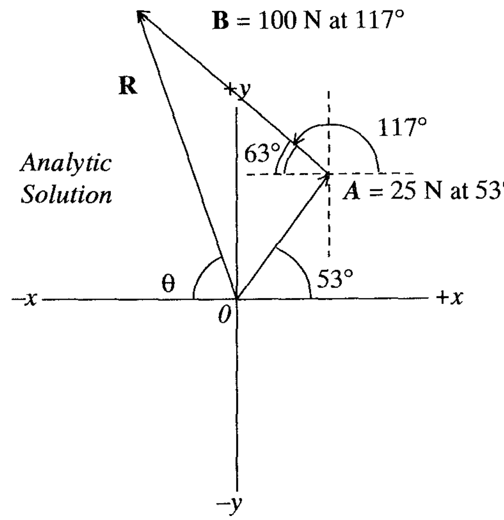
$$\tan\theta = \frac{R_y}{R_x} = \frac{45.0\text{ km}}{100\text{ km}} = 0.450$$

θ = 24.2° north of west
The graphical solution to the problem requires the use of a ruler and protractor. The scale for the diagram is 1 cm = 10 km. Measuring the hypotenuse to be 10.9 cm, equivalent to 109 km, and a measured angle of 24.5° with protractor) north of west.





21.



We need
A + B = R
Therefore
$A_x + B_x = R_x$
$A_y + B_y = R_y$
R_x = (25 N) cos 53° – (100 N) cos 63°
R_x = –30.4 N
R_y = (25 N) sin 53° + (100 N) sin 63°
R_y = 109.1 N

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-30.4\text{ N})^2 + (109.1\text{ N})^2} = 113\text{ N}$$

Direction: R_x is negative and R_y is positive; θ is in the 2nd Quadrant.

$$\tan\theta = \frac{R_y}{R_x} = \frac{109\text{ N}}{30.4\text{ N}} = 3.59$$

θ = 74.4° above the – x-axis

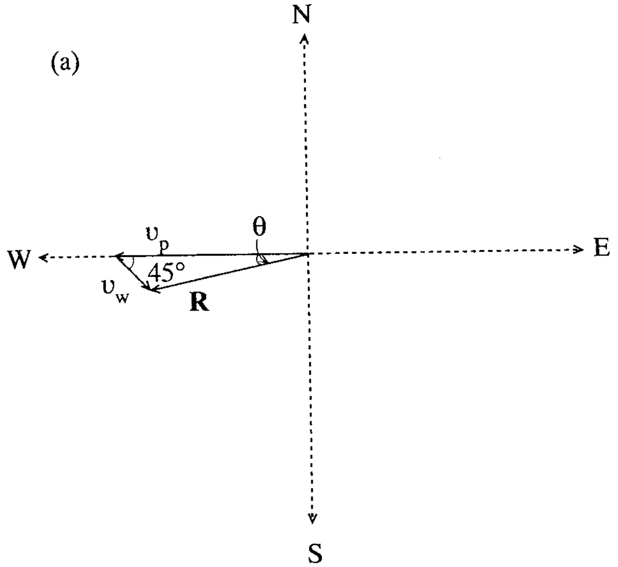
22. Find the x-components; the wind blows from the northwest toward the southeast. fig. (a)
a. v_{px} = –200 km/hr
v_{Wx} = (50 km/hr) cos 45° = 35.4 km/hr
Sum the x-components, west is negative.
$R_x = u_{px} + u_{wx}$ = –200 km/hr + 35.4 km/hr
= –164.6 km/hr = –165 km/hr
Find the y-components.
v_{py} = 0
v_{Wy} = –(50 km/hr) sin 45° = –35.4 km/hr
Sum the y-components, south is negative.
R_y = –35.4 km/hr
The resultant determined from the Pythagorean theorem. fig. (b)

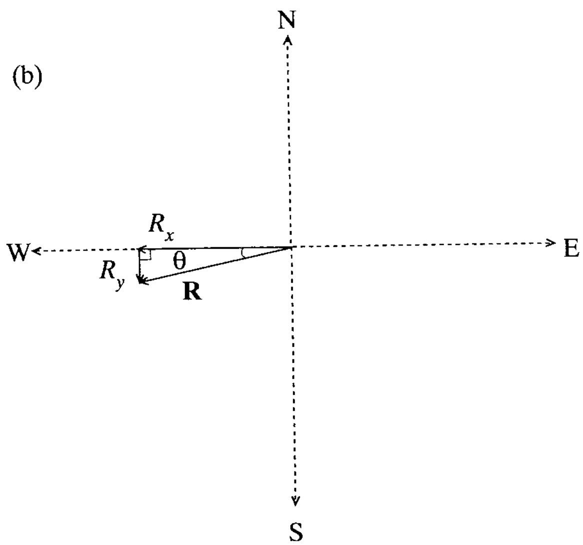
$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-165)^2 + (-35.4)^2} = 169\text{ km/hr}$$

$$\tan\theta = \frac{R_y}{R_x} = \frac{35.4}{165} = 0.215$$

θ =12.1° (in the third quadrant)

The velocity of the aircraft is 169 km/hr in the direction 12.1° south of west.





b. In order for the plane to travel due west, the pilot must point the plane at some angle into the wind. The final direction of the plane is due west. fig. (c)

$\upsilon_{wind,x}$ = 50 km/hr cos 45°

$\upsilon_{wind,y}$ = –50 km/hr sin 45°

$\upsilon_{plane,x}$ = –200 km/hr cos θ

$\upsilon_{plane,y}$ = 200 km/ hr sin θ

$\mathbf{v}_{result,\,x} = \upsilon_{result,\,x}$ '

$\mathbf{v}_{result,\,y} = 0$

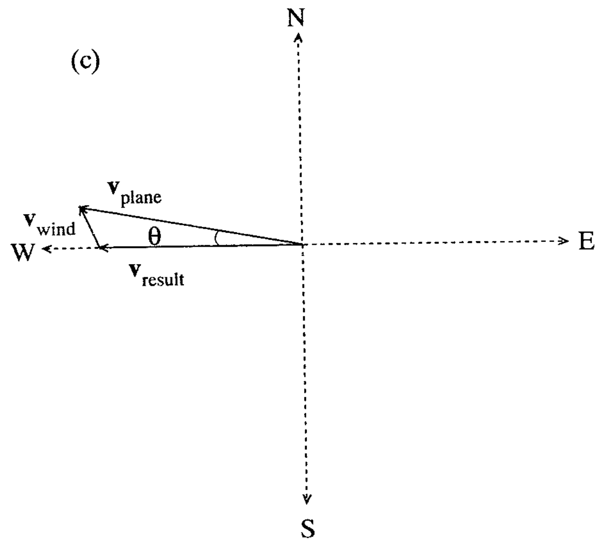
Using the information for the y(north - south) direction, $\upsilon_{wind,y} + \upsilon_{plane,y} = \mathbf{v}_{result,y} = 0$

(–50 km/hr) sin 45° + 200 km/hr sin θ = 0

$$\sin\theta = \frac{(50\text{ km/hr})\sin 45°}{200\text{ km/hr}} = 0.177$$

θ = 10.2° north of west

The pilot must point the plane in a direction 10.2° N of W.



c. To find the velocity of the plane, find the resultant velocity in the east - west direction.

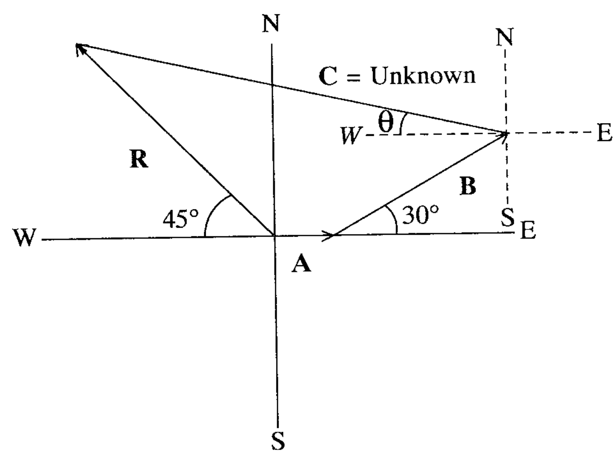
$\upsilon_{result,\,x} = \upsilon_{plane,x} + \upsilon_{wind,x}$

= –200 km/hr cos 10.2° + 50 km/hr cos 45°

$\upsilon_{result,\,x}$ = velocity of plane due west = –162 km/hr = due west.

$$\text{Time to travel} = \frac{\text{distance}}{\text{velocity}} = \frac{400\text{ km}}{162\text{ km/hr}} = 2.47\text{ hr}$$

23.



At the end of the 3 segments of the trip, the airplane is to be 200 km and 45° north of west (Resultant); Therefore

A + **B** + **C** = **R**

A = 50 km due east

B = 75 km at 30.0° north of east

C = Unknown

Therefore:

$A_x + B_x + C_x = R_x$

$A_y + B_y + C_y = R_y$
x-component:
50 km + (75 km) cos 30° + C_x = (–200 km) cos 45°
C_x = –256 km
y-component:
0 + (75 km) sin 30° + C_y = (200 km) sin 45°
C_y = 103.9 km = 104 km

$$|\mathbf{C}| = \sqrt{C_x^2 + C_y^2} = \sqrt{(-256\text{ km})^2 + (104\text{ km})^2} = 276\text{ km}$$

Direction: θ is a second quadrant angle
$C_x < O$; $C_y > 0$

$$\tan\theta = \frac{C_y}{C_x} = \frac{104\text{ km}}{256\text{ km}} = 0.406$$

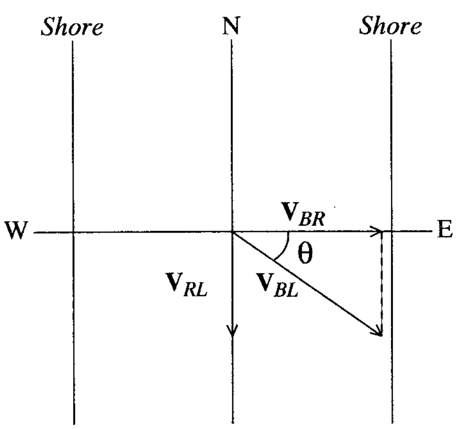
θ = 22.1° north of west

24. The vectors representing the velocity of the boat and river are at right angles to each other [See fig. (a)].
$\mathbf{V}_{RL}$ = velocity of the river relative to the land
= 7 km/hr
V_{BR} = velocity of boat relative to the river
= 19 km/hr
$\mathbf{V}_{BL}$ = velocity of the boat relative to the land
a. The Vector Equation is:
$\mathbf{V}_{BL} = \mathbf{V}_{BR} + \mathbf{V}_{RL}$

$$|\mathbf{V}_{BL}| = \sqrt{V_{BR}^2 + V_{RL}^2}$$

$$= \sqrt{(19.0\text{ km/hr})^2 + (7\text{ km/hr})^2} = 20.25\text{ km/hr}$$

(a)



b. The speed of the boat relative to the land is 20.25 km/hr. Since the river current does not change the component of the boat's velocity directly across the river, the boat travels the 1.5 km at 19 km/hr. The time to cover this distance is

$$d = V_{BR}\, t$$

$$t = \frac{d}{V_{BR}} = \frac{1.5\text{ km}}{19\text{ km/hr}} = 0.79\text{ hr or } 4.74\text{ minutes}$$

c. During the time it takes the boat to cross, the river current carries the boat downstream (southward) a distance

