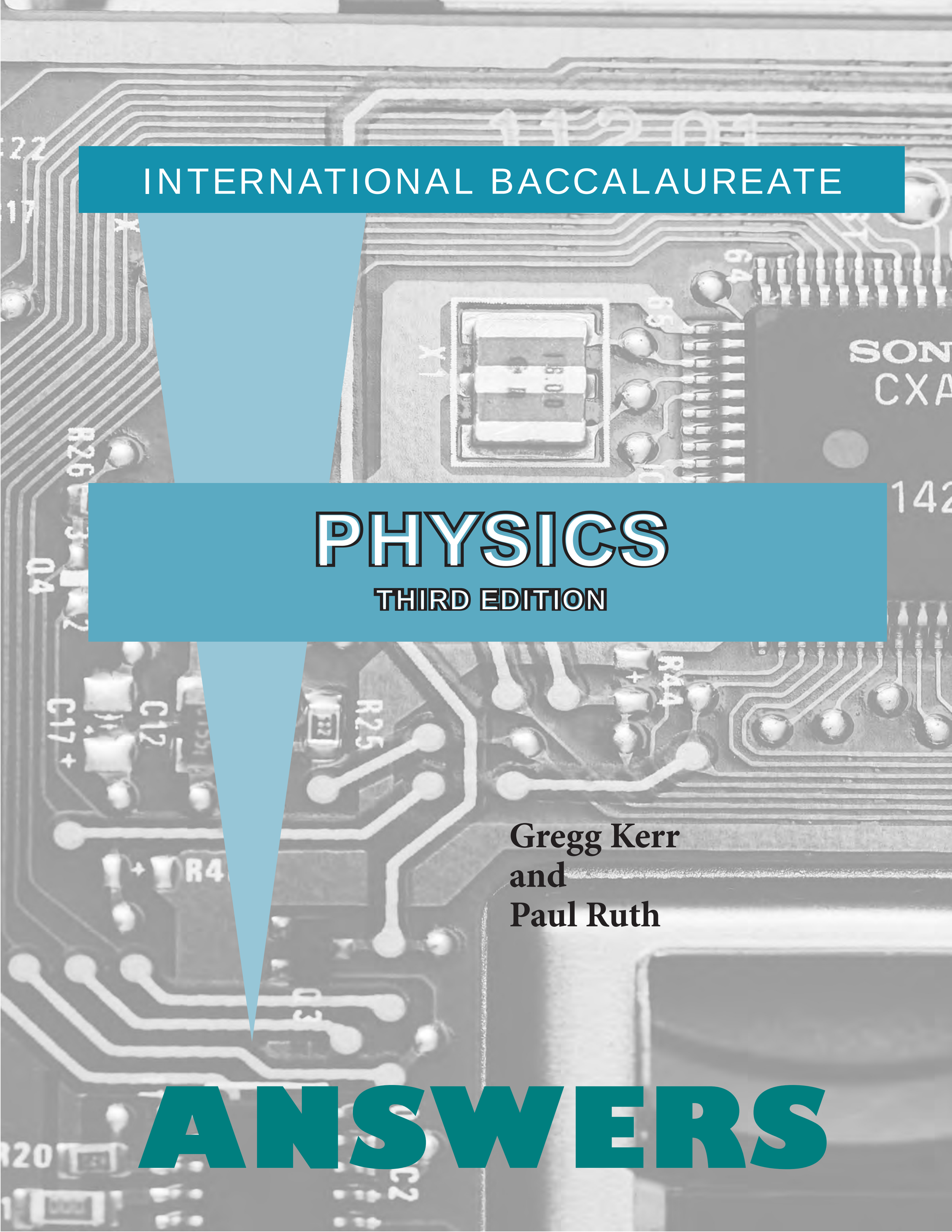

INTERNATIONAL BACCALAUREATE

PHYSICS

THIRD EDITION

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and
Paul Ruth

ANSWERS

CHAPTER 1 PHYSICS AND PHYSICAL MEASUREMENT

Exercise 1.1 (a) (page 2,3)

1. D
2. (a) 10^4 (b) 10^4 (c) 10^8 (d) 10^{16} (e) 10^{-24} (f) 10^{-29}
3. (a) 10^7 (b) 10^{-3} (c) 10^{27} (d) 10^9 (e) 10^{-6}
4. C
5. (a) 10^7 (b) 10^6
6. (a) 10^7 (b) 10^{13}

Exercise 1.1 (b) (page 3)

1. B
2. (a) 25 cm × 10 cm × 5 cm (b) 150 g (c) 1 sec (d) 20°C
3. (a) 3×10^{14} (b) 1×10^{-2} (c) 4×10^{-12}
4. 2×10^{10} yrs
5. (a) 10^0 (b) 10^6 (c) 10^4 (d) 10^{-4} (e) 10^5 (f) 10^9 (China)

Exercise 1.2 (a) (page 6,7)

1. C
2. C
3. A
4. C
5. D
6. (a) 5.6×10^{-3} kg (b) 3.5×10^{-6} A (c) 3.2×10^{-2} m
   (d) 6.3×10^{-9} m (e) 2.25×10^3 kg (f) 440 s^{-1}
7. (a) 2.24×10^6 J (b) 2.50×10^3 N m^{-2} (c) 7.5×10^{-1} m s^{-1}
   (d) 2.5×10^{-6} m^2 (e) 2.4×10^{-3} m^3 (f) 3.6×10^{-6} m^3
   (g) 2.301×10^5 m^3 (h) 3.62×10^{-9} m^3
8. (a) 10^0 (b) 10^5 (c) 10^{-5} (d) 10^9 s
9. 400 m
10. N m^2 kg^{-2}
11. N s m^{-2}

CHAPTER 1 PHYSICS AND PHYSICAL MEASUREMENT

Exercise 1.2 (b) (page 9,10)

1. C
2. C
3. A
4. (a) 4 (b) 4 (c) 2 (d) 3 (e) 3 (f) 2 (g) 3 (h) 3 (i) 2 (j) 2 (k) 3 (l) 2
5. (a) 1.25×10^3 (b) 3.0007×10^4 (c) 2.510×10^1 (d) 4×10^6 (e) 1.20×10^{-17}
6. 1.0×10^1 m^2
7. 21.8435 = 21.8 ~ 22 m
8. 490 cm^3
9. 200 g cm^{-3}
10. (a) 7.12 (b) 2560 (c) 2.00×10^3 (d) 2130 (e) 6.56
11. (a) 89.8 (b) 98.5
12. 3.7×10^{-5} cm

Exercise 1.2 (c) (page 12,13)

1. D
2. B
3. C
4. B
5. 0.932 ± 0.0005 μm
6. (a) 2.35 ± 0.005 mm (b) random error
7 (a) Yes. Random error evident for the 1.2 A reading.

   (b) Average = 8.28 greatest residual from the average is 0.13 So answer is 0.8±0.1 A
8. 9.0 ± 0.1 N
9. 1.47 ± 0.03 m
10. 27.0 ± 0.3 cm^3
11. $(1.2 \pm 0.3) \text{ x } 10^{-3}$ g cm^{-3}
12. 0.488 ± 0.003
13. mean sin 60 = 0.87. max sin 65 = 0.91. min sin 55 = 0.82

    Answer = 0.87 ± 0.05.

CHAPTER 1 PHYSICS AND PHYSICAL MEASUREMENT

Exercise 1.2 (d) (page 19)

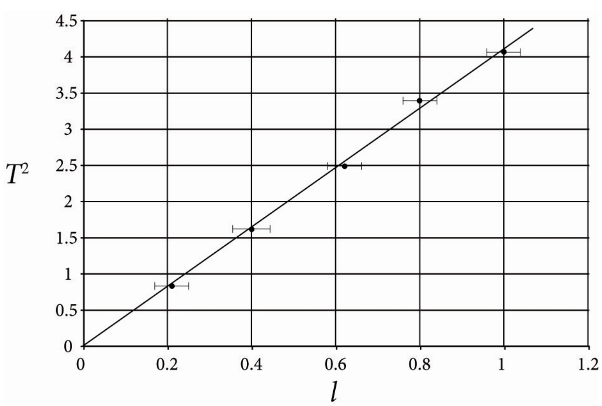
1. D
2. B
3. $R_0 =$ 22 ± 1 W, $\mu = 0.0046 \pm 0.0005$ W q^{-1}
4. 10 m s^{-2}
5. C
6. $\log_{10} V$ versus $\log_{10} d$
7. ln I versus x.

