ANSWERS

Chapter 2

2.1 (a) 10^{-6} ; (b) 1.5×10^{4} ; (c) 5 ; (d) 11.3, 1.13×10^{4}.

2.2 (a) 10^{7} ; (b) 10^{-16} ; (c) 3.9×10^{4} ; (d) 6.67×10^{-8}.

2.5 500

2.6 (c)

2.7 0.035 mm

2.9 94.1

2.10 (a) 1 ; (b) 3 ; (c) 4 ; (d) 4 ; (e) 4 ; (f) 4.

2.11 8.72 m^2; 0.0855 m^3

2.12 (a) 2.3 kg ; (b) 0.02 g

2.13 13%; 3.8

2.14 (b) and (c) are wrong on dimensional grounds. Hint: The argument of a trigonometric function must always be dimensionless.

2.15 The correct formula is $m = m_0 (1 - v^2/c^2)^{-½}$

2.16 $\cong 3 \times 10^{-7}$ m^3

2.17 $\cong$ 10^4; intermolecular separation in a gas is much larger than the size of a molecule.

2.18 Near objects make greater angle than distant (far off) objects at the eye of the observer. When you are moving, the angular change is less for distant objects than nearer objects. So, these distant objects seem to move along with you, but the nearer objects in opposite direction.

2.19 $\cong 3 \times 10^{16}$ m; as a unit of length 1 parsec is defined to be equal to 3.084×10^{16} m.

2.20 1.32 parsec; 2.64″ (second of arc)

2.23 1.4×10^{3} kg m^{-3}; the mass density of the Sun is in the range of densities of liquids / solids and *not* gases. This high density arises due to inward gravitational attraction on outer layers due to inner layers of the Sun.

2.24 1.429×10^{5} km

2.25 Hint: tan θ must be dimensionless. The correct formula is tan $\theta = v/v'$ where v' is the speed of rainfall.

2.26 Accuracy of 1 part in 10^{11} to 10^{12}

2.27 $\cong$ 0.7×10^3 kg m^{-3}. In the solid phase atoms are tightly packed, so the atomic mass density is close to the mass density of the solid.

2.28 $\cong 0.3 \times 10^{18}$ m^{-3} – Nuclear density is typically 10^{15} times atomic density of matter.

2.29 3.84×10^8 m

2.30 55.8 km

2.31 2.8×10^{22} km

2.32 3,581 km

2.33 Hint: the quantity $e^4/\ (16\ \pi^2\ \epsilon_0^2 m_p\ m_e^2 c^3\ G)$ has the dimension of time.

Chapter 3

3.1 (a), (b)

3.2 (a) A....B, (b) A....B, (c) B....A, (d) Same, (e) B....A....once.

3.4 37 s

3.5 1000 km/h

3.6 3.06 m s^{-2}; 11.4 s

3.7 1250 m (Hint: view the motion of B relative to A)

3.8 1 m s^{-2} (Hint: view the motion of B and C relative to A)

3.9 T = 9 min, speed = 40 km/h. Hint: $vT/(v-20) = 18$; $vT/(v+20) = 6$

3.10 (a) Vertically downwards; (b) zero velocity, acceleration of 9.8 m s^{-2} downwards; (c) $x > 0$ (upward and downward motion); $v < 0$ (upward), $v > 0$ (downward), $a > 0$ throughout; (d) 44.1 m, 6 s.

3.11 (a) True;, (b) False; (c) True (if the particle rebounds instantly with the same speed, it implies infinite acceleration which is unphysical); (d) False (true only when the chosen positive direction is along the direction of motion)

3.14 (a) 5 km h^{-1}, 5 km h^{-1}; (b) 0, 6 km h^{-1}; (c) $\frac{15}{8}$ km h^{-1}, $\frac{45}{8}$ km h^{-1}

3.15 Because, for an arbitrarily small interval of time, the magnitude of displacement is equal to the length of the path.

3.16 All the four graphs are impossible. (a) a particle cannot have two different positions at the same time; (b) a particle cannot have velocity in opposite directions at the same time; (c) speed is always non-negative; (d) total path length of a particle can never decrease with time. (Note, the arrows on the graphs are meaningless).

3.17 No, wrong. x-t plot does not show the trajectory of a particle. Context: A body is dropped from a tower ($x = 0$) at $t = 0$.