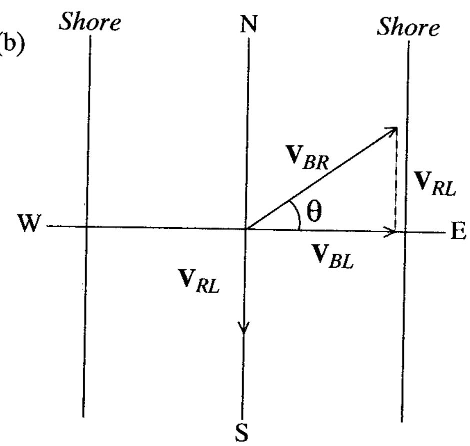
$$d = V_{RL}\, t = 7\text{ km/hr } (.079\text{ hr}) = 0.55\text{ km}$$

d. In this case, the boat must head against the flow of the river, so that its resultant is pointed straight across (due east). Referring to the diagram (fig. b)

$$\sin\theta = \frac{V_{RL}}{V_{BR}} = \frac{7\text{ km/hr}}{19\text{ km/hr}} = 0.368$$

θ = 21.6°
Directions: 21.6° north of east
21.6° Against the flow of the river (above the horizontal)

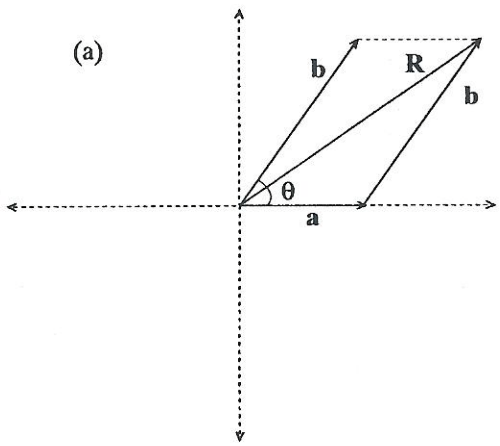
(b)

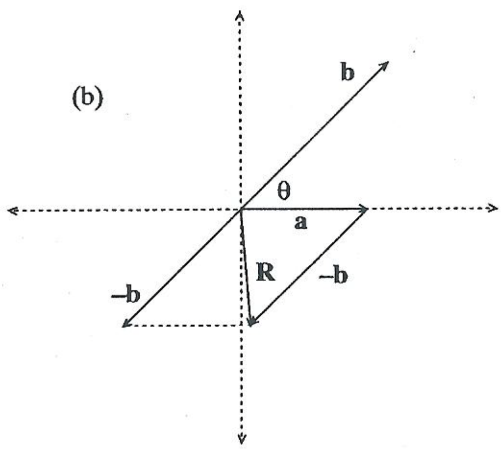


25. The easiest way to do this problem is by construction (graphically).
Given θ < 90°
1. Transfer tail of vector **b** to head of vector **a**.
2. Resultant of **a** + **b** is the vector **R** drawn from the tail of **a** to the head of **b**.
3. Examine the figure (a); **R** is the main diagonal of a parallelogram.

For **a** – **b** = **a** + (–b):
1. Transfer tail of vector – **b** to the head of vector **a**.
2. Resultant of **a** + (–**b**) is vector **R** drawn from the tail of **a** to the head of (–**b**).
3. Examine the figure (b); **R** is the minor diagonal of a parallelogram.

For 0 > 90°: follow the same procedure for the addition of two vectors as described in the previous part of this example.





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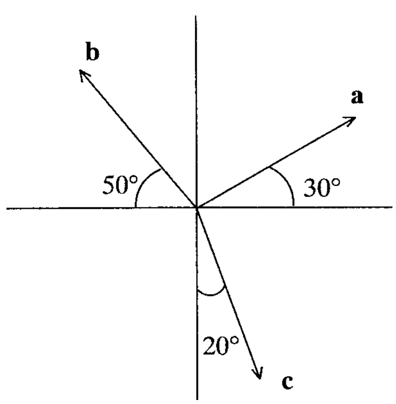


Find the components (x and y) for each vector and sum to determine components of the Resultant

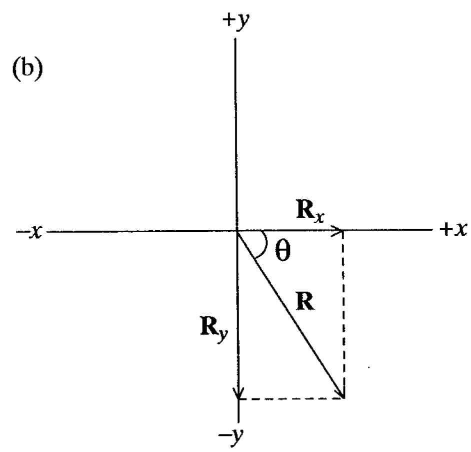
$a_x = (5\text{ km})\cos 30°$
$a_y = (5\text{ km})\sin 30°$
$b_x = -(10\text{ km})\cos 50°$
$b_y = (10\text{ km})\sin 50°$
$c_x = (20\text{ km})\sin 20°$
$c_y = -(20\text{ km})\cos 20°$
$R_x = a_x + b_x + c_x$
$R_x = 4.33\text{ km} - 6.43\text{ km} + 6.84\text{ km}$
$R_x = 4.74\text{ km}$

$R_y = a_y + b_y + c_y$
$= 2.5\text{ km} + 7.66\text{km} - 18.8\text{ km}$
$R_y = -8.63\text{ km}$

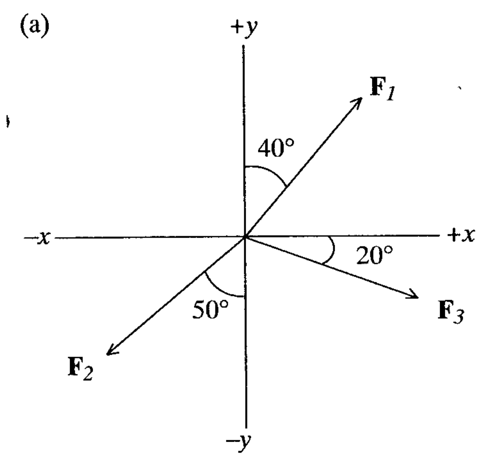
$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(4.74\text{ km})^2 + (-8.63\text{ km})^2} = 9.85\text{ km}$$

$$\tan\theta = \frac{R_y}{R_x} = \frac{8.63\text{ km}}{4.74\text{ km}} = 1.82$$

$\theta = 61.2^0$ below $+x$-axis



27.



Find the x- and y-components for each vector and sum to determine the components of the Resultant

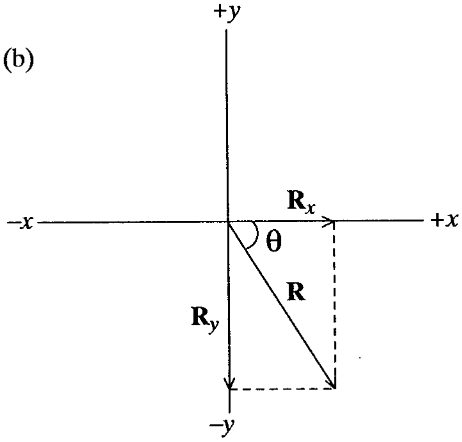
$F_{1x} = (2.00\text{ N})\sin 40°$
$F_{1y} = (2.00\text{ N})\cos 40°$
$F_{2x} = -(8.00\text{ N})\sin 50°$
$F_{2y} = -(8.00\text{ N})\cos 50°$
$F_{3x} = (6.00\text{ N})\cos 20°$
$F_{3y} = -(6.00\text{ N})\sin 20°$
$R_x = F_{1x} + F_{2x} + F_{3x}$
$= 1.29\text{ N} - 6.13\text{ N} + 5.64\text{ N} = 0.80\text{ N}$
$R_y = F_{1y} + F_{2y} + F_{3y}$
$= 1.53\text{ N} - 5.14\text{ N} - 2.05\text{ N} = -5.66\text{ N}$

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(0.80\text{ N})^2 + (-5.66\text{ N})^2} = 5.71\text{ N}$$

$$\tan\theta = \frac{R_y}{R_x} = \frac{5.66 \text{ N}}{0.80 \text{ N}} = 7.07$$

θ = 82°
θ = 82° below + x-axis

(b)



28. Given three vectors **A**, **B**, and **C**, a linear combination can be constructed so that

$$\mathbf{C} = n\mathbf{A} + m\boldsymbol{B},$$

where n and m are scalars. Write vectors **A** and **B** in terms of their components, A_x, A_y and B_x, B_y.
Multiply **A** by n, which yields nA_x and nA_y.
Multiply **B** by m which yields mB_x and mB_y.
By summing the x-components of **A** and **B**, the x-component of **C** is acquired:

$$C_x = nA_x + mB_x$$

Repeating the process for the y-components yields

$$C_y = nA_y + mB_y$$

The new vector **C** has components C_x and C_y given by $nA_x + mB_y$ and $nA_y + mB_y$, respectively.
The magnitude of **C** is

$$|\mathbf{C}| = \sqrt{C_x^2 + C_y^2} = \sqrt{(nA_x + mB_x)^2 + (nA_y + mB_y)^2}$$

$$\theta = \tan^{-1}\frac{C_y}{C_x} = \tan^{-1}\left(\frac{nA_y + mB_y}{nA_x + mB_x}\right)$$

29. Show that a = a_x **i** + a_y **j**
i = unit vector in x-direction
j = unit vector in y-direction
a_x = magnitude of x-component
a_y = magnitude of y-component
i has a magnitude of 1 unit. a_x = scalar and a_y = scalar.
Therefore a_x **i** is a vector of length a_x in the x-direction, which corresponds to the x-component of vector **a**.
Also, a_y **j** is a vector of length a_y in the y-direction, which corresponds to the y-component of vector **a**. Therefore **a** equals the vector sum of its x-and y-components and can be represented as **a** = a_x **i** + a_y **j**

$$|\mathbf{a}| = \sqrt{|a_x\mathbf{i}|^2 + |a_y\mathbf{j}|^2} = \sqrt{(a_x)^2 + (a_y)^2}$$

which is the definition of vector magnitude as expressed by equation 2.24.