Exercise 1.2 (e) (page 21)

1. (a), (b) and (c)

Period $T \pm 0.1$ s	T^2 s^2	Absolute error of T^2
0.905	0.819	0.02
1.28	1.64	0.03
1.58	2.48	0.03
1.84	3.39	0.04
2.02	4.08	0.04

(d)



(e) T^2 is directly proportional to l as seen from the straight line graph

(f) The value for $l = 0.8$ m falls outside the line of best fit

(g) gradient = $4\pi^2 / g = 4.1$, so $g = 9.6$ m s^{-2}

CHAPTER 1 PHYSICS AND PHYSICAL MEASUREMENT

Exercise 1.3 (a) (page 25,26)

1. A
2. C
3. D
4. C
5. C
6. (a) 4 m north (b) 13 m west 23° north
   (c) 8.5 N north–west (d) 5.0 m.s^{-1} east 37° north
7. (a) 3 m east (b) 13 m.s^{-2} south
   (c) 5.0 N east 54° south (d) 6.0 T south 32° west
8. (a) 60 ms^{-1} north (b) 60 N north 12° east
9. 20 ms^{-1} W
10. 9.1 m north 22°east

Exercise 1.3 (b) (page 27)

1. B
2. 4.2 N
3. vertical = 22.7 m s^{-1}, horizontal = 10.6 m s^{-1}
4. 11 N
5. 13 N east 23° north
6. 2.8 N south
7. $a = g \times \sin 30 = 4.90$ ms^{-2}
8. Horizontal = 12 cos 45 – 8 cos 25 = 1.235 N west.
   Vertical = 15 – (12 sin 45 + 8 sin 25 = 3.13 N south.
   Resultant = $\sqrt{(3.13^2 + 1.235^2)}$ = 3.4 N. tan θ = 1.235 ÷ 3.13 = 21.5.
   Answer = 3.4 N south 22^0 west.

Exercise 1.3 (c) (page 29)

1. 0.76 76%
2. 46.7 2.08
3. $y = \frac{1}{2}x + 3$
4. $v = \sqrt{\frac{Fr}{m}}$
5. $\frac{4\pi^2}{T^2}$
6. $x = 7/3$, $y = 10/3$
7. (a) 4352 (b) 125 (c) 4 (d) 0.33
8. (a) 3 (b) –2
9. (a) 5.03 cm (b) 2.01 cm^2
10. V = 5.1×10^{-5} m^3 SA = 6.6×10^{-3} m^2
11. (a) 4.7 rad (b) 0.79 rad
12. 45°

CHAPTER 2 MECHANICS

Exercise 2.1 (a) (page 34)

1 C

Exercise 2.1 (b) (page 37)

1 29 m (*assume 'g' = 10 m* s^{-2} *and neglect the speed of sound*)

2. (i) (25 + 11.25) = 36 m (above sea level) (ii) 1.5 s (iii) 27 m s^{-1} (iv) 4.2 s;

3. 40 m

Exercise 2.1 (c) (page 39)

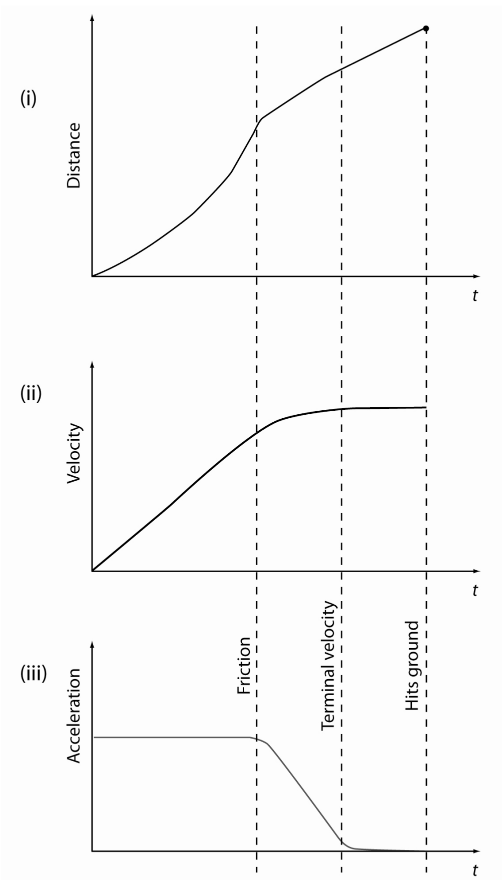
1. (a) D

   (b) B

   (c) A

   (d) C

2.



CHAPTER 2 MECHANICS

Exercise 2.2 (a) (page 43)

1. (a) less

   (b) same

   (c) same

   (d) less pain

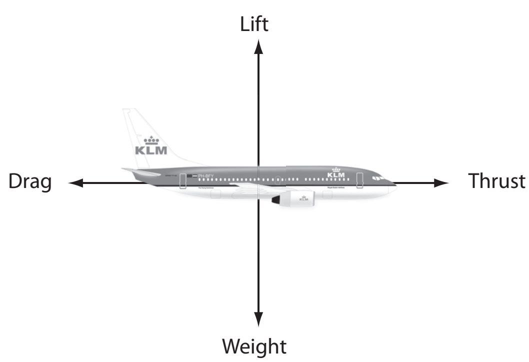
   (e) same pain

   (f) use lighter materials

Exercise 2.2 (b) (page 45)

1. (i) 20 cm (ii) 90 N m^{-1}

Exercise 2.2 (c) (page 46)



Exercise 2.2 (d) (page 50)

1. 680 N → 1.3 m s^{-2} , 600 N →0 , 500 N → 1.7 m s^{-2}' 600 N → 0.
2. 0

Exercise 2.2 (e) (page 54)

1. 4.0 m s^{-1}
2. 40 kg
3. HINT: consider $F = \dfrac{\Delta p}{\Delta t}$
4. (a) 3.5 Ns (b) 14 N

CHAPTER 2 MECHANICS

Exercise 2.2 (f) (Page 56)

Newton's second law can be stated as force is directly proportional to the rate of change of momentum. Rockets used a controlled explosion which is the opposite to a collision as objects move apart. According to Newton's third law, the rocket moves upwards and the hot gases move downwards. Applying the Law of conservation of momentum, the gain in momentum of the rocket is equal and opposite to the momentum of the ejected hot gases. Therefore these gases do not need to 'push against' anything to provide the propulsion.

Exercise 2.2 (g)(page 59)

(a) 2000 J (b) 2500 J

Exercise 2.3 (page 66)

1. (i) 4.0 m s^{-1} (ii) 8000 J
2. 46 %
3. 1800 N

Exercise 2.4 (page 70)

1. 20 m s^{-2}
2. (a) 11 m s^{-2} (b) 57 N (c) 1.1 s
3. A
4. 2.1 m s^{-2}
5. 6.3 N;
6. 19 m s^{-2}

7 see text

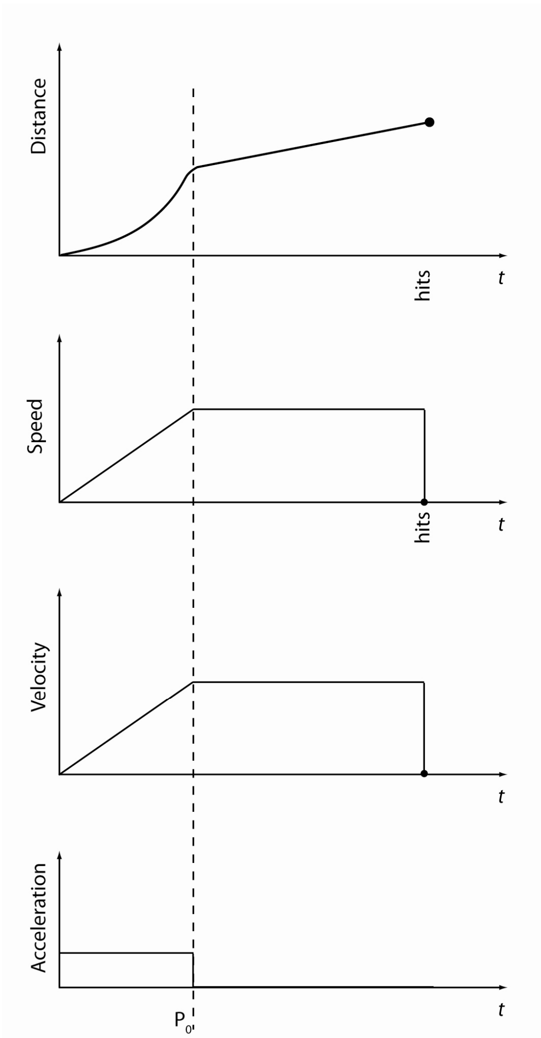
8. (a) 455 N (b) 485 N
9. (a) 3 mg (b) 6 mg (c) 9 mg.

CHAPTER 2 MECHANICS

Miscellaneous Exercises (pages 71,72)

Topic 2.1

1.