3.18 105 m s^{-1}

3.19 (a) A ball at rest on a smooth floor is kicked, it rebounds from a wall with reduced speed and moves to the opposite wall which stops it; (b) A ball thrown up with some initial velocity rebounding from the floor with reduced speed after each hit; (c) A uniformly moving cricket ball turned back by hitting it with a bat for a very short time-interval.

3.20 $x < 0$, $v < 0$, $a > 0$; $x > 0$, $v > 0$, $a < 0$; $x < 0$, $v > 0$, $a > 0$.

3.21 Greatest in 3, least in 2; $v > 0$ in 1 and 2, $v < 0$ in 3.

3.22 Acceleration magnitude greatest in 2; speed greatest in 3; $v > 0$ in 1, 2 and 3; $a > 0$ in 1 and 3, $a < 0$ in 2; $a = 0$ at A, B, C, D.

3.23 A straight line inclined with the time-axis for uniformly accelerated motion; parallel to the time- axis for uniform motion.

3.24 10 s, 10 s

3.25 (a) 13 km h^{-1} ; (b) 5 km h^{-1}; (c) 20 s in either direction, viewed by any one of the parents, the speed of the child is 9 km h^{-1} in either direction; answer to (c) is unaltered.

3.26 $x_2 - x_1 = 15\, t$ (linear part); $x_2 - x_1 = 200 + 30\, t - 5\, t^2$ (curved part).

3.27 (a) 60 m, 6 m s^{-1} ; (b) 36 m, 9 m s^{-1}

3.28 (c), (d), (f)

Chapter 4

4.1 Volume, mass, speed, density, number of moles, angular frequency are scalars; the rest are vectors.

4.2 Work, current

4.3 Impulse

4.4 Only (c) and (d) are permissible

4.5 (a) T, (b) F, (c) F, (d) T, (e) T

4.6 Hint: The sum (difference) of any two sides of a triangle is never less (greater) than the third side. Equality holds for collinear vectors.

4.7 All statements except (a) are correct

4.8 400 m for each; B

4.9 (a) O; (b) O; (c) 21.4 km h^{-1}

4.10 Displacement of magnitude 1 km and direction 60° with the initial direction; total path length = 1.5 km (third turn); null displacement vector; path length = 3 km (sixth turn); 866 m, 30°, 4 km (eighth turn)

4.11 (a) 49.3 km h^{-1} ; (b) 21.4 km h^{-1}. No, the average speed equals average velocity magnitude only for a straight path.

4.12 About 18° with the vertical, towards the south.

4.13 15 min, 750 m

4.14 East (approximately)

4.15 150.5 m

4.16 50 m

4.17 9.9 m s^{-2}, along the radius at every point towards the centre.

4.18 6.4 g

4.19 (a) False (true only for uniform circular motion)

(b) True, (c) True.

4.20 (a) $\mathbf{v}(t) = (3.0\ \hat{\mathbf{i}} - 4.0\,t\ \hat{\mathbf{j}})\ \ \hat{\mathbf{a}}(t) = -4.0\,\hat{\mathbf{j}}$

(b) 8.54 m s^{-1}, 70° with *x*-axis.

4.21 (a) 2 s, 24 m, 21.26 m s^{-1}

4.22 $\sqrt{2}$, 45° with the *x*-axis; $\sqrt{2}$, – 45° with the *x* - axis, $\left(5/\sqrt{2},\ -1/\sqrt{2}\right)$.

4.23 (b) and (e)

4.24 Only (e) is true

4.25 182 m s^{-1}

4.27 No. Rotations in *general* cannot be associated with vectors

4.28 A vector can be associated with a plane area

4.29 No

4.30 At an angle of $\sin^{-1}(1/3) = 19.5°$ with the vertical; 16 km.

4.31 0.86 m s^{-2}, 54.5° with the direction of velocity

Chapter 5

5.1 (a) to (d) No net force according to the First Law
(e) No force, since it is far away from all material agencies producing electromagnetic and gravitational forces.

5.2 The only force in each case is the force of gravity, (neglecting effects of air) equal to 0.5 N vertically downward. The answers do not change, even if the motion of the pebble is not along the vertical. The pebble is not at rest at the highest point. It has a constant horizontal component of velocity throughout its motion.

5.3 (a) 1 N vertically downwards (b) same as in (a)
(c) same as in (a); force at an instant depends on the situation at that instant, not on history.
(d) 0.1 N in the direction of motion of the train.