30. This relationship is called the Cauchy - Schwartz inequality and can be demonstrated by using the special case of the right triangle. Let **a** be 4 units and **b** be 3 units. Also let **a** be perpendicular to **b**. Then **a** and **b** form the sides of a right triangle with an hypotenuse of 5 units, represented by the vector **c**.

$$|\mathbf{c}| = \sqrt{|\mathbf{a}|^2 + |\mathbf{b}|^2} = \sqrt{(4)^2 + (3)^2} = 5 \text{ units}$$

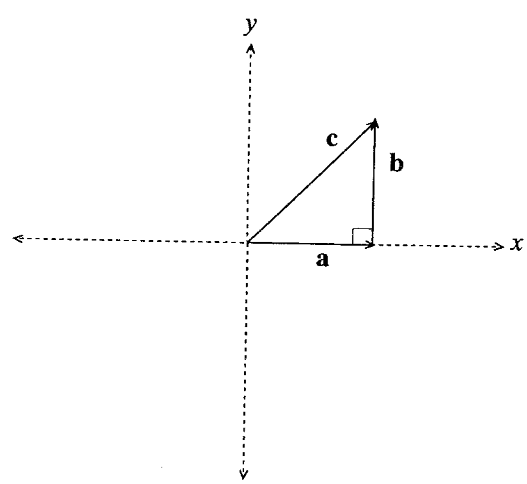
$$|\mathbf{a} + \mathbf{b}| = |\mathbf{c}| = 5 \text{ units}$$

but $|\mathbf{a}| + |\mathbf{b}| = 4 \text{ units} + 3 \text{ units} = 7 \text{ units}$

It is therefore demonstrated that

$$|\mathbf{a} + \mathbf{b}| < |\mathbf{a}| + |\mathbf{b}|$$

By adding **a** and **b** in the same direction,
$|\mathbf{c}| = |\mathbf{a}| + |\mathbf{b}|$
$|\mathbf{a} + \mathbf{b}| = |\mathbf{a}| + |\mathbf{b}|$ = 4 units + 3 units = 7 units.
In this special case it has been demonstrated that
$|\mathbf{a} + \mathbf{b}| = |\mathbf{a}| + |\mathbf{b}|$
To prove this for all possible vectors, a vector algebra technique that is beyond the scope of the course must be employed.



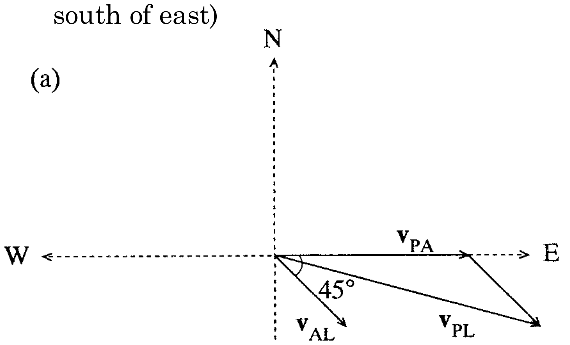
31. velocity of plane relative to the air
v_{PA} = 200 km/hr due east
velocity of air (wind) relative to land
$\mathbf{v}_{AL}$ = 40 km/hr; 45° S of E
$\mathbf{v}_{PL}$ = velocity of plane relative to land. Remember the wind direction is given from the direction in which it blows-northwest to southeast. fig. (a)
$\mathbf{v}_{PL} = \mathbf{v}_{PA} + \mathbf{v}_{AL}$
v_{PA}. = 200 km/hr

v_{ALx} = (40 km/hr) cos 45° = 28.3 km/hr
v_{PLx} = 200 km/hr + 28.3 km/hr = 228.3 km/hr
v_{PAy} = 0
v_{ALy} = –(40 km/hr) sin 45° = –28.3 km/hr
v_{PLy} = –28.3 km/hr
In 1 hr time, the plane will be
$d_x = v_x\, t$ = 228.3 km/hr (1 h) or 228.3 km east of its starting point A, and
$d_y = v_y$ t = 28.3 km/hr(1 h) = 28.3 km south of it starting point. If the city at *B* is 200 km from A, due east, then the plane has flown 228.3 km – 200 km = 28.3 km east and 28.3 km south of the city.
Its final position would be **D**. fig. (b)

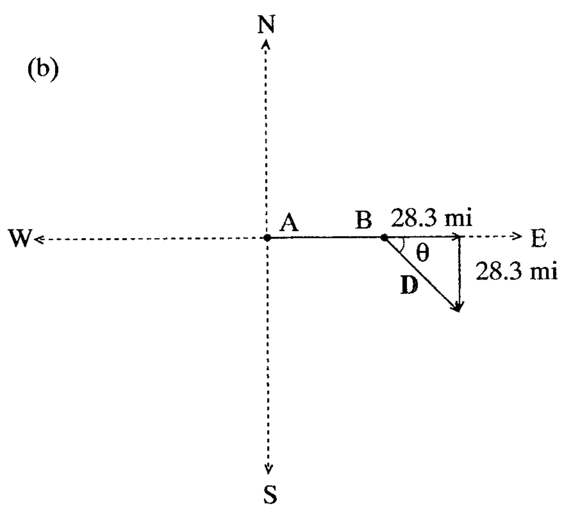
$$|\mathbf{D}| = \sqrt{(28.3)^2 + (28.3)^2}$$

= 40.0 km to the south east of the city at B (45° south of east)

(a)



(b)



32. a. **a** + **b** = **R**
a_x = 50 cos 33° = 41.9
a_y = 50 sin 33° = 27.2
b_x = 80 cos 128° = –49.3
b_y = 80 sin 128° = 63.0
$R_x = a_x + b_x$ = 41.9 + (–49.3) = –7.4
$R_y = a_y + b_y$ = 27.2 + 63.0 = 90.2

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-7.4)^2 + (90.2)^2} = 90.5$$

Direction second quadrant:

$$\tan\theta = \frac{R_y}{R_x} = \frac{90.2}{7.4} = 12.2$$

θ = 85.3° above – x-axis

b. **a** – **b** = **R**
$R_x = a_x - b_x$ = 41.9 – (–49.3) = 91.2
$R_y = a_y - b_y$ = 27.2 – 63.0 = – 35.8

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(91.2)^2 + (-35.8)^2} = 97.97 = 98.0$$

Direction fourth quadrant:

$$\tan\theta = \frac{R_y}{R_x} = \frac{35.8}{91.2} = 0.393$$

θ = 21.4° below + x-axis

c. **a** – 2**b** = **R**
$R_x = a_x - 2b_x$ = 41.9 – 2(-493) = 140.5 = 141
$R_y = a_y - 2b_y$ = 27.2 – 2(63.0) = –98.8

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(141)^2 + (-98.8)^2} = 172$$

Direction fourth quadrant

$$\tan\theta = \frac{R_y}{R_x} = \frac{98.8}{141} = 0.701$$

θ = 35.0° below + x-axis

d. 3**a** + **b** = **R**
$R_x = 3a_x + b_x$ = 3(41.9) + (–49.3) = 76.4
$R_y = 3a_y + b_y$ = 3(27.2) + (63.0) = 145

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(76.4)^2 + (145)^2} = 164$$

Direction first quadrant:

$$\tan\theta = \frac{R_y}{R_x} = \frac{145}{76.4} = 1.90$$

θ = 62.2° above + x-axis

e. 2**a** – **b** = **R**
$R_x = 2a_x - b_x$ = 2(41.9) – (–49.3) =133
$R_y = 2a_y - b_y$ = 2(27.2) – (63.0) = –8.60

$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(133)^2 + (-8.60)^2} = 133$$

Direction fourth quadrant:
θ = 3.7° below + x-axis

f. 2**b** – **a** = **R**
$R_x = 2b_x - a_x$ = 2(–49.3) – 41.9 = –141
$R_y = 2b_y - a_y$ = 2(63.0) – 27.2 = 98.8

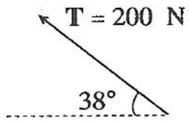
$$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-141)^2 + (98.8)^2} = 172$$

Direction second quadrant

$$\tan\theta = \frac{R_y}{R_x} = \frac{98.8}{141} = 0.701$$

θ = 35.0° above – x-axis

33. T_y = (200 N) sin 38° = 123 N
T_x = (200 N) cos 38° = 158 N



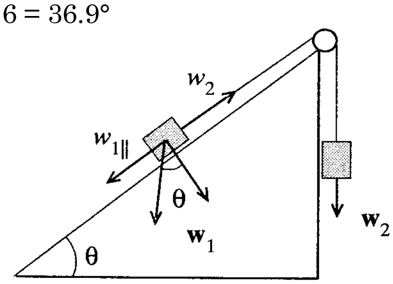
34. The force exerted by the hanging block ($\mathbf{w}_2$) is transmitted through the string and is equal to the force, exerted up the incline, that holds the second block in place. Since the blocks do not move, the force $\mathbf{w}_2$ must balance, be equal to, the component of $\mathbf{w}_1$ that acts parallel to and down the incline.