2. (i) 1.3 m s^{-2} , – 2.5 m s^{-2} (ii) 130 m (iii) 2.9 km

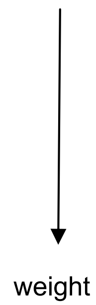
3. 20 m *(neglect the speed of sound)*

4. (i) 11.3 m (ii) t = 3.0 s

CHAPTER 2 MECHANICS

Topic 2.2

1



2. 29 N
3. 72 kg
4. 3.3 m s^{-2}
5. A and B
6. 7.0×10^3 N (*average is 3.5×10^3 N, minimum is 0)*
7. (i) 6.3 m s^{-1} (ii) 5.5 m s^{-1} (iii) 1.2 kg m s^{-1} (iv) 1.2 N s (v) 24 N
8. 600 m s^{-1}
9. $v = 4.9$ m s^{-1} $F = 250$ N

Topic 2.3

1. 3.6×10^4 N (both cases)
2. (i) 1000 J (ii) 1000 J (iii) 50% (iv) 500 W
3. (i) 5.0×10^{-3} litre s^{-1} (ii) 2.5×10^4 J s^{-1}

   (iii) 50 kW (iv) 2.5×10^4 W (v) 1000 N

CHAPTER 3 THERMAL PHYSICS

Exercise 3.1 (a) (page 77,78)

1. B .
2. Heat is the thermal energy that is absorbed, given up or transferred from one object to another.Temperature is a scalar quantity that gives an indication of the degree of hotness or coldness of a body. Alternatively, temperature is a microscopic property that measures the average kinetic energy of particles on a defined scale such as the Celsius or Kelvin scales. The chosen scale determines the direction of thermal energy transfer between two bodies in contact from the body at higher temperature to that of lower temperature.
3. Alcohol thermometer, because mercury freezes at low temperatures.
4. i) It is portable and direct reading. Small and not very accurate.

   ii) Sensitive, accurate and wide range. Cumbersome, slow and inconvenient
5. 0 °C
6. Ice point is 273 K. Steam point is 373 K.
7. Absolute zero is that temperature at which the kinetic energy of the molecules is a minimum value but not zero.
8. 310 K

Exercise 3.1 (b) (page 82)

1. B
2. C
3. B
4. B
5. A
6. C
7. (a) 71 g mol^{-1} (b) 36.5 g mol^{-1} (c) 159.6 g mol^{-1} (d) 106 g mol^{-1} (e) 16 g mol^{-1}
8. (a) 111.6 g (b) 13.1 g (c) 110 g (d) 6.4×10^{-2} g (e) 3.9×10^{3} g
9. (a) 1.57 mol (b) 0.16 mol (c) 1 mol (d) 0.1 mol (e) 2 mol
10. (a) n [$Al_2(SO_4)_3$] = 0.1 mol. Therefore n (Al^{3+}) = 2 × 0.1 mol = 0.2 mol.

    The number of Al^{3+} ions = 0.2 × 6.02 x 10^{23} = 1.2 × 10^{23} Al^{3+} ions

    (b) 1.8×10^{23}
11. (a) macro (b) macro (c) micro (d) macro (e) macro

Exercise 3.2 (a) (page 86–88)

1. B
2. C
3. 5.4×10^6 J / (28 kg × 428 K) = 450.6 = 450 $Jkg^{-1}K^{-1}$
4. Molten sodium has a higher thermal conductivity than water.

   This allows for rapid conduction of heat from the reactor.
5. 8.7×10^6 J = 600 kg × 8.40 x 10^2 $Jkg^{-1}K^{-1}$ × (95 – T_f)

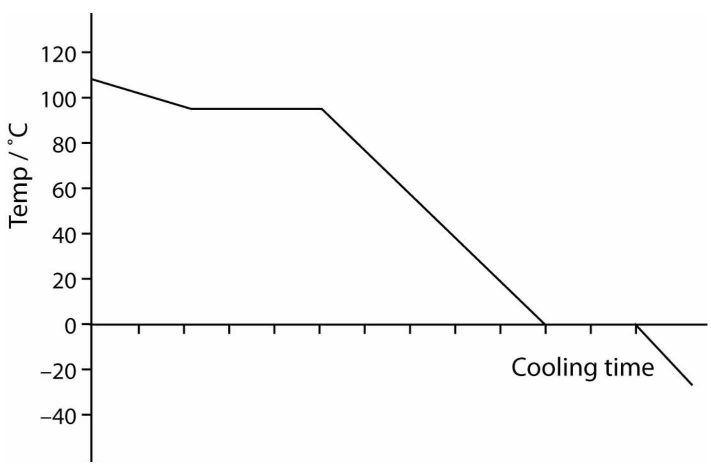
   = $4.788 \times 10^7 - 5.04 \times 10^6 T_f$. Final temperature = 77.7 ^{0}C.
6. Wood has a higher heat capacity than metal
7. 3.0 J s^{-1}
8. 1.07×10^5 J
9. 8.3 kg
10. 3.0×10^2 J kg^{-1} K^1
11. 19 °C
12. 40 °C
13. Put it in boiling water for a long period of time, so that temp ~ 100 °C, remove from boiling water and place in a fixed quantity of water in a calorimeter. Then apply equations for conservation of heat energy. The main source of error is loss of heat to the surroundings. This can be minimised by insulating the calorimeter. The value obtained is likely to be higher because of the heat lost to the surroundings.
14. $Q = mc\Delta T$ = 250 kg × 4180 Jkg^{-1} $^0C^{-1}$ × (71 – 15)^{0}C = 5.852×10^7 J.

    If 65% efficient, some heat was lost to the surroundings. Therefore, the heat supplied is 5.852×10^7 J / 0.65 = 9.0×10^7 J. The fluid releases 4.2×10^7 J for 1 kg.

    For 9.0×10^7 J it would require $9.0 \times 10^7 / 4.2 \times 10^7$ = 2.1 kg.
15. 0.30 K
16. 627 m
17. 4.4 K
18. 7.5 kJ.

Exercise 3.2 (b) (page 91,92)

1. B
2. C
3. C
4. D
5. C
6. A
7. Macroscopic – highly compressed, low density, fast diffusion, large pressure
8. (a) kinetic energy only (b) potential energy due to intermolecular forces kinetic energy vibrational and rotational (c) potential energy increases during phase change kinetic energy remains constant
9. Heat is the thermal energy that is absorbed, given up or transferred from one object to another.Temperature is a scalar quantity that gives an indication of the degree of hotness or coldness of a body. Alternatively, temperature is a microscopic property that measures the average kinetic energy of particles on a defined scale such as the Celsius or Kelvin scales. The chosen scale determines the direction of thermal energy transfer between two bodies in contact from the body at higher temperature to that of lower temperature. Heat– transfer of kinetic energy due to a change in temperature (average kinetic energy). Thermal energy– the internal energy of a body of particles.
10. Yes. Ice particles held firmly in a lattice structure by strong forces. High potential energy and some vibrational kinetic energy
11.



12. (a) 336 K (b) –221 ºC
13. Air and water have different specific heat values.

14. No. Boiling is a constant temperature process

15. Wrap a towel around it. The water in the wet towel will evaporate and lose thermal energy. To compensate, thermal energy will be taken from the liquid in the bottle and it will become cooler. Evaporation produces cooling.

16. Evaporation of the perspiration results in a loss of thermal energy from the body so that body temperature can be maintained. By standing in a draught your body temperature can be lowered to an unhealthy level due to the increased amount of surface liquid due to the exercise and this can cause infections such as the common cold.

17. A small number of particles in a liquid have kinetic energies greater than the average kinetic energy. If these particles are near the surface, they will have enough kinetic energy to overcome the attractive forces of neighbouring particles and to escape the liquid as a gas. Now that the more energetic particles have escaped, the average kinetic energy of the remaining particles will be lower. The temperature of the liquid falls as evaporative cooling takes place.

Exercise 3.2 (c) (page 94)

1. C
2. A
3. D
4. 1.2×10^7 J
5. 0.48 kg
6. Steam has more internal energy as it absorbed latent heat to change phase.
7. Energy required = $mc\Delta T + mL_v$

   $=[1.25 \times 10^{-1}\ \text{kg} \times 4180\ \text{J kg}^{-1}\text{K}^{-1} \times (100 - 21\ {}^0\text{C}]+[1.25 \times 10^{-1}\ \text{kg} \times 2.25 \times 10^6\ \text{J kg}^{-1}]$

   $= 4.13 \times 10^4\ \text{J} + 2.81 \times 10^5\ \text{J} = 3.23 \times 10^5$ J.

   Time required = $3.23 \times 10^5 / 5.2 \times 10^2 = 6.2 \times 10^2$ s.
8. $4.0 \times 10^3\ \text{J kg}^{-1}\text{K}^{-1}$
9. 0.25 kg
10. $27 \times 10^2\ \text{J s}^{-1}$
11. You could use an electrical method or the method of mixtures in order to find the specific heat capacity of the metal. Refer to Figure 312 on page 86.
12. $Q = mL_v = 1.2\ \text{kg} \,.\, 2.25 \times 10^6\ \text{J kg}^{-1} = 2.7 \times 10^6$ J.
13. $Q = mL_V + mc\Delta T_{WATER} + mL_f + mc\Delta T_{ICE}$

    $= m\,[L_V + c\Delta T_{WATER} + L_f + c\Delta T_{ICE}]$

    $= 1.5\ [22.5 \times 10^5 + (4180 \text{ x } 100) + 3.34 \times 10^5 + (2100 \times 7)]$

    $= 4.425 \times 10^6$ J. The energy released is 4.4×10^6 J or 4.4 MJ.
14. The latent heat of vaporisation can be found using a self–jacketing vaporiser. The liquid to be vaporised is heated electrically so that it boils at a steady rate. The vapour that is produced passes to the condenser through holes in the neck of the inner flask. Condensation occurs in the outer flask and the condenser.

    Eventually, the temperature of all the parts of the apparatus becomes steady. When this steady state is reached, a container of known mass is placed under the condenser outlet for a measured time t, and the measured mass of the condensed vapour m is determined. The heater current I is measured with the ammeter A and potential difference V is measured with a voltmeter V. They are closely monitored and kept constant with a rheostat.