5.4 (i) T

5.5 $a = -2.5$ m s^{-2}. Using $v = u + at$, $0 = 15 - 2.5\,t$ i.e., $t = 6.0$ s

5.6 $a = 1.5/25 = 0.06$ m s^{-2}

$F = 3 \times 0.06 = 0.18$ N in the direction of motion.

5.7 Resultant force = 10 N at an angle of $\tan^{-1}(3/4) = 37°$ with the direction of 8 N force. Acceleration = 2 m s^{-2} in the direction of the resultant force.

5.8 $a = -2.5$ m s^{-2}, Retarding force = 465 × 2.5 = 1.2 × 10^3 N

5.9 $F - 20{,}000 \times 10 = 20000 \times 5.0$, i.e., $F = 3.0 \times 10^5$ N

5.10 $a = -20$ m s^{-2} $0 \le t \le 30$ s

$t = -5$ s : $x = u\,t = -\,10 \times 5 = -50$ m
$t = 25$ s : $x = u\,t + (½)\ a\,t^2 = (10 \times 25 - 10 \times 625)$m $= -\,6$ km
$t = 100$ s : First consider motion up to 30 s
$x_1 = 10 \times 30 - 10 \times 900 = -\,8700$ m
At $t = 30$ s, $v = 10 - 20 \times 30 = -590$ m s^{-1}
For motion from 30 s to 100 s : $x_2 = -\,590 \times 70 = -\,41300$ m
$x = x_1 + x_2 = -\,50$ km

5.11 (a) Velocity of car (at $t = 10$ s) $= 0 + 2 \times 10 = 20$ m s^{-1}
By the First Law, the horizontal component of velocity is 20 m s^{-1} throughout.
Vertical component of velocity (at $t = 11$s) $= 0 + 10 \times 1 = 10$ m s^{-1}

Velocity of stone (at $t = 11$s) $= \sqrt{20^2 + 10^2} = \sqrt{500} = 22.4$ m s^{-1} at an angle of $\tan^{-1}$ (½) with the horizontal.
(b)10 m s^{-2} vertically downwards.

5.12 (a) At the extreme position, the speed of the bob is zero. If the string is cut, it will fall vertically downwards.
(b) At the mean position, the bob has a horizontal velocity. If the string is cut, it will fall along a parabolic path.

5.13 The reading on the scale is a measure of the force on the floor by the man. By the Third Law, this is equal and opposite to the normal force N on the man by the floor.
(a) $N = 70 \times 10 = 700$ N ; Reading is 70 kg
(b) $70 \times 10 - N = 70 \times 5$; Reading is 35 kg
(c) $N - 70 \times 10 = 70 \times 5$; Reading is 105 kg
(d) $70 \times 10 - N = 70 \times 10$; Reading would be zero; the scale would read zero.

5.14 (a) In all the three intervals, acceleration and, therefore, force are zero.
(b) 3 kg m s^{-1} at $t = 0$; (c) –3 kg m s^{-1} at $t = 4$ s.

5.15 If the 20 kg mass is pulled,
$600 - T = 20\,a$, $T = 10\,a$
$a = 20$ m s^{-2}, $T = 200$ N
If the 10 kg mass is pulled, a = 20 m s^{-2}, $T = 400$ N

5.16 $T - 8 \times 10 = 8\,a, 12 \times 10 - T = 12a$
i.e. $a = 2$ m s^{-2}, $T = 96$ N

5.17 By momentum conservation principle, total final momentum is zero. Two momentum vectors cannot sum to a null momentum unless they are equal and opposite.

5.18 Impulse on each ball = 0.05 ×12 = 0.6 kg m s^{-1} in magnitude. The two impulses are opposite in direction.

5.19 Use momentum conservation : $100\,v = 0.02 \times 80$
$v = 0.016$ m s^{-1} = 1.6 cm s^{-1}

5.20 Impulse is directed along the bisector of the initial and final directions. Its magnitude is $0.15 \times 2 \times 15 \times \cos 22.5° = 4.2$ kg m s^{-1}

5.21 $v \quad 2 \quad 1.5 \quad \frac{40}{60} \quad 2$ m s^{-1}

$$T \quad \frac{mv^2}{R} \quad \frac{0.25 \quad 4 \quad ^2}{1.5} \quad 6.6\,\text{N}$$