$w_{1||} = w_2$

$w_{1||} = w_1 \sin\theta = w_2$

$\sin\theta = \dfrac{w_2}{w_1} = \dfrac{3\text{ N}}{5\text{ N}} = 0.6$

$\theta = \sin^{-1}0.6 = 36.9°$

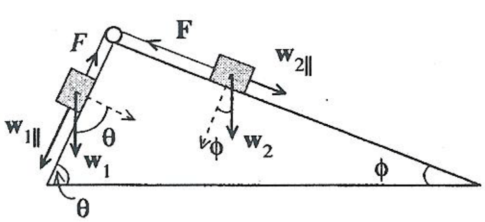


35. The force holding block 1 up is equal to the force holding block 2 up. This force **F**, is also equal to the component of $\mathbf{w}_1$ downward and parallel to the plane. Further more, this force **F** is equal to the component of $\mathbf{w}_2$ downward and parallel to the plane. Therefore,

$F = w_1 \sin\theta = w_2 \sin\phi$

$\sin\phi = \dfrac{w_1}{w_2}\sin\theta = \dfrac{2\text{ N}}{5\text{ N}}\sin 65° = 0.363$

$\phi = \sin^{-1} 0.363 = 21.3^0$



36. The force **F** acts all along the string. Redraw the diagram.

θ = 10°

The components of **F** acting in the vertical direction must sum to equal the weight **w** for the object to be held in place. The component of **F** in the vertical direction is $F\sin\theta$, therefore,

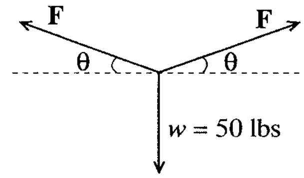
$2F\sin\theta = w$

$F = \dfrac{w}{2\sin\theta} = \dfrac{50\text{ N}}{2\sin 10°} = 144\text{ N}$

if θ = 20°,

$F = \dfrac{50\text{ N}}{2\sin 20°} = 73.1\text{ N}$

Note that the force is about half as great.



37. $\mathbf{r}_1$ = 20 m, $\theta_1 = 60^0$
$\mathbf{r}_2$ = 25 m, θ_2 = 25°

r_{1x} = (20 m) cos 60^0 = 10.0 m

r_{1y} = (20 m) sin 60° = 17.3 m

r_{2x} = (25 m) cos 25° = 22.7 m

r_{2y} = (25 m) sin 25° = 10.6 m

$\mathbf{R} = \mathbf{r}_2 - \mathbf{r}_1$

$R_x = r_{2x} - r_{1x}$ = 22.7 m – 10.0 m = 12.7m

$R_y = r_{2y} - r_{1y}$ = 10.6m – 17.3 m= –6.7m

$|\mathbf{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(12.7)^2 + (-6.7)^2} = 14.4$

Direction first quadrant:

$\tan\theta = \dfrac{R_y}{R_x} = \dfrac{-6.7}{12.7} = -0.528$

θ = –27.8° below the + x-axis

Chapter 3 Kinematics - The Study of Motion

1. (25 min(1 hr/60 min) = 0.417 hr

$\Delta t = 5.00 \text{ hr} + 0.417 \text{ hr} = 5.417 \text{ hr}$

a. $v_{av} = \frac{\Delta x}{\Delta t} = \frac{500 \text{ km}}{5.417 \text{ hr}} = 92.3 \text{ km/hr}$

b. 92.3 km/hr (1000 m/km)(1 hr/3600 s) = 25.6 m/s

2. $v = \Delta x/\Delta t$

Determine the distance traveled for each part

$\Delta x_1 = 65 \text{ km/hr}(2 \text{ hr}) = 130 \text{ km}$

$\Delta x_2 = 100 \text{ km/hr}(3 \text{ hr}) = 300 \text{ km}$

$\Delta x = \Delta x_1 + \Delta x_2 = 130 \text{ km} + 300 \text{ km} = 430 \text{ km}$

The average velocity is defined as the total distance traveled divided by the total time.

$v_{av} = \frac{\Delta x}{\Delta t} = \frac{430 \text{ km}}{5.00 \text{ hr}} = 86.0 \text{ km/hr}$

3. $x = v_{av}\, t = 343 \text{ m/s } (5 \text{ s}) = 1715 \text{ m} = 1720 \text{ m}$ away

4. $v_{av} = \frac{\Delta x}{\Delta t} = \frac{3.84 \times 10^8 \text{ m}}{3.00 \text{ day}} = 1.28 \times 10^8 \text{ m/day}$

$v_{av} = 1.28 \times 10^8 \text{ m/day}(1 \text{ day}/24 \text{ hr})(1 \text{ hr}/3600 \text{ s})$

$= 1480 \text{ m/s}$

5. Since this is a radio transmission

v_{avg} = speed of light = c

$x = v_{avg}\, t$

$t = \frac{x}{c} = \frac{7.80 \times 10^7 \text{ km}}{3 \times 10^8 \text{ m/s}} = \frac{7.80 \times 10^7 \text{ km } (1000 \text{ m/km})}{3 \times 10^8 \text{ m/s}}$

$t = 260 \text{ sec} = 4.33 \text{ min}$

6. $x = v_{avg}\, t$

160 km/hr(1000 m/km)(1 hr/3600 s) = 44.4 m/s

$t = \frac{x}{v_{avg}} = \frac{18.5 \text{ m}}{44.4 \text{ m/s}} = 0.417 \text{ s}$

For a speed of 95.0 km/hr,

95 km/hr(1000 m/km)(1 hr/3600 s) = 26.4 m/s

$t = \frac{x}{v_{avg}} = \frac{18.5 \text{ m}}{26.4 \text{ m/s}} = 0.700 \text{ s}$

7. Student 1 will run around the track in a time

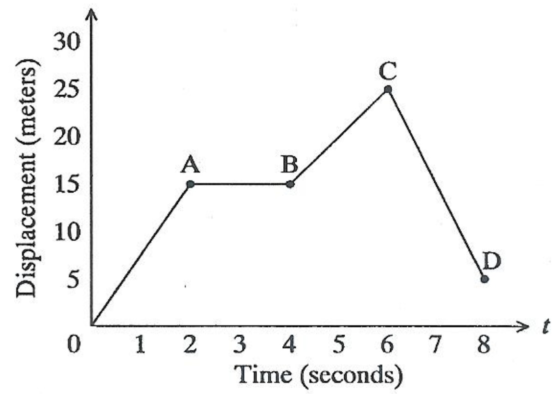
$t = \frac{x}{v_{1avg}} = \frac{2\pi r_1}{v_{avg}} = \frac{2\pi(250 \text{ m})}{4.50 \text{ m/s}} = 349.1 \text{ s}$

In order for student 2 to "keep up" with student 1 he must also run around the track in 349.1 sec. However, student 2 travels a greater distance $x = 2\pi r_2$. His speed must therefore be

$v_{2avg} = \frac{x_2}{t} = \frac{2\pi r_2}{t} = \frac{2\pi(255 \text{ m})}{349.1\text{s}}$

$v_{2avg} = 4.59 \text{ m/s}$

8. To find the velocity along each segment, find the slope of the line along each segment.



a. $OA: v_{avg} = \frac{\Delta x}{\Delta t} = \frac{15 \text{ m} - 0 \text{ m}}{2 \text{ s} - 0 \text{ s}} = 7.5 \text{ m/s}$

b. $AB: v_{avg} = \frac{\Delta x}{\Delta t} = \frac{15 \text{ m} - 15 \text{ m}}{4 \text{ s} - 2 \text{ s}} = 0 \text{ m/s}$

c. $BC: v_{avg} = \frac{\Delta x}{\Delta t} = \frac{25 \text{ m} - 15 \text{ m}}{6 \text{ s} - 4 \text{ s}} = 5 \text{ m/s}$

d. $CD: v_{avg} = \frac{\Delta x}{\Delta t} = \frac{5 \text{ m} - 25 \text{ m}}{8 \text{ s} - 6 \text{ s}} = -10 \text{ m/s}$

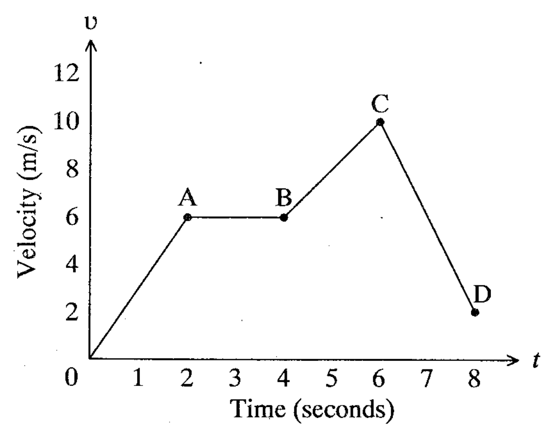
9. To find the acceleration along each segment, find the slope of the line along each segment.

a. $OA: a_{avg} = \frac{\Delta v}{\Delta t} = \frac{6 \text{ m/s} - 0 \text{ m/s}}{2 \text{ s} - 0 \text{ s}} = 3 \text{ m/s}^2$

b. $AB: a_{avg} = \frac{\Delta v}{\Delta t} = \frac{6 \text{ m/s} - 6 \text{ m/s}}{4 \text{ s} - 2 \text{ s}} = 0 \text{ m/s}^2$

c. $BC: a_{avg} = \frac{\Delta v}{\Delta t} = \frac{10 \text{ m/s} - 6 \text{ m/s}}{6 \text{ s} - 4 \text{ s}} = 2 \text{ m/s}^2$

d. $CD: a_{avg} = \frac{\Delta v}{\Delta t} = \frac{2 \text{ m/s} - 10 \text{ m/s}}{8 \text{ s} - 6 \text{ s}} = -4 \text{ m/s}^2$



10. **a.** (110 naut. mi/hr)(6076 ft/naut. mi) ×
(1m/3.281 ft)(1 km/1000 m) = 204 km/hr

b. (110 naut. mi/hr)(6076 ft/naut. mi) × (1m/3.281 ft)(1 hr/3600 s) = 56.6 m/s

11. Using the kinematic equations derived in the chapter, the girl's initial speed is 1.00 m/s and her final speed is 2.50 m/s

$v = v_o + at$

$\frac{v - v_o}{t} = a$

$a = \frac{2.50\text{ m/s} - 1.00\text{ m/s}}{5.00\text{ s}} = 0.300\text{ m/s}^2$

12. The final velocity of the car is zero.

$v_o = (95\text{ km/hr})(1000\text{ m/km})(1\text{ hr}/3600\text{ s})$
$= 26.4\text{ m/s}$

$v^2 = v_o^2 + 2ax$

$\frac{v^2 - v_o^2}{2x} = a$

$a = \frac{0 - (26.4\text{ m/s})^2}{2(60\text{ m})} = -5.81\text{ m/s}^2$

Note: the result is negative, which demonstrates that the car is decelerating.