CHAPTER 4 OSCILLATIONS AND WAVES

Exercise 4.1 (page 107)

1 (a) (i) 2.4 s

(ii) 6.2 cm

(iii) 16 cm s^{-1}

(iv) 1.3ms^{-1}

(v) 61 cm s^{-2}

(b) (i) the velocity is a maximum at $t = 0$ and $t = 1.2$s

(ii) the acceleration is a maximum at $t = 0.6$ s and $t = 1.8$ s

Exercise 4.2 (page 108)

1.2×10^{-20} J

Ex 4.3 (page 110)

Lightly damped	1, 3, 5, 8
Heavily damped	2, 4, 6, 7

Exercise 4.5 (a) (page 122)

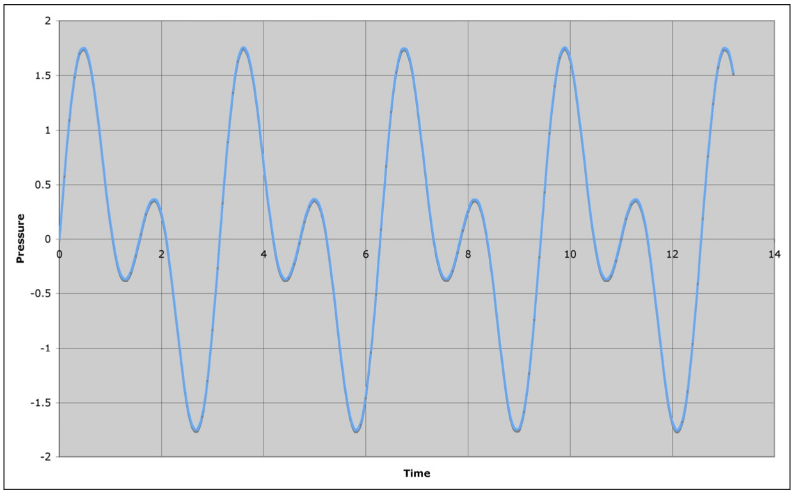
1. (a) (i) 3.1 m

(ii) 1500 m

((b) HINT : consider diffraction.

2. The low frequency, long wavelength waves are diffracted more in the open sea environment thus a wider awareness of another ship. Another explanation is that the method of generating the sound involves the production of a very strong pressure pulse.

Exercise 4.5 (b) (page 124)



The pressure patterns produced when two tuning forks are sounded together is dependent on their frequencies. If the frequencies are simple multiples of one another, the sounds are 'harmonious' (a fact discovered by the Ancient Greeks) and the pressure pattern is regular (see example graph above). If the frequencies are close to one another, the phenomenon of 'beats' is heard.

This can be investigated by downloading the spreadsheet: *Tuning fork.xls* from the IBID website:

https://www.ibid.com.au/ibid/web.nsf/productlookup/72?opendocument

Sophia will hear a beat pattern; a series of high and low amplitudes due to the superposition of the two sounds from tuning forks A and B

CHAPTER 5 ELECTRIC CURRENTS

Exercise 5.1 (page 135,136)

1. C
2. A
3. B
4. B
5. A
6. B
7. a) electrons b) Na^+ and Cl^- c) charged particles
8. a) collisons with the crystal lattice atoms b) collisions with lattice atoms transfers energy.
9. 0.2 Ω
10. 5.0×10^{-3} A
11. 1.35 V
12. 280 m
13. 50 m
14. Electrons drift through the lattice, as temperature increases the lattice atoms vibrate more and this increases the probability of collision and hence resistance to electrons has increased.
15. 14400 °C
16. Ohmic: constant resistance, *I*–*V* garph is linear through origin;

    Non–ohmic: non–linear *I*–*V* graph
17.

Appliance	**Power (Watt)**	**p.d (Volt)**	**Current (Ampere)**	**Fuse rating needed (3,5,10,13 A)**
Digital clock	4	240	$1.7 \text{ x } 10^{-2}$	3
Television	200	240	0.83	3
Hair dryer	550	110	5	10
Iron	920	230	4	5 or 10
Kettle	2400	240	10	13

18. 23 cents
19. 9.3 cents
20. $2.86
21. 1.5×10^{-6} J
22. 2.5×10^{3} eV

Exercise 5.2 (page 147–150)

1. A
2. D
3. C
4. D
5. A
6. A
7. C
8. A. ($1 / R$ = 1/3 +1/3 + 1/3 = 3/3 R = 1Ω)
9. B. ($W = qV$ V = 18 J / 2 C = 9.0 V)
10. C. (One ampere is defined as the current flowing in 2 infinitely–long wires of negligible cross–sectional area separated by a distance of one metre in a vacuum that results in a force of exactly 2×10^{-7} N per metre of length in each wire).
11. C. ($P = VI$. If the voltage is constant, power is directly proportional to the current).
12. A. (Closing the switch will create a short–circuit, and the electrons will by–pass lamp 2, other lamps will then be brighter).
13. C. ($1/R = 1 / R_1 + 1 / R_2$ $1 / R = R_2 + R_1 / R_1R_2$ $R = R_1R_2 / R_1 + R_2$)
14. B. ($V_1 = I_1R_1$ = (100) (2.2×10^{-3}) = 0.22 V

    $V_2 = I_2R_2$ = (150) (1.5×10^{-3}) = 0.225 V

    $V_1 = -I_1r + \varepsilon$ $0.22 = -(2.2 \times 10^{-3})\, r + \varepsilon$

    $V_2 = -I_2r + \varepsilon$ $0.225 = -(1.5 \times 10^{-3})\, r + \varepsilon$

    Subtracting equations $-0.005 = -(0.7 \times 10^{-3})r$

    r = 7.143 Ω)
15. C. ($V = IR$ $I = V/R$ = 12/2 = 6A)
16. C. ($1 / R$ = ¼ + ¼ = 2/4 R = 2 Ω R_{eff} = 2 + 3 = 5Ω

    I = 15 / 5 = 3A V in 3Ω resistor = 3Ω × 3A = 9V

    Therefore, voltage across XY = 15 – 9 = 6V)
17. a) 22 Ω b) 2 Ω
18. 2.9×10^{-3}J
19. a) 24.4 Ω b) 0.5 A c) 10 V d) 1.2 V e) 0.3 A
20. 4.7 Ω

21. When a dry cell goes "flat" its internal resistance has become large. Therefore it can't really charge it. NiCad batteries have a very low internal resistance. Also dry cell chemistry is not reversible.

22. a) 1.54 V b) 0.74 Ω.

23. $I = \Delta q / \Delta t = (2.40 \times 10^3 \text{ C}) / (3.0 \text{ min}) (60 \text{ s.min}^{-1}) = 13.3$ A.

The current flowing is 13A.

24. $V = IR$, $V / I = R = (240 \text{ V}) / (6.0 \text{ A}) = 40\ \Omega$.

The resistance of the iron is $4.0 \times 10^1\ \Omega$.

25. (a) $P = V.I$ $I = P / V$ $I = 2.5 \times 10^3 \text{ J} / 240 \text{ V} = 10.4$ A

The current drawn is 1.0×10^1 A.

(b) $W = V.I.t = (240 \text{ V}) . (10.4 \text{ A}) . (7.2 .10^3 \text{ s}) = 1.8 \times 10^7$ J

The energy consumed is 1.8×10^7 J.

26. Energy consumed = power . time = 2.5 kW × 8 h = 20 kW.h

Cost = (20 kW.h) × $0.14 =$ 2.40

27. (i) Voltage in bottom arm is 100 V

V=IR 100 = I (1.0 Ω + 3.0 Ω) Current in bottom arm I = 25 A.The current entering the top arm = 35 – 25 = 10 A

Voltage in 4.0 Ω resistor = IR = 10 A × 4.0 Ω = 40 V

Voltage in R and 24.0 Ω resistor = 100 – 40 V= 60 V

The current in the 24.0 Ω resistor = V / R = 60 / 24 = 2.5 A

Current in R = 10 – 2.5 A = 7.5 A

$R = V / I$ = 60 V / 7.5 A = 8.0 Ω

(ii) 40 V – 25 V = 15 V

28. (i) 12 V means that it requires 12 J of energy to move 1 coulomb of charge

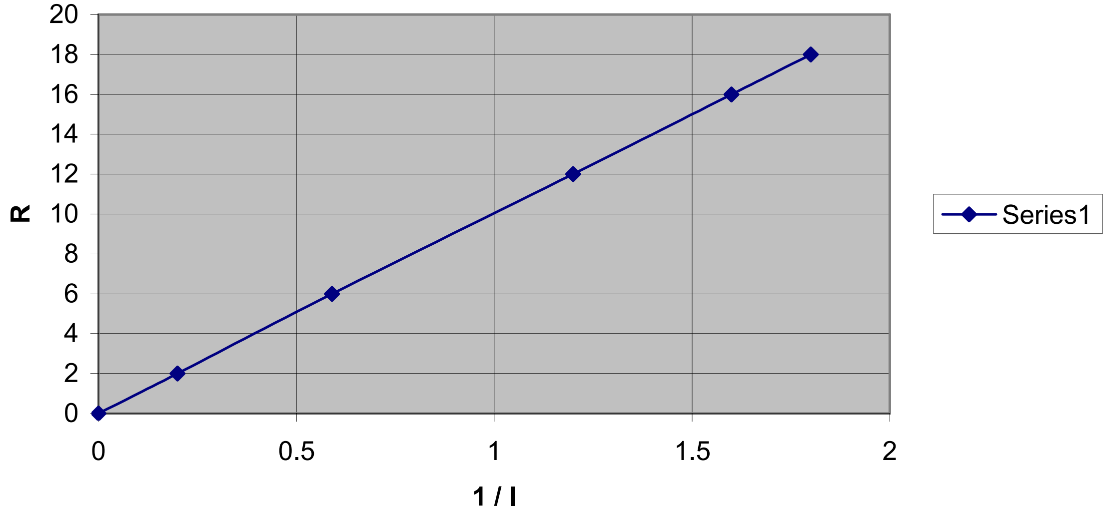
between two points.