13. Convert from km/hr to m/s.

$v_o = 25\text{ km/hr }(1000\text{ m/km})(1\text{ hr}/3600\text{s}) = 6.94\text{ m/s}$

$v_f = 65\text{ km/hr }(1000\text{ m/km})(1\text{ hr}/3600\text{ s}) = 18.1\text{ m/s}$

The acceleration is determined from

$v_f = v_o + at$

$a = \frac{v_f - v_o}{t} = \frac{18.1\text{ m/s} - 6.94\text{ m/s}}{8.5\text{ s}} = 1.31\text{ m/s}^2$

The distance is determined from

$x = v_ot + {}^1/_2\, at^2$ assuming $x_o = 0$

$x = (6.94\text{ m/s})(8.5\text{ s}) + 1/2\,(1.31\text{ m/s}^2)(8.5\text{ s})^2$

$x = 106\text{ m}$

14. To determine the "takeoff" velocity use:

$v_f = v_o + at$ where $v_o = 0$ and $t = 15.0$ s.

To determine the needed acceleration use:

$x = v_ot + \frac{1}{2}at^2$

$a = \frac{2x}{t^2} = \frac{2(0.450\text{ km})(1000\text{ m/km})}{-(15.0\text{ s})^2} = 4.00\text{ m/s}^2$

The final velocity at takeoff is

$v_f = v_o + at = 0 + (4.00\text{ m/s}^2)15\text{ s} = 60.0\text{ m/s}$

$v_f = 60\text{ m/s}(3600\text{ s/hr})(1\text{ km}/1000\text{ m})$

$v_f = 216\text{ km/hr}$

15. $v_o = 0$;

$v = 30.0\text{ km/hr}(1000\text{ m/km})(1\text{ hr}/3600\text{s}) = 8.33\text{ m/s}$

The acceleration needs to be determined in order to use it in the distance relationships.

$v = v_o + at$

$a = \frac{v}{t} = \frac{8.33\text{ m/s}}{10.0\text{ s}} = 0.833\text{ m/s}^2$

To find the distance, we need the relationship

$x = v_ot + \frac{1}{2}\, at^2$

$x_1 = \frac{1}{2}\, at^2 = \frac{1}{2}\,(0.833\text{ m/s}^2)(10\text{ s})^2 = 41.7\text{ m}$;

$v_1 = at = (0.833\text{ m/s}^2)(10\text{ s}) = 8.33\text{ m/s}$

$x_2 = \frac{1}{2}\, at^2 = \frac{1}{2}\,(0.833\text{ m/s}^2)(15\text{ s})^2 = 93.7\text{ m}$;

$v_2 = at = (0.833\text{ m/s}^2)(15\text{ s}) = 12.5\text{ m/s}$

$x_3 = \frac{1}{2}\, at^2 = \frac{1}{2}\,(0.833\text{ m/s}^2)(20\text{ s})^2 = 167\text{ m}$;

$v_3 = at = (0.833\text{ m/s}^2)(20\text{ s}) = 16.7\text{ m/s}$

$x_4 = \frac{1}{2}\, at^2 = \frac{1}{2}\,(0.833\text{ m/s}^2)(25\text{ s})^2 = 260\text{ m}$;

$v_4 = at = (0.833\text{ m/s}^2)(25\text{ s}) = 20.8\text{ m/s}$

16. $v^2 = v_o^2 + 2ax$

$a = \frac{v^2 - v_o^2}{2x} = -\frac{(75.0\text{ m/s})^2 - 0}{2(725\text{ m})} = 3.88\text{ m/s}^2$

17. $v^2 = v_o^2 + 2ax$

$a = \frac{v^2 - v_o^2}{2x} = -\frac{(5.3 \times 10^8\text{ cm/s})^2 - 0}{2(0.25\text{ cm})} = 3.88\text{ m/s}^2$

$= 5.62 \times 10^{17}\text{ cm/s}^2$

18. $v = 100\text{ km/hr}(1000\text{ m/km})(1\text{ hr}/3600\text{s})$
$= 27.8\text{ m/s}$

$v^2 = v_o^2 + 2ax$

$a = \frac{v^2 - v_o^2}{2x} = \frac{0 - (27.8\text{ m/s})^2}{2(130\text{ m})} = -2.97\text{ m/s}^2$

Note: The negative sign indicates a deceleration.

19. Convert km/hr to m/s.

$v_o = 140\text{ km/hr}(1000\text{ m/km})(1\text{ hr}/3600\text{s}) = 38.9\text{ m/s}$

Knowing the distance to come to a stop,

$v^2 = v_o^2 + 2ax$

$a = \frac{v^2 - v_o^2}{2x} = \frac{0 - (38.9\text{ m/s})^2}{2(120\text{ m})} = -6.31\text{ m/s}^2$

$v_f = v_o + at$

$t = \frac{v_f - v_o}{a} = \frac{0 - 38.9\text{ m/s}}{-6.31\text{ m/s}^2} = 6.16\text{ s}$

20. $v^2 = v_o^2 + 2ax$

$a = \frac{v^2 - v_o^2}{2x} = \frac{(30.0\text{ m/s})^2 - 0}{2(2.50\text{ m})} = 180\text{ m/s}^2$

21. $v_o = 95\text{ km/hr}(1000\text{ m/km})(1\text{ hr}/3600\text{s}) = 26.4\text{ m/s}$

The final velocity is zero.

$v = v_o + at$

Using the above equation, solve for a and substitute into the equation for distance traveled.

$a = \frac{v - v_o}{t} = \frac{0 - 26.4\text{ m/s}}{4.55\text{ s}} = -5.80\text{ m/s}^2$

$x = v_ot + {}^1/_2\, at^2$

$x = (26.4\text{ m/s})(4.55\text{ s}) + {}^1/_2\,(-5.80\text{ m/s}^2)(4.55\text{ s})^2$.

$x = 60.1$ m traveled before the car comes to rest

22. $v_o = ?$; $a = ?$; $v = 50$ m/s; $x = 200$ m
Since the initial velocity v_o is unknown, solve for it and substitute $v = v_o + at$ into the given distance equation.
$x = v_o t + {}^1/_2\, at^2$
$v - a\,t = v_o$
$x = (v - at)t + {}^1/_2\, at^2 = v\,t - at^2 + {}^1/_2\, at^2 = v\,t - {}^1/_2\, at^2$
Solve for the acceleration, it is the only unknown in the equation.
$$a = -2\frac{(x - ut)}{t^2} = -2\frac{[200\text{ m} - 50\text{ m/s }(8\text{ s})]}{(8\text{ s})^2}$$
$= 6.25$ m/s ^{2}
$v_o = v - at = 50$ m/s $- 6.25$ m/s ^{2} (8 s) $= 0$ m/s

23. $v_o = 30$ km/hr(1000 m/km)(1 hr/3600) $= 8.33$ m/s
The velocity is constant during the reaction time of the driver, $t = 0.600$ s, therefore the distance traveled is
$x_{react} = v_{avg}\, t = 8.33$ m/s(0.600 s) $= 5.00$ m
Deceleration: $a = -4.50$ m/s'
The stopping distance during deceleration is determined from
$v^2 = v_o^2 + 2ax$
$$x = \frac{v^2 - v_o^2}{2a} = \frac{0 - (8.33\text{ m/s})^2}{2(-4.5\text{ m/s}^2)} = 7.71\text{ m}$$
The total distance traveled at 30 km/hr
$= x_{react} + x_{decel} = 5.00$ m $+ 7.71$ m $= 12.7$ m.
By tripling the speed to 90 km/hr or 25.0 m/s the reaction time distance is tripled from 5.0 m to 15 m.
$$x_{decel} = \frac{v^2 - v_o^2}{2a} = \frac{0 - (25.0\text{ m/s})^2}{2(-4.5\text{ m/s}^2)} = 69.4\text{ m}$$
Total distance traveled $= x_{react} + x_{decel}$
$= 15.0$m $+ 69.4$m $= 84.4$m

24. $v_o = 25.0$ km/hr (1000 m/km)(1 hr/3600)
$= 6.94$ m/s
$x = v_o t + 1/2\, at^2$
$$a = \frac{2(x - v_o t)}{t^2} = \frac{2(125\text{ m} - (6.94\text{ m/s})(12\text{ s}))}{(12\text{ s})^2}$$
$= 0.579$ m/s^2
$v = v_o + at = 6.94$ m/s $+ 0.579$ m/s^2 (12s)
$= 13.9$ m/s

25. $v_o = 80$ km/hr(1000 m/km)(1 hr/3600s)
$= 22.2$ m/s
$v = 130$ km/hr(1000 m/km)(1 hr/3600s)
$= 36.1$ m/s
There are two possible methods to solve this problem. First, find the acceleration and then the distance.
$$a = \frac{v - v_o}{t} = \frac{36.1\text{ m/s} - 22.2\text{ m/s}}{26.9\text{ s}} = 0.517\text{ m/s}^2$$
$x = v_o t + {}^1/_2\, at^2$
$= 22.2$ m/s (26.9 s) $+ {}^1/_2$ (0.517 m/s^2)(26.9 s)^2
$= 784$ m
Or, find the average velocity and then the distance.
$x = v_{avg}\, t = {}^1/_2\,(v_o + v)t$
$= {}^1/_2$ (22.2 m/s + 36.1 m/s)(26.9 s)
$= 784$ m

26. Find the distance during each type of motion and then the total distance $= d_1 + d_2 + d_3$.
1. The acceleration of 4 m/s ^{2}
$d_1 = v_0 t_1 + 1/2\, at^2 = 0 +$ (4 m/s^2)(5 s)$^2 = 50$ m
2. Determine the velocity after 5 s; and this velocity is constant for 25 s.
$d_2 = v_2 t_2 = (v_o + at_1)t_2 = (0 + 4$ m/s^2 (5 s))(25 s) $= 500$ m
$v_2 = v_0 + at_1 = 0 + 4$ m/s ^{2} (5 s) $= 20$ m/s
$v^2 = v_3^2 + 2ad_3$
3. The deceleration of 2.00 m/s ^{2}
$v_3 = v_2 = 20$ m/s
$v = 0$
$$d_3 = \frac{v^2 - v_3^2}{2a_3} = \frac{0 - (20\text{ m/s})^2}{2(-2.00\text{ m/s}^2)} = 100\text{ m}$$
The total distance $= d_1 + d_2 + d_3$
$= 50$ m $+ 500$ m $+ 100$ m $= 650$ m

27. Total time $= t_1 + t_2$;
$a_1 = 3.00$ m/s ^{2}; $a_2 = +0.500$ m/s^2
t_1 is the time to reach a velocity of 18 m/s.
$v = v_o + at_1$
$$\frac{v - vo}{a} = t_1 = \frac{18\text{ m/s} - 0}{3\text{ s}} = 6\text{ s}$$
t_2 is the time to cover a distance of 250 m.
$x = v_1 t_2 + {}^1/_2\, a_2 t_2^2$
250 m $= 18$ m/s $(t_2) + 1/2\,(+0.5$ m/s$^2)t_2^2$
$0.25t_2^2 + 18t_2 - 250 = 0$
Apply the quadratic formula
$$t_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$t_2 = \frac{-18 \pm \sqrt{18^2 - 4(0.25)(-250)}}{2(0.25)}$$
$= 12.0$ s
Total time $T = t_1 + t_2 = 6$ s $+ 12.0$ s $= 18.0$ s
Another way to solve is as follows: $t_1 = 6$ s
$v^2 = v_1^2 + 2ax$
Find the velocity after traveling 250 m
$v^2 = (18.0$ m/s$)^2 + 2(+0.5$ m/s^2)(250 m)
$= 574$ m^2/s^2
$v = 24.0$ m/s
Find the time to accelerate to that velocity.
$v = v_1 + at_2$
$$t_2 = \frac{v - v_1}{a} = \frac{24.0\text{ m/s} - 18\text{ m/s}}{-0.500\text{ m/s}^2} = 12\text{ s}$$
Total time $T = 6$ s $+ 12.0$ s $= 18.0$ s

28. The deck is to be $y = 0$ and the water is $y = -15$ m; downward is negative.
$v^2 = v_o^2 - 2gy = 0 - 2(9.8 \text{ m/s}^2)(-15 \text{ m})$
$= 294 \text{ m}^2/\text{s}^2$
We must choose the minus root because downward is negative.
$v = -17.2$ m/s

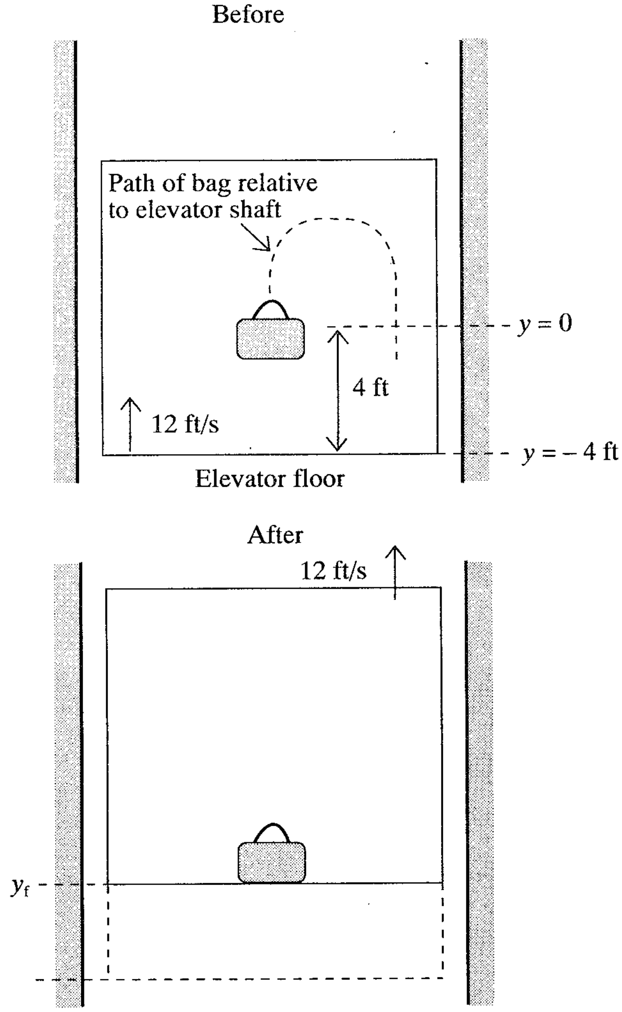
29. The level of the bridge is taken as $y = 0$, and the water below as $y = -30$ m.
$y = v_o t - 1/2 gt^2$
$-30 \text{ m} = 0 - 1/2(9.8 \text{ m/s}^2)t^2$
$\sqrt{\dfrac{2(30 \text{ m})}{9.8 \text{ m/s}^2}} = t = 2.47$ s
$v = v_o - gt$
$v = 0 - 9.8 \text{ m/s}^2(2.47 \text{ s}) = -24.2$ m/s

30. $v = 95 \text{ km/hr}(1000 \text{ m/km})\left(\dfrac{1 \text{ hr}}{3600 \text{ s}}\right) = 26.4$ m/s
$v^2 = v_o^2 - 2gy$
$$y = \frac{v^2 - v_0^2}{-2g} = \frac{(26.4 \text{ m/s})^2 - 0}{-2(9.80 \text{ m/s}^2)} = 35.6 \text{ m}$$
The car must fall a distance downward of 35.6 m.

31. The top of the building is taken as $y = 0$.
$y = v_o t - 1/2\, gt^2 = 0 - 1/2\,(9.8 \text{ m/s}^2)(8 \text{ s})^2 = -314$ m
The rock falls 314 m; the building is 314 m tall.

32. $y = v_o t - 1/2 gt^2$ $\quad v_o = 0$
$$t = \sqrt{\frac{-2y}{g}} = \sqrt{\frac{-2(-50 \text{ m})}{9.8 \text{ m/s}^2}} = 3.19 \text{ s}$$

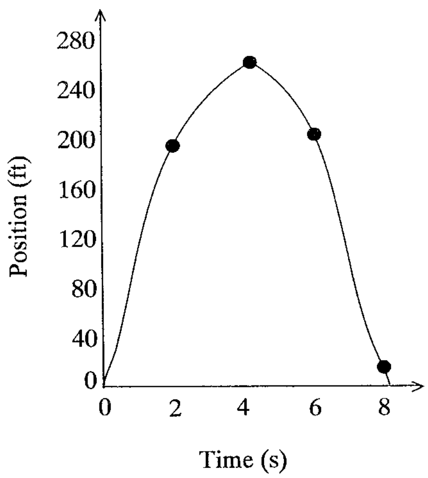
33. The handbag has an initial velocity of 3.75 m/s upward, and its position is taken as $y = 0$, relative to the elevator shaft. The motion of the handbag is taken as
$y_f = v_o t - 1/2 gt^2$
$-(3.75 \text{ m/s})t - 1/2\,(9.80 \text{ m/s}^2)t^2 = 3.75t - 4.9t^2$
y_f is the position where the handbag meets the elevator floor relative to the elevator shaft.
The floor of the elevator is moving upward at a constant speed of 3.75 m/s and meets the handbag at the same position y_f. The floor, however, starts off 1.25 m below the handbag's initial position
$y_f = -1.25 \text{ m} + (3.75 \text{ m/s})t = -1.25 + 3.75t$
The two final positions are the same.
$3.75t - 4.9t^2 = -1.25 + 3.75t$
$t^2 = 0.255 \text{ s}^2$
$t = 0.505$ s
The bag will hit the floor in 0.505 s (see diagram). Since the velocity of the elevator is constant, the time for the bag to hit the floor should be the same as the time for the handbag to hit the floor if the elevator was

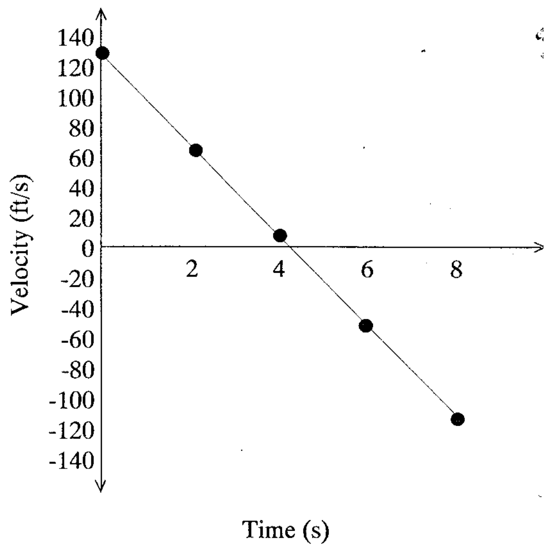


not moving at all
$y_f = v_i t - 1/2 gt^2$
$-1.25 \text{ m} = 1/2\,(9.80 \text{ m/s}^2)t^2$
$0.505 \text{ s} = t$ It is the same!

34. $y = v_o t - 1/2 gt^2$
$v = v_o - gt$
$y_2 = (40 \text{ m/s})(2 \text{ s}) - 1/2\,(9.80 \text{ m/s}^2)(2 \text{ s})^2 = 60.4$ m
$v_2 = 40 \text{ m/s} - (9.80 \text{ m/s}^2)(2 \text{ s}) = 20.4$ m/s
$y_4 = (40 \text{ m/s})(4 \text{ s}) - 1/2\,(9.80 \text{ m/s}^2)(4 \text{ s})^2 = 81.6$ m
$v_4 = 40 \text{ m/s} - (9.80 \text{ m/s}^2)(4 \text{ s}) = 0.800$ m/s
$y_6 = (40 \text{ m/s})(6 \text{ s}) - 1/2\,(9.80 \text{ m/s}^2)(6 \text{ s})^2 = 63.6$ m
$v_6 = 40 \text{ m/s} - (9.80 \text{ m/s}^2)(6 \text{ s}) = -18.8$ m/s
$y_8 = (40 \text{ m/s})(8 \text{ s}) - 1/2\,(9.80 \text{ m/s}^2)(8 \text{ s})^2 = 6.4$ m
$v_8 = 40 \text{ m/s} - (9.80 \text{ m/s}^2)(8 \text{ s}) = -38.4$ m/s
Note: The velocity is negative on the way down.

Position versus Time





35. $y = v_0t - 1/2gt^2$

$v = v_0 - gt$

$y_1 = (40\text{ m/s})(1\text{ s}) - 1/2\,(9.80\text{ m/s}^2)(1\text{ s})^2 = 35.1\text{ m}$

$v_1 = 40\text{ m/s} - (9.80\text{ m/s}^2)(1\text{ s}) = 30.2\text{ m/s}$

$y_3 = (40\text{ m/s})(3\text{ s}) - 1/2\,(9.80\text{ m/s}^2)(3\text{ s})^2 = 75.9\text{ m}$

$v_3 = 40\text{ m/s} - (9.80\text{ m/s}^2)(3\text{ s}) = 10.6\text{ m/s}$

$y_5 = (40\text{ m/s})(5\text{ s}) - 1/2\,(9.80\text{ m/s}^2)(5\text{ s})^2 = 77.5\text{ m}$

$v_5 = 40\text{ m/s} - (9.80\text{ m/s}^2)(5\text{ s}) = -9.0\text{ m/s}$

$y_7 = (40\text{ m/s})(7\text{ s}) - 1/2\,(9.80\text{ m/s}^2)(7\text{ s})^2 = 39.9\text{ m}$

$v_7 = 40\text{ m/s} - (9.80\text{ m/s}^2)(7\text{ s}) = -28.6\text{ m/s}$

Note: The velocity is negative on the way down

36. Let $y = 0$ at top of building. The final position is 40 m below the top of the building.

$y = -40\text{ m} \quad v_0 = 25\text{ m/s}$

$y = v_0t - 1/2gt^2$

$-40\text{ m} = (25\text{ m/s})t - 1/2\,(9.8\text{ m/s}^2)t^2$

$4.9t^2 - 25t - 40 = 0$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{25 \pm \sqrt{(-25)^2 - 4(4.9)(-40)}}{2(4.9)} = \frac{25 \pm 37.5}{9.8}$$

$= 6.38$ s or -1.28 s (Time cannot be negative.)