(ii) $\varepsilon = IR$ R=2/5.0 R = 0.4 Ω

29 (a)

$R \pm 0.5\Omega$	$I \pm 0.1$ A	$1 / I$ A^{-1}
2.0	5.0	0.20
6.0	1.7	0.59
12	0.83	1.2
16	0.63	1.6
18	0.56	1.8

(b)



(c) the resistance is directly proportional to 1/I OR the resistance is inversely proportional to the current OR other correct statement

(d) the e.m.f. is the slope of the graph

e.m.f. = 10 / 1.0 = 10V

30. From the law of conservation of charge: $I = I_1 + I_2$

From the law of conservation of energy: $V = V_1 = V_2$

From Ohm's law $R = V / I$ $\quad \therefore 1/R = I / V$

$1/R = I_1 / V + I_2 / V$ AND $V = V_1 = V_2$

$\therefore 1/R = I_1 / V_1 + I_2 / V_2 = 1 / R_1 + 1 / R_2$

31. a) $R_{ABC} = 3\Omega$ $\quad R_{ADC} = 1.5\Omega$

$1/R = 1/3 + 2/3 = 1$ $\quad R_{AC} = 1\ \Omega$

Effective resistance = 1 + 1 = 2 Ω

(b) Total current $I = V / R_{eff} = 1.5 / 2 = 0.75$ A

Voltage in 1Ω series resistor = (1)(0.75) = 0.75 V

Voltage in each network = 1.5 – 0.75 = 0.75 V

$I_{ABC} = (0.75) / 3 = 0.25$ A $\quad I_{ADC} = 0.75 / 1.5 = 0.5$ A

(c) $V_{AB} = (1)(0.25) = 0.25$ V $\quad V_{AD} = (0.5)(0.5) = 0.25$ V

(d) 0 V

32. Voltage in the 1 kΩ resistor: $V = IR = 1000 \times 4.5 \times 10^{-3} = 4.5$ V

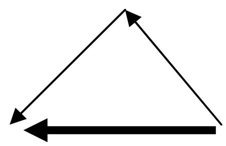
Therefore, voltage in the LDR = 4.5 V.

Resistance in the LDR = $4.5 / 4.5 \times 10^{-3} = 1000 = 1$ kΩ

CHAPTER 6 FIELDS AND FORCES

Exercise 6.2 (pages 162–164)

1. C
2. D
3. B
4. D
5. B
6. C
7. B. ($F \propto 0.5q \times 0.5q$ / $¼^2 = 16 \times 0.25 = 4F$)
8. D. (see diagram adjacent)



9. C. ($F \propto q_1 \times q_2 \quad F \propto ½ \times ½ = ¼$)
10. B. (Charge is a scalar. Potential difference is the work done per unit charge and power is the time rate of doing work. Work is a scalar.)
11. A. $F \propto 1 / d^2$
12. The outside of the tanker can become charged due to air resistance friction. The chain ensures that there is no build–up of charge. If there was an excess of charge, sparking could occur.
13. The droplets of paint all will have the same charge. Therefore, they repel each other causing the paint to spread out.
14. Plastic containers are insulator and can accumulate charge.
15. The conductor (the golf stick) brings electrons from earth through your body. An electrical discharge can occur between the charged clouds and the golf stick.
16. The charge on the inside of a hollow conductor is zero.
17. 64 C
18. 1.2 cm
19. 8.9×10^3 N C^{-1}
20. 9.5×10^4 N C^{-1}
21. Similar – region of influence around a body that causes a force when another body is moved in its field of influence. Different – g is force per unit mass and E is force per unit charge.
22. One charge with twice as many lines of electric flux. Electric field of zero closer to the smaller point charge.

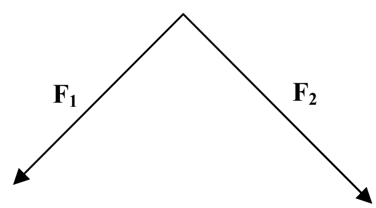
23. 1.9×10^{-12} N repulsion

24. 6.2 N at 30° below the line joining BA and to the left.

25. $F = k.\ q_1q_2 / r^2 = (9.0 \times 10^9\ \text{N.m}^2.\text{C}^{-2}) . (+10\mu\text{C}) . (-5\mu\text{C}) / (0.1\ \text{m}^2)$

$= 45$ N attraction

26. If several point charges are present, the net force on any one of them will be the vector sum of the forces due to each of the others. Since the three point charges are positive, then there will be repulsion on the bottom charge due to each of the top two charges. The rough vector diagram could be shown as follows



The force on the charge on the right angle due to the top two charges is calculated

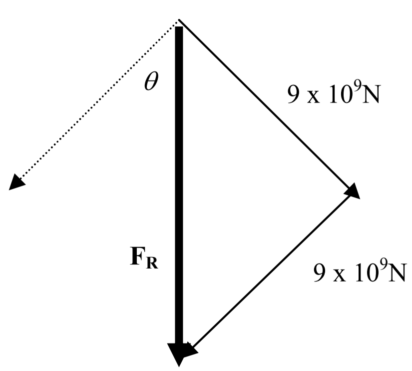
$\boldsymbol{F}_1 = k.\ q_1q_2 / r^2 = (9.0 \times 10^9\ \text{N.m}^2.\text{C}^{-2}) \times (+1\text{C}) \times (+1\text{C}) / (1\ \text{m}^2)$

$= 9 \times 10^9$ N

$\boldsymbol{F}_2 = k.\ q_1q_2 / r^2 = (9.0 \times 10^9\ \text{N.m}^2.\text{C}^{-2}) \times (+1\text{C}) \times (+1\text{C}) / (1\ \text{m}^2)$

$= 9 \times 10^9$ N

The resultant force is given by the vector addition of the two forces that can be obtained by Pythagorean theorem.



$\boldsymbol{F}_\mathbf{R}^{\mathbf{2}} = (9 \times 10^9\ \text{N})^2 + (9 \times 10^9\ \text{N})^2$

$\boldsymbol{F}_\mathbf{R} = 12.7 \times 10^9$ N

The direction of the resultant force can be calculated using trigonometry

$\tan\theta$ = opposite/adjacent = 9×10^9 N / 9×10^9 N = 1

hence $\theta = 45^\circ$

The resultant force is 1.3×10^{10} N in a vertical direction downwards.

27. 5.7×10^6 NC^{-1} away from the charge $E = kq/r^2$

$E = (9 \times 10^9)\ (5.7 \times 10^{-3}) / 3^2 = 5.7 \times 10^6$ NC^{-1}

28. The electric potential at infinity is zero. For convenience, the zero of potential is taken as the Earth's surface.

29. 250 eV or 4.0×10^{-17} J. An electron–volt is defined as the energy gained by one electronic charge when accelerated by a potential of one volt.

30. 0.33 m from the 1μC charge.

Let x = the distance from the 1 μC charge where the magnitude of the electric field equals zero. $kq_1 / x^2 = kq_2 / (1-x)^2$ 1×10^{-6} C / $x^2 = 4 \times 10^{-6}$ C / $(1-x)^2$

$1 / x^2 = 4 / (1-x)^2$ $3x^2 + 2x - 1 = 0$

Factoring $(3x - 1)(x + 1) = 0$, $3x - 1 = 0$, $x = 0.3333$m from the 1 μC charge.

CHAPTER 6 FIELDS AND FORCES

Exercise 6.3 (a) (page 167)

1. During welding processes the iron becomes hot and semi–liquid. When it cools it will often retain the magnetic fields of the Earth or any fields due to the electric currents of the equipment being used at the time (Not ac. currents, only dc.).
2. The magnets cause magnetic induction in the iron casing of the refrigerator causing a force of attraction between them.
3. Draw a diagram to show a north pole of one magnet and the south pole of another magnet side by side. Have the pole with the weaker field strength closer to the other pole. Have the lines of flux coming out of the north pole and going into the south pole between the poles. Then have other lines of flux radially at the corners of their poles.
4. North pole.

Exercise 6.3 (b) (page 170,171)

1. B ($B = F / Il$ = kg m s^{-2} / A m)
2. A
3. D
4. B
5. A
6. B
7. D
8. B
9. 1.2×10^{-13} N
10. 7.5 N
11. 1.0 N
12. 3.0×10^{6} m s^{-1}
13. (a) 6.5×10^{7} m s^{-1} (b) 0.62 m
14. $\boldsymbol{F} = q\boldsymbol{vB}$ = –15C × 1.0 × 10^{3} ms^{-1} × of 1.2 × 10^{-4} T = 0.18 N east
15. (a) $\boldsymbol{B} = \boldsymbol{F} / I\,l$ = 0.2 N / 1.5 A × 0.5 m = 0.2666 = 0.3 T

    (b) increase the product BI by a factor of 10.