$t = 6.38$ s to reach ground

37. Let $y = 0$ at top of bridge. The final position is 30 m below the top of the bridge.

$y = v_0t - 1/2gt^2$

$-30\text{ m} = (15\text{ m/s})t - 1/2\,(9.80\text{ m/s}^2)t^2$

$4.90t^2 - 15t - 30 = 0$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{15 \pm \sqrt{(-15)^2 - 4(4.9)(-30)}}{2(4.9)} = \frac{15 \pm 28.5}{9.8}$$

$= 4.44$ s or -1.38 s

Time must be positive, so it took

$t = 4.44$ s to reach water level

38. The initial velocity is downward, v_0 is negative.

$v_0 = -15\text{ m/s}$

$y = 0$ at the top of bridge.

$y = v_0t - 1/2gt^2$

$-30\text{ m} = (-15\text{ m/s})t - 1/2\,(9.80\text{ m/s}^2)t^2$

$4.90t^2 + 15t - 30 = 0$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{-15 \pm \sqrt{(15)^2 - 4(4.9)(-30)}}{2(4.9)} = \frac{-15 \pm 28.5}{9.8}$$

$= 1.38$ s or -4.44 s

Time must be positive, so it took 1.38 s to reach water.

39. The initial velocity is downward, v_0 is negative.

$y_0 = 0$ at the top of the building

a. $v^2 = v_0^2 - 2gy$

$v^2 = (-15\text{ m/s})^2 - 2(9.8\text{ m/s}^2)(-40\text{ m})$

$= 1009\text{ m}^2/\text{s}^2$

$v = -31.8\text{ m/s}$

We must take the negative sign because the object is moving downward.

b. $v = v_0 - gt$

$$\frac{(v_0 - v)}{g} = t = \frac{[(-15\text{ m/s}) - (-31.8\text{ m/s})]}{9.8\text{ m/s}^2}$$

$t = 1.71$ s

40. Solve for initial speed first. We know it rises 30.0 m and at the top of the rise, the velocity $v = 0$.

$v^2 = v_0^2 - 2gy$

$2gy = v_o^2$

$v_0 = \sqrt{2gy} = \sqrt{2(9.80 \text{ m/s}^2)(30.0 \text{ m})} = 24.2 \text{ m/s}$

To find the time to reach the height, $v = 0$,

$v = v_o - gt$

$t = \dfrac{v - v_o}{-g} = \dfrac{0 - 24.2 \text{ m/s}}{-9.80 \text{ m/s}^2} = 2.47 \text{ s}$

The total time of the trip = $2t$

= 2.47 s(up) + 2.47 s(down) = 4.94 s

41. Determining the time it takes to travel the horizontal distance of 85 m.

$x = v_x t$

$t = \dfrac{x}{v_x} = \dfrac{85 \text{ m}}{15 \text{ m/s}} = 5.67 \text{ s}$

5.67 s is the time for the object to fall the height of the building with initial vertical velocity equal to zero.

$v_{oy} = 0$

$y = v_{oy}t - 1/2\, gt^2 = -1/2\,(9.8 \text{ m/s}^2)(5.67 \text{ s})^2$

$= -158 \text{ m}$

The building is 158 m tall.

42. $y = 0$ at the position of the nozzle and falls 0.650 m by the time it reaches the wall.

$y = v_{oy}t - ½\, gt^2$

$v_{oy} = 0$

$-0.650 \text{ m} = 0 - 1/2\,(9.8 \text{ m/s}^2)t^2$

$t = 0.364$ s, which is the time to fall 0.650 m.

The time to fall 0.650 m = the time to travel 7.00 m horizontally

$x = v_{0x}t$

$v_{0x} = \dfrac{x}{t} = \dfrac{7.00 \text{ m}}{0.364\text{s}} = 19.2 \text{ m/s}$

43. $v_0 = 970 \text{ km/hr}(1000 \text{ m/km})(1 \text{ hr}/3600 \text{ s}) = 269 \text{ m/s}$

Set $y = 0$ at the position of the airplane.

$v_{oy} = 0$

Find the time it takes for the bomb to fall 2000 m, with the initial vertical velocity = 0.

$y = -½\, gt^2$

$t = \sqrt{\dfrac{-2y}{g}} = \sqrt{\dfrac{-2(-2000 \text{ m})}{9.8 \text{ m/s}^2}} = 20.2 \text{ s}$

The horizontal distance is determined to be

$x = v_{0x}t = 269 \text{ m/s } (20.2 \text{ s}) = 5430 \text{ m}$

44. The initial velocity in the vertical direction = 0; determine the time to hit ground.

$y = 0$ at top of hill, $v_{ox} = 300$ m/s, $v_{oy} = 0$

$y = -½\, gt^2$

$t = \sqrt{\dfrac{-2y}{g}} = \sqrt{\dfrac{-2(-20 \text{ m})}{9.8 \text{ m/s}^2}} = 2.02 \text{ s}$ to reach ground

$x = v_{ox}t = 300 \text{ m/s } (2.02 \text{ s})$

= 606 m horizontal distance away

The velocity in the x-direction remains unchanged.

v_{ox} at ground = 300 m/s

The y-component is determined from the free–fall relationship

v_{yg} at ground $= v_{oy} - gt = 0 - 9.8 \text{ m/s}^2 (2.02\text{s})$

$v_{yg} = -19.8$ m/s downward

$|\mathbf{v}| = \sqrt{v_{0x}^2 + v_{0y}^2} = \sqrt{(300 \text{ m/s})^2 + (-19.8 \text{ m/s})^2} = 301 \text{ m/s}$

$\tan\theta = \dfrac{v_{0y}}{v_{0x}} = \dfrac{-19.8 \text{ m/s}}{300 \text{ m/s}} = -0.0660$

$\theta = -3.78°$ below the horizontal

45. Given the range, solve for the angle θ.

Range $= \dfrac{v_0^2 \sin 2\theta}{g}$

$\sin 2\theta = \dfrac{gR}{v_0^2} = \dfrac{(9.8 \text{ m/s}^2)(3000 \text{ m})}{(300 \text{ m/s})^2} = 0.327$

$2\theta = \sin^{-1} 0.327 = 19.1°$

$\theta = 9.55°$

46. By aiming 1.00 m above the target the angle of launch becomes

$\tan\theta = \dfrac{1.00 \text{ m}}{300 \text{ m}} = 3.33 \times 10^{-3}$

$\theta = 0.191^0$

Using the equation (3.47) for Range

$R = \dfrac{v_0^2 \sin 2\theta}{g}$

$v_o^2 = \dfrac{Rg}{\sin 2\theta}$

$v_0 = \sqrt{\dfrac{Rg}{\sin 2\theta}} = \sqrt{\dfrac{(300 \text{ m})(9.80 \text{ m/s}^2)}{\sin 2(0.191)}}$

$v_o = 664$ m/s

47. $v_o = 50.0$ m/s

$v_{oy} = (50.0 \text{ m/s}) \sin 55° = 41.0 \text{ m/s}$

$v_{ox} = (50.0 \text{ m/s}) \cos 55° = 28.7 \text{ m/s}$

$v_y = 0$ (The vertical component of the velocity at the top.)

a. $v^2 = v_o^2 - 2gy$

$y = \dfrac{-v_{oy}^2}{-2g} = \dfrac{-(41.0 \text{ m/s})^2}{-2(9.80 \text{ m/s}^2)} = 85.8 \text{ m}$

b. The final position of the golf ball is on the ground $y = 0$.

$y = v_{oy}t - 1/2gt^2$

$0 = v_{oy}t - 1/2gt^2$

$v_{oy} = 1/2gt$

$t = \dfrac{2v_{oy}}{g} = \dfrac{2(41.0 \text{ m/s})}{9.80 \text{ m/s}^2} = 8.37 \text{ s}$

c. $R = \dfrac{v_0^2 \sin 2\theta}{g} = \dfrac{(50.0 \text{ m/s})^2 \sin 2(55°)}{9.80 \text{ m/s}^2}$

$= 240 \text{ m}$

48. $v_0 = 20$ m/s
The vertical component of the velocity at the top $v_y = 0$.

a. $v_y^2 = v_{oy}^2 - 2gy$
$v_y = 0$
$$y = \frac{-v_{oy}^2}{-2g} = \frac{-(v_o \sin\theta)^2}{-2g}$$
$$= -\frac{[(20 \text{ m/s}) \sin 40^0]^2}{-2(9.8 \text{ m/s}^2)} = 8.43 \text{ m}$$

b. $v_y = v_{oy} - gt$
$$t = \frac{-v_{oy}}{-g} = \frac{-v_o \sin\theta}{-g} = \frac{-(20 \text{ m/s}) \sin 40°}{-9.8 \text{ m/s}^2}$$
$=1.31$ s

c. At top of trajectory, the vertical component $v_y = 0$.
$v_x = v_{ox} = v_o \cos\theta = (20 \text{ m/s})(\cos 40°)$
$=15.3$ m/s horizontally

d. $$R = \frac{v_o^2 \sin 2\theta}{g} = \frac{(20 \text{ m/s})^2 \sin 2(40°)}{9.8 \text{ m/s}^2}$$
$= 40.2$ m

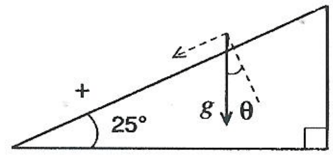
e. The time of flight is equal to twice the time to reach maximum height (path is symmetrical), from part (b)
$T = 2t = 2(1.31 \text{ s}) = 2.62$ s