CHAPTER 7 ATOMIC AND NUCLEAR PHYSICS

Exercise 7.2 (Page 182)

1. 22.5 hours
2. 10 seconds

Exercise 7.3 (a) (Page 186)

1. 30.57 MeV, 5.1 MeV
2. 6.82 MeV
3. Yes

Exercise 7.3 (b) (Page 188)

1. $x = 2$, 180 MeV
2. By calculation using given values for each particle.

Exercise 8.1 (page 194)

1. D
2. A
3. C
4. D
5. D
6. B
7. Approximately 15% lost in furnace, 40% lost in heat exchanger, 10% lost as friction in turbine and the generator, 35% output as electrical energy. Therefore the power station is about 35% efficient.
8. Chemical to thermal and light

   Chemical to thermal and kinetic

   Sound to electrical

   Chemical to thermal and kinetic and sound

   Electrical to light and thermal

   Electrical to light

   Electrical to thermal

   Electrical to sound

   Thermal to electrical

   Nuclear to thermal, sound and light

Exercise 8.3 (page 208)

1. B
2. C
3. D
4. It is determined in joules per gram J g^{-1} or kilojoules per gram kJ g^{-1} as bomb calorimetry is used to determine the value and this technique requires only small masses of a sample. A mole can be a large mass. And we buy fuels by mass/volume not moles thus it is more useful to use this unit.
5. To increase the surface area of the coal to allow for a greater rate of combustion.
6. Energy required to convert the water to steam = $mc\Delta T + mL_V$

   Since there is 65% moisture content, there is 65 g of water per 100g of coal

   The heat energy absorbed to turn 65 grams of water into steam would be:

   $Q = 65\text{g} \times 4.18\ \text{Jg}^{-1}\text{K}^{-1} \times (100\ ^{o}\text{C} - 20\ ^{o}\text{C}) + 65\text{g} \times (22.5 \times 10^{2}\ \text{J g}^{-1})$

   = 167986 J = 168 kJ

   The energy density in the other 35 grams of lignite is 28 kJ g^{-1} × 35

   = 980 kJ

   The total usable energy in 100 grams = 980 – 168 kJ = 812kJ

   For one gram this would be 8.1 kJ g^{-1}

   The energy density as it is mined will be 8.1 kJ per gram less than when the coal is dried.

   = 28 kJ g^{-1} – 8.1 kJ g^{-1}

   The energy density of the coal as it is mined is 19.9 kJ g^{-1} .
7. (a) Assuming the hydrogen and oxygen is converted to steam, the total amount of steam

   = 30% + 30% of the remaining 70% = 51%

   51% of 1000 tonnes = 510 tonnes.

   (b) 510 × 24 × 7 = 8.6 x 10^4 tonnes

   (c) 1 tonne = 1000 kg 1dm^3 = 1kg

   8.6 × 10^4 tonnes × 1000 = 8.6 × 10^7 dm^3

8. Crude oil is used in the petrochemical industry to produce many products such as plastics, polymers, pharmaceuticals, synthetic textiles and fabrics. Other fuels such as LPG and LNG have a higher energy density than petrol and there are more supplies of gases than crude oil. The petrol engine is only 25% efficient and a greater efficiency can be obtained from cars that run on liquid petroleum gas. LPG is cleaner than petrol as it burns more efficiently and it contains less pollutants. In the future, the petrochemical industries will need feedstock to continue to produce products for consumers.

9. (a) $C_5H_4 + 6\ O_2 \rightarrow 5CO_2 + 2H_2O$

(b) One mole of coal (64 grams per mole) requires 6 moles of oxygen (32 grams per mole).The mass in grams in 1000 tonne of coal

$= 1000$ tonne $\times$ 1000 kg $\times$ 1000g $= 10^9$ g.

The number of mole of coal $= 10^9$ g / 64 g per mol $= 1.56 \times 10^7$ mol.

The number of mol of oxygen $= 1.56 \times 10^7$ mol $\times 6 = 9.36 \times 10^7$ mol.

Therefore, the mass of oxygen required $= 32 \times 9.36 \times 10^7$ g

$= 300 \text{ x } 10^7$g $= 3.0 \times 10^6$ kg $= 3000$ tonnes of oxygen.

(c) Volume of oxygen $= 25\ dm^3 \times 9.36 \times 10^7$ mol $= 2.34 \times 10^9\ dm^3$.

(d) Volume of air $= 5 \times 2.34 \times 10^9\ dm^3 = 1.2 \times 10^{10}\ dm^3$.

10. (a) Since 35% efficient heat must be supplied at 500 MW / 0.35 = 1429 MW

(b) 1 kg consumed for $31.5 \times 10^6\ J\ s^{-1}$. So for $1429 \times 10^6\ J\ s^{-1}$ the kg s^{-1} is

$1429 / 31.5 = 45.4$ kg s^{-1}.

(c) The amount of heat entering the cooling towers = 1429 – 500 = 929 MW.

$Q = mc\Delta T$. So $Q / t = mc\Delta T / t$. Therefore, $m/t = Q / c\Delta T$

$m / t = 929 \times 10^6 / 4180 \times 10 = 2.2 \times 10^4$ kg s^{-1}.

Exercise 8.4 (a) (page 217)

1. C
2. B
3. C
4. A
5. D
6. The longer half–life of the fission process makes alpha decay a more probable form of decay. 7. a. Once a reaction is induced by neutron bombardment, the reaction produces additional neutrons to continue the reaction.b. Control rods are used to control nuclear reactors – they do so by absorbing neutrons thus limiting the rate of slow neutron capture and hence the reaction rate.
8. (i) 1000 MW (ii) 400 MW (iii) 1000 MW
9. Arguments for include cheap, readily available fuel, and longevity of fuel supplies, as well as the possibility of recycling fission products for fuel. b. Arguments against are the possibility of a catastrophic accident, and the risk to the environment and future generations of long term waste disposal.
10. 200 MeV = 200×10^6 eV x 1.6×10^{-19} C = 3.2 x 10^{-11} J.

    500 MW = 500×10^6 Js^{-1}

    Therefore, the number of fissions = 500×10^6 Js^{-1} / 3.2×10^{-11} J.

    = 1.56×10^{19} fissions.
11. Chemical bond breaking is endothermic while nuclear fission may be exothermic or endothermic. Fission involves the breakdown of the nucleus while chemical bond breaking involves the rearrangement of electrons. No new elements are formed in chemical bond breaking but they are in nuclear fission. Mass is lost in nuclear fission and retained in chemical bond breaking.
12. 200 MeV = 200×10^6 eV $\times$ 1.6×10^{-19} C = 9.6×10^{-11} J.

    500 MW = 500×10^6 Js^{-1}.

    The total number of seconds in a year = $60 \times 60 \times 24 \times 365.25 = 3.16 \times 10^7$ s

    Per year the total electrical energy = 3.16×10^7 s $\times$ 500×10^6 J s^{-1}

    = 1.58×10^{16} J yr^{-1}.

    Since 35% efficient, the total energy needed = 1.896×10^{16} Jyr^{-1} / 0.35

    = 4.51×10^{16} J yr^{-1}.

    1 fission produces 3.2×10^{-11} J. So for 4.51×10^{16} J there would be

    4.51×10^{16} J / 3.2×10^{-11} J = 1.41×10^{27} fissions.

    Mass of uranium–235 = $235 \times 1.661 \times 10^{-27}$ kg = 3.90335×10^{-25} kg per fission

    Mass of uranium–235 needed = 3.90335×10^{-25} kg $\times$ 1.41×10^{27} fissions

    = 550.2 kg

Exercise 8.4 (b) (page 226–228)

1. C
2. C
3. D
4. A
5. solar panel: solar energy → thermal energy (heat).
   solar cell: solar energy → electrical energy.
6. (a) power = energy / time = 150 × 10^{12} J / 60 × 60 x 24 × 365 = 4.75 × 10^6 MW

   therefore, for one turbine = 4.75 × 10^6 / 25 = 0.19 MW

   (b) Power = ½ $A \rho v^3$ and $A = \pi r^2$

   0.19 × 10^6 Js^{-1} = 0.5 × π × r^2 m^2 × 1.3 kgm^{-3} × 15^3 m^3s^{-3}

   $r = \sqrt{2P/\pi\rho v^3}$ √[(2 × 0.19 × 10^6) / (π × 1.3 kgm^{-3} × 3 375 m^3s^{-3})]

   = 5.25 m
7. (a) mass of water = 2.4 × 10^3 kg;
   energy required = 2.4 × 10^3 kg × 4.18 × 10^3 Jkg^{-1} ^0C× 40 ^0C

   = 4.0 × 10^8 J.