49. $v =(16{,}000 \text{ km/hr})(1000 \text{ m/km})(1 \text{ hr}/3600\text{s})$
$= 4440$ m/s

a. The average acceleration is
$$a = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{\Delta t} = \frac{4440 \text{ m/s} - 0}{120\text{s}}$$
$= 37.0 \text{ m/s}^2$

b. $g = 9.8 \text{ m/s}^2$
$$\frac{37.0 \text{ m/s}^2}{9.8 \text{ m/s}^2} = 3.78 \times \text{acceleration due to gravity}$$
$= 3.78$ g's

50. $\theta = 25°$ (see figure below)
Acceleration down the ramp is the component of gravity (g) parallel to the surface of the ramp.
$a = g \sin\theta = 9.8 \text{ m/s}^2 (\sin 25°) = 4.14 \text{ m/s}^2$
(positive is downward in this case)
The length $=10.0$ m
$v^2 = v_o^2 + 2ax$
$v^2 = 0 + 2(g \sin\theta)x = 2(9.8 \text{ m/s}^2 \sin 25°)(10 \text{ m})$
$= 82.8 \text{ m}^2/\text{s}^2$
$v = 9.10$ m/s
$v = v_0 + at$ (positive direction is down the ramp)
$$t = \frac{v}{a} = \frac{9.1 \text{ m/s}}{4.14 \text{ m/s}^2} = 2.20 \text{ s}$$



51. $a_{car} = 2.50 \text{ m/s}^2$
$v_{caro} = 0$ m/s
$v_{trucko} = 60.0 \text{ km/hr}(1000 \text{ m/km})(1 \text{ hr}/3600 \text{ s})$
$= 16.7$ m/s

a. The time for the car to overtake the truck occurs when the car and the truck have traveled the same distance.
$x_{car} = v_{caro}t + 1/2\, a_{car}t^2$(position of car)
$x_{truck} = v_{trucko}t$ (position of truck)
$x_{car} = x_{truck}$
$0 + ½\, a_{car}t^2 = v_{trucko}\, t$
$$t = \frac{2v_{trucko}}{a_{car}} = \frac{2(16.7 \text{ m/s})}{2.50 \text{ m/s}^2} = 13.3 \text{ s}$$

b. $x_{car} = v_{caro}\, t + 1/2\; a_{car}t^2$
$= 0 + 1/2\,(2.5 \text{ m/s}^2)(13.3 \text{ s})2 = 221$ m

c. $v_{car} = v_{caro} + a_{car}\, t = 0 + 2.5 \text{ m/s}^2 (13.3\text{s})$
$v_{car} = 33.3$ m/s

52. $v = v_o + at$; to the right is positive (+)

a. $$a = \frac{v - v_0}{t} = \frac{-3.00 \text{ m/s} - 8.00 \text{ m/s}}{10 \text{ s}}$$
$= -1.1 \text{ m/s}^2$
The acceleration is to the left.

b. The boat reverses its direction when it has a velocity = 0.
$v = v_o + at$
$0 = 8.00 \text{ m/s} - (1.1 \text{ m/s}^2)t$
$t = 7.27$ s
The boat reverses direction after 7.27 s and covers a distance
$x = v_ot + 1/2\, at^2$
$= (8.00 \text{ m/s})(7.27 \text{ s}) + 1/2\,(-1.1 \text{ m/s}^2)(7.27 \text{ s})^2$
$= 29.1$ m

c. The boat would take an additional 7.27 s to return to the buoy. Total time to return to the buoy is 14.54 s.

d. Since the motion is symmetrical, the speed is -8.00 m/s or $v = v_o + at$
$v = 8.00 \text{ m/s} +(-1.1 \text{ m/s}^2)(14.54 \text{ s})$
$= -7.99 \text{ m/s} = -8.00$ m/s

53. The first train is 50 m ahead of the second.
$a_1 = 2.00 \text{ m/s}^2$ $\quad x_1 = x_o + v_ot + 1/2\, a_1t^2$
$a_2 = 2.50 \text{ m/s}^2$ $\quad x_2 = v_ot + 1/2\, a_2t^2$
$x_1 = 50 \text{ m} + 0 + 1/2\,(2.00 \text{ m/s}^2)t^2$
$x_2 = 0 + 1/2\,(2.50 \text{ m/s}^2)t^2$
The final positions will be the same; set the two equations equal and solve

$x_1 = x_2$
$50 + t^2 = 1.25t^2$
$50 = 0.25t$
$200 = t^2$
$14.1 \text{ s} = t$ Train 2 will travel
$x_2 = v_0t + 1/2\, a_2t^2 1$
$= 0 + 1/2\, (2.50 \text{ m/s}^2)(14.1 \text{ s})^2 = 249 \text{ m}$

54. The relationships remain the same, only this time train 1 has an initial velocity $v_{10} = 5.00$ m/s and train 2 has an initial velocity $v_{20} = 7.00$ m/s.
$x_1 = x_0 + v_{10}t + {}^1/_2\, a_1t^2$
$x_2 = v_{20}t + {}^1/_2\, a_2t^2$
$x_1 = x_2$
$x_1 = 50 \text{ m} + (5.00 \text{ m/s})t + {}^1/_2\, (2.00 \text{ m/s}^2)t^2$
$x_2 = (7.00 \text{ m/s})t + 1/2\, (2.50 \text{ m/s}^2)t^2$
$50 + 5t + t^2 = 7t + 1.25t^2$
$0.25t^2 + 2t - 50 = 0$

$$t = \frac{-(+2) \pm \sqrt{(+2)^2 - 4(0.25)(-50)}}{2(0.25)} = \frac{-2 \pm 7.35}{0.5}$$

$= 10.7$ s or -18.7 s
Time must be positive: 10.7 s for train 2 to overtake train 1.
Train 2 travels a distance
$x_2 = v_{20}t + {}^1/_2\, a_2t^2$
$= 7.00 \text{ m/s } (10.7 \text{ s}) + {}^1/_2\, (2.50 \text{ m/s}^2)(10.7 \text{ s})^2$
$= 218$ m

55. $v_{\text{police}} = 80$ km/hr(1000 m/km)(1 hr/3600 s)
$= 22.2$ m/s
$v_{\text{car}} = 120$ km/hr(1000 m/km)(1 hr/3600 s) = 33.3 m/s
In order for the policewoman to catch the speeding car she must reach the county line in the same amount of time as the other car. The distance she travels will be 400 m.
$x_{\text{police}} = v_{0\text{police}}\, t + {}^1/_2\, a_1t^2$
The distance the speeding car travels is
$x_{\text{car}} = x_0 + v_{\text{car}}t$
The speeding car would reach the county line in a time of

$$t = \frac{x_{\text{car}} - x_0}{v_{\text{car}}} = \frac{400 \text{ m} - 50 \text{ m}}{33.3 \text{ m/s}} = 10.5 \text{ s}$$

Solve for the acceleration of the police car.

$$a_{\text{police}} = 2\,\frac{(x_{\text{police}} - v_0t)}{t^2}$$

$$= \frac{2(400 \text{ m} - (22.2 \text{ m/s})(10.5 \text{ s})}{(10.5 \text{ s})^2}$$

$a_{\text{police}} = 3.03 \text{ m/s}^2$

56. Let x_1 = distance traveled by train 1 during deceleration
Let x_2 = distance traveled by train 2 during deceleration
$v_1 = 125$ km/hr(1000 m/km)(1 hr/3600 s) = 34.7 m/s
$v_2 = 80$ km/hr(1000 m/km)(1 hr/3600 s) = 22.2 m/s
$a_1 = -2.00 \text{ m/s}^2$
$a_2 = -1.50 \text{ m/s}^2$
The total distance available to stop is 2.00 km; therefore, $x_1 + x_2 \leq 2.00$ km or 2000 m in order for the trains to stop safely.
$v_{1f}{}^2 = 0 = v_1{}^2 + 2a_1x_1$
$v_{2f}{}^2 = 0 = v_2{}^2 + 2a_2x_2$

$$x_1 = \frac{-v_1{}^2}{2a_1} = \frac{-(34.7 \text{ m/s})^2}{2(-2.00 \text{ m/s}^2)}$$

$x_1 = 301$ m

$$x_2 = \frac{-v_2{}^2}{2a_2} = \frac{-(22.2 \text{ m/s})^2}{2(-1.50 \text{ m/s}^2)}$$

$x_2 = 165$ m
$x_1 + x_2 = 466$ m
The trains will stop in time.

57. Since the boy and the elevator are at rest relative to each other and traveling at constant speed, the boy will need to jump up with a velocity of
$v^2 = v_o{}^2 - 2gy$
The speed at height 0.500 m is zero relative to the elevator floor.
$v_o{}^2 = v^2 + 2gy = 2gy$
$= 2(9.8 \text{ m/s}^2)(0.5 \text{ m}) = 3.13 \text{ m/s}$
The boy will be in the air a time
$y = v_ot - 1/2gt^2$ $y = 0$ at the floor
$0 = v_ot - 1/2gt^2$
$v_ot = 1/2\, gt^2$

$$t = \frac{2v_o}{g} = \frac{2(3.13 \text{ m/s})}{9.8 \text{ m/s}} = 0.639 \text{ s}$$

The floor, moving at – 5.00 m/s (downward) will travel a distance relative to the elevator shaft (earth)
$y = v_yt = -5.00 \text{ m/s } (0.639 \text{ s}) = -3.19 \text{ m}$

58. $v^2 = v_o{}^2 - 2g_{\text{moon}}\, y$
The velocity at the maximum height is zero.
$0 = (25 \text{ m/s})^2 - 2(1.62 \text{ m/s}^2)y$
$y = 193$m

59. $v_{oy} = 20$ m/s is the vertical velocity at the end of the wheel's rise. Wheel will rise an additional
$v^2 = v_o{}^2 - 2gy$

$$y = \frac{-v_o{}^2}{-2g} = \frac{-(20 \text{ m/s})^2}{-(2)(9.8 \text{ m/s}^2)} = 20.4 \text{ m}$$

Total height above the ground = 300 m + 20.4 m
= 320.4 m
For the wheel to hit ground, the time will be
$y = v_ot - ½\, gt^2$
$-300 \text{ m} = (20 \text{ m/s})t - 1/2\, (9.8 \text{ m/s}^2)t^2$
$4.9t^2 - 20t - 300 = 0$

$$t = \frac{-(-20) \pm \sqrt{(-20)^2 - 4(4.9)(-300)}}{2(4.9)} = \frac{20 \pm 79.3}{9.8}$$

Must take positive Result: $t = 10.1$ s