   (b) energy provided in 2 hours = 7 200 × 1000 × A. therefore A

   = (4.0 × 10^8 J) / (7200 s × 1000 Js^{-1}) = 55.6 m^2. *(note change to Q)*
8. Power / λ = ½ $\rho g A^2 f$

   = 30 m × 0.5 × 1020 kgm^{-3} × 10 ms^{-2} × $(6)^2$ m^2 × 1m × 0.1s^{-1}

   = 550 × 10^3 kg m^2 s^{-3}

   = 550 kW per metre. *(note change to Q)*
9. Power = ½ $\rho g A^2 \lambda / T$

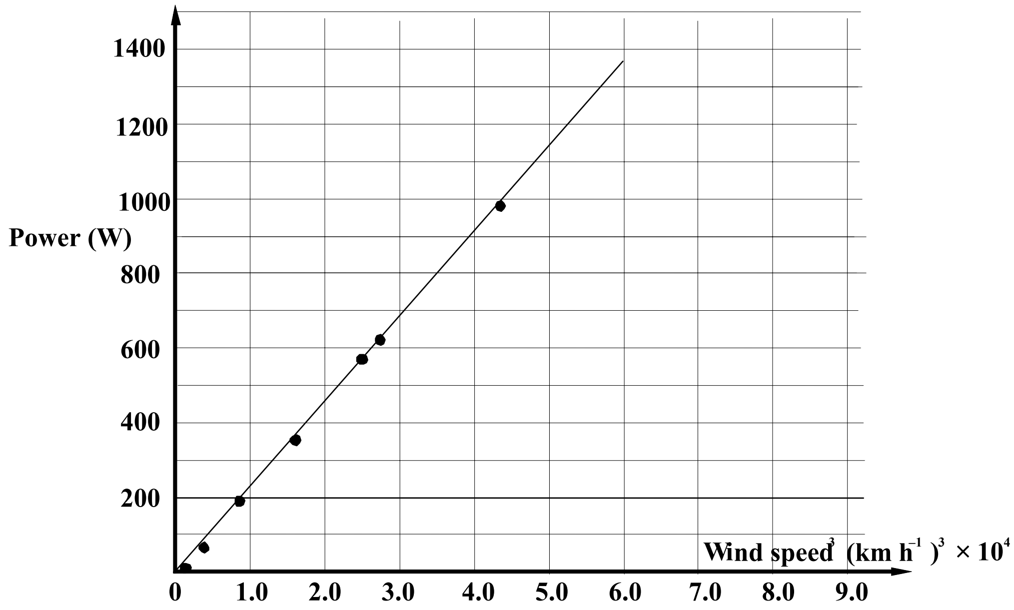
   = 0.5 × 1020 kgm^{-3} × 10 ms^{-2} × $(6)^2$ m^2 × 25m × 1m / 8s

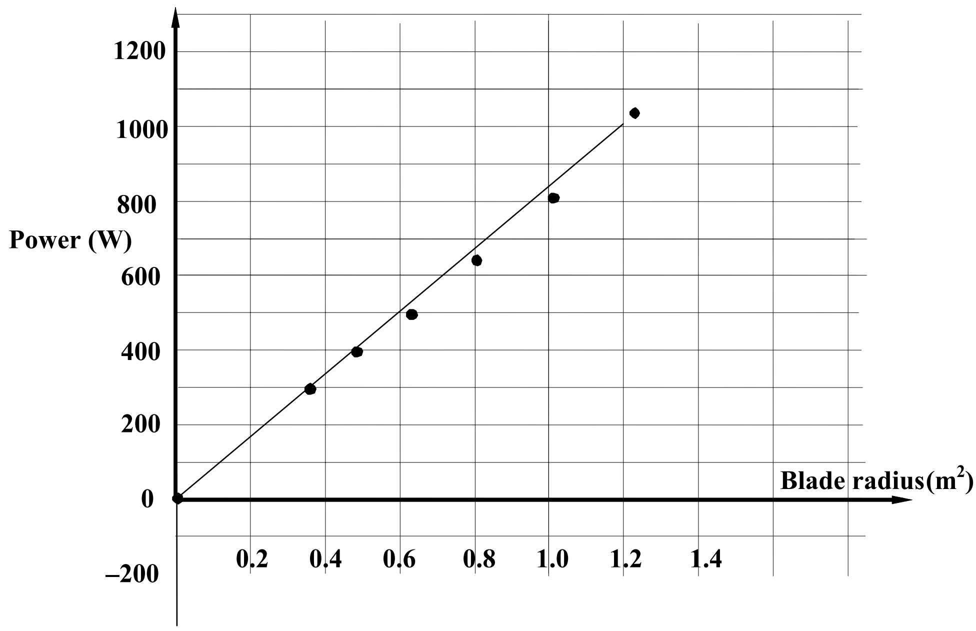
   = 5.74 × 10^5 kg m^2 s^{-3}

   = 574 kW per metre.

   Wave speed = wavelength / period = 25 m / 8 s = 3.1 ms^{-1}
10. 880 MW
11. 1.9 × 10^3 m^2 ~ 2000 m^2

12.


1400
1200
1000
Power (W)
800
600
400
200
Wind speed^3 (km h^{-1})^3 × 10^4
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


1200
1000
800
Power (W)
600
400
200
0
–200
Blade radius(m^2)
0.2
0.4
0.6
0.8
1.0
1.2
1.4

Exercise 8.5 (page 241)

1. B
2. D. (The temperature is doubled. So the factor is $2^4 = 16 \times 300 = 4800$ W.)
3. B. (The radius is double so the factor is $(2r)^2 = 4 \times 300 = 1200$ W.)
4. A. (The same as the rate is only dependant on the temperature of the black body.)
5. A. (There is no thermal energy transfer and so no net rate of heat loss)
6. B. (It is only dependant on temperature.)
7. (a) Black–body radiation is the radiation emitted by a "perfect" emitter. A non–black body is not a perfect radiator of energy.

   (b) The spectrum extends into the red region of the visible spectrum at 1500 K. It extends into the ultra–violet region at 3000 K.

   (c) The total area under a spectral emission curve for a certain temperature T represents the total energy radiated per metre ^{2} per unit time E and for that assigned temperature it has been found to be directly proportional to the fourth power T^4.

   (d) The energy distribution of the wavelengths move into shorter wavelength regions while still being found in the infrared and visible regions.
8. $P = 2\pi r \sigma (T^4 - T_0^4) = 2\pi \times 0.01 \times 5.67 \times 10^{-8} (340^4 - 300^4) = 18.75 = 19 \text{ Wm}^{-1}$

9. (a) Power from the Sun = $4\pi r_S^2 \sigma T^4$. Power received by the earth = the area on which the Sun's radiation is normally incident ÷ the total suface area on which the Sun's radiation falls when the earth is 1.5×10^{11} m from the Sun × the power radiated by the Sun.

   $= (\pi r_E^2 \div 4\pi r^2) \times 4\pi r_S^2 \sigma T_S^4$.

   If the earth is in radiative equilibrium with the Sun, the power received by the earth = the power radiated by the earth.

   $4\pi r_E^2 \sigma T_E^4 = (\pi r_E^2 \div 4\pi r^2) \times 4\pi r_S^2 \sigma T_S^4$

   $T_E^4 = (r_S^2 \div 4\pi r^2) \times T_S^4$

   $T_E = T_S x (r_S / 2r)^{½} = 6000 \times (6.5 \times 10^8 / 3 \times 10^{11})^{½} = 306$ K

   (b) Assumptions: both bodies are black bodies, no radiation is lost in the atmosphere, no heat is radiated by the earth's interior.

10. $C_S = f \rho c h$

    So $C_S = 0.7 \times 1000 \text{ kgm}^{-3} \times 4200 \text{ Jkg}^{-1}\text{K}^{-1} \times 50 \text{ m} = 2.1 \times 10^6 \text{ Jm}^{-2}\text{K}^{-1}$.

11 Incoming radiation = $(1 - \alpha) \times 1.2$ x solar constant / 4
   $= (1 - 0.3) \times 1.2 \text{ x } 1.35 \times 10^3 \text{ Wm}^{-2} \div 4 = 283.5 \text{ Wm}^{-2}$

   Outgoing radiation = $\sigma T_E^4 = 5.7 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (255)^4 \text{ K}^4 = 241 \text{ Wm}^{-2}$

   The change in temperature ΔT would equal:
   $(283.5 \text{ Wm–}^2 - 241 \text{ Wm}^{-2})\ 60 \times 60 \times 24 \times 365 \times 2 \div 4 \times 10^8 \text{ J m}^2 \text{K}^{-1}$
   = 6.7 K

Exercise 8.6 (page 248)

1. (a) *energy* – the capacity to do work.

   (b) *energy density* – the amount of potential energy stored in a fuel per unit mass, or per unit volume depending on the fuel being discussed.

   (c) *efficiency* of an energy conversion process – ratio of the useful energy output to the total energy input usually expressed as a percentage.

   (d) *albedo* (α) – (Latin for white) at a surface is the ratio between the incoming radiation and the amount reflected expressed as a coefficient or as a percentage.

   (e) *resonance* – when the frequency of the infrared radiation is equal to the frequency of vibration then resonance occurs.

   (f) *emissivity* – the ratio of the amount of energy radiated from a material at a certain temperature and the energy that would come from a blackbody at the same temperature and as such would be a number between 0 and 1.

   (g) *surface heat capacity* C_s – the energy required to raise the temperature of a unit area of a planet's surface by one degree Kelvin and is measured in $Jm^{-2}K^{-1}$.

   (h) *coefficient of volume (or cubica) expansion* β – the fractional change in volume per degree change in temperature and is given by the relation: $\Delta V = \beta V_0 \Delta T$ where V_0 is the original volume, ΔV is the volume change, ΔT is the temperature change and β is the coefficient of volume expansion.

2. (a) *thermodynamic cycle* – a process in which the system is returned to the same state from which it started. That is, the initial and final states are the same in the cyclic process.

   (b) *energy degradation* – when energy is transferred from one form to other forms, the energy before the transformation is equal to the energy after (Law of conservation of energy). However, some of the energy after the transformation may be in a less useful form. We say that the energy has been degraded.

   (c) *fossil fuels* – naturally occurring fuels that have been formed from the remains of plants and animals over millions of years. The common fossil fuels are peat, coal, crude oil, oil shale, oil tar and natural gas.

   (d) *renewable energy source* – one that is permanent or one that can be replenished as it is used. Renewable sources being developed for commercial use include solar energy, biomass, wind energy, tidal energy, wave energy, hydro–electric energy and geothermal energy.

   (e) *pump storage systems* – used in off–peak electicity demand periods. The water is pumped from low resevoirs to higher resevoirs during this period.

   (f) *combined cycle gas turbines* (CCGT) – a jet engine is used in place of the turbine to turn the generator. Natural gas is used to power the jet engine and the exhaust fumes from the jet engine are used to produce steam which turns the generator.

(g) *oscillating water column* (OWC) – wave energy devices that convert wave energy to electrical energy. These can be moored to the ocean floor or built into cliffs or ocean retainer walls.

(h) *black–body radiation* – the radiation emitted by a "perfect" emitter. The radiation is sometimes called temperature radiation because the relative intensities of the emitted wavelengths are dependant only on the temperature of the black body.

3. (a) *Intergovernmental Panel on Climate Change (IPCC)* – in the 1980s, the United Nations Environment Program in conjunction with the World Meteorological Organization set up a panel of government representatives and scientists to determine the factors that may contribute to climate change. The panel was known as the Intergovernmental Panel on Climate Change (IPCC). This body has published many extensive reports that formed the basis for many discussions and decision–making about the enhanced greenhouse effect.

(b) *Kyoto Protocol* – this agreement required industrialized countries to reduce their emissions by 2012 to an average of 5 percent below 1990 levels. A system was developed to allow countries who had met this target to sell or trade their extra quota to countries having difficulty meeting their reduction deadlines.

(c) *Asia–Pacific Partnership for Clean Development and Climate (APPCDC)* –it proposed that rather than imposing compulsory emission cuts, it would work in partnership to complement the Kyoto protocol. The six countries involved were Australia, China, India, Japan, South Korea and the USA. They have agreed to develop and share clean technology for improved emissions of fossil fuel plants together with rewards for the enhancement of renewable energy resources in their countries.

4. The **natural greenhouse effect** is a phenomenon in which the natural greenhouse gases absorb the outgoing long wave radiation from the earth and re–radiate some of it back to the earth. It is a process for maintaining an energy balancing process between the amount of long wave radiation leaving the earth and the amount of energy coming in from the sun. Provided that the Sun's radiant energy remains constant and the percentage of greenhouse gases remains the same, then the established equilibrium will remain steady and the average temperature of the earth will be maintained at 16 ^{0}C.

CHAPTER 9 MOTION IN FIELDS

Exercise 9.1 (Page 254)

1. (b) It has no physical significance. It does not apply to the upward journey as on its upward journey, the stone will reach a height of 15m in +1 s.

   (c) (100 + 11.25) = 110 m (2sd), 160 m

Exercise 9.2 (page 258)

1. (a) 10^{10} J

   (b) 1.3×10^{10} J

   (c) 10 = numerical value of ‘g’ at surface

Exercise 9.3 (page 265–267)

1. B

2. The electric potential of the +2 μC charge at B due to the 2 μC charge at A is:

   $V = (9 \times 10^9 \text{ N m}^2 \text{C}^{-2} \times 2 \times 10^{-6} \text{ C}) \div 0.25 \text{ m} = 7.2 \times 10^4 \text{ V}$

   The electric potential of the +2 μC charge at B due to the 2 μC charge is:

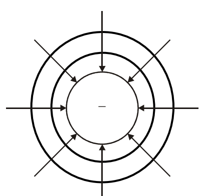
   $V = (9 \times 10^9 \text{ N m}^2 \text{C}^{-2} \times 2 \times 10^{-6} \text{ C}) \div 0.25 = 7.2 \times 10^4 \text{ V}$

   The net absolute potential is the sum of the 2 potentials

   $7.2 \times 10^4 \text{ V} + 7.2 \times 10^4 \text{ V} = 1.4 \times 10^5 \text{ V}$.

3. $\boldsymbol{E} = -V / x = 20 / 0.05 = 400 \text{ Vm}^{-1}$

4. (a)



   N.B.– Sufficient arrows to show decreasing radial field, direction, no field in the centre.

   – Three concentric circles, with increasing radii.

   (b) The field strength is the gradient of the potential so E must be decreasing since the distance is increasing.

   (c) (i) Use $E = kq / r^2 = 9 \times 10^9 \times 6 \times 10^{-6} / 0.025^2$ $E = 8.6 \times 10^7 \text{ V m}^{-1}$

   (d) (i) along a field line outwards.

   (ii) $F = ma = qE$, $a = \text{Eq/m} = (1.6 \times 10^{-19}/9.11 \times 10^{-31}) \times 8.6 \times 10^7$

$= 1.5 \times 10^{19}$ m s^{-2}.

5. $W = qV = 10 \times 10^{-9} \times 1.50 \times 10^{2} = 1.5 \times 10^{-6}$ J.

6. The electric potential of the +2 μC charge at B due to the 2 μC charge at the apex is:

   $V = (9 \times 10^{9}$ N m^{2} C$^{-2} \times 2 \times 10^{-6}$ C$) \div 0.25$ m $= 7.2 \times 10^{4}$ V

   The electric potential of the +2 μC charge at B due to the 2 μC charge is:

   $V = (9 \times 10^{9}$ N m^{2} C$^{-2} \times 2 \times 10^{-6}$ C$) \div 0.25 = 7.2 \times 10^{4}$ V

   The net absolute potential is the sum of the 2 potentials

   7.2×10^{4} V $+ 7.2 \times 10^{4}$ V $= 1.4 \times 10^{5}$ V.

7. Using $E = -V/x$, $x = V / E = 2.5 \times 10^{2} / 2.00 \times 10^{3} = 0.125$ m

8. (i) $W = qV = 1.6 \times 10^{-19}$ C $\times 1.0 \times 10^{4} = 1.6 \times 10^{-15}$ J. (ii) ½ mv$^{2} = 1.6 \times 10^{-15}$ J

   $v = \sqrt{}$ $(1.6 \times 10^{-15}$ J $\times 2 \div 9.11 \times 10^{-31}$ kg$) = 5.9 \times 10^{7}$ ms^{-1}. (iii) $E = -V/x$

   $E = 1.0 \times 10^{4}$ V $/ 1.00 \times 10^{-3}$ m $= 1.0 \times 10^{7}$ Vm^{-1}.

9. $W = qV = 1$ eV $\times 2.5 \times 10^{3} = 2.5 \times 10^{3}$ eV.

10. Using the formula $V = kq / r$, we have $V = 9 \times 10^{9} \times -1.0 \times 10^{-5} \div 2.0 \times 10^{-2}$

    $= 4.5 \times 10^{6}$ V.

11. The electric potential due to the +5 pC charge at the mid point is:

    $V = (9 \times 10^{9}$ Nm^{2}C$^{-2} \times +5 \times 10^{-12}$ C$) \div 0.05$ m $= +0.9$ V. The electric potential due to the –20 μC charge is V = $(9 \times 10^{9}$ N m^{2}C$^{-2} \times -20 \times 10^{-12}$ C$) \div 0.05 = -3.6$V

    The net absolute potential is the sum of the 2 potentials $= -3.6 + 0.9 = -2.7$ V

12. 1.0×10^{9} eV

13. (a) $\Delta W = -qE\Delta x = -1.5 \times 10^{-6}$ C $\times 1.4 \times 10^{3}$ N C$^{-1} \times -0.055$ m $= 1.2 \times 10^{-4}$ J.

    (b) $\Delta V = Ex = 1.4 \times 10^{3}$ NC$^{-1} \times 0.055$ m $= 77$ V.

    (c) $\Delta V = Ed = 1.4 \times 10^{3}$ NC$^{-1} \times 0.15$ m $= 210$ V.

14. (a) $\Delta W = q\Delta V = 32$ C $\times 1.2 \times 10^{9}$ V $= 3.8 \times 10^{10}$ J.

    (b) KE = ½ mv^{2} and $v = \sqrt{}$ $(2 \times KE \div m) = \sqrt{}$ $(2 \times 3.8 \times 10^{10}$ J / 1000 kg)

    $= 8.7 \times 10^{3}$ ms^{-1}.

    (c) $Q = mL_f$ and $m = Q / L_f = 3.8 \times 10^{10}$ J $/ 3.34 \times 10^{5}$ Jkg$^{-1} = 1.1 \times 10^{5}$ kg.

15. (a) – 2.25 V (b) – 2.25 V (c) 0 V

16. $V = kq / r = k\,(-6 +3 +2 +5$ μC$) / \sqrt{2} \times 0.5 = 5.1 \times 10^{4}$ V.

Exercise 9.4 (page 272)

1 D

2 2.6×10^3 m s^{-1}, T = 1.6×10^4 s

3 1.0×10^4 m s^{-1}

4 8:1

5 (a) GM/5R

(b) GM/10R

(c) GMm/5R

6 9.6×10^3 m s^{-1}

7 $g_{Earth} = 4g_{Moon}$

8 1.67 N kg^{-1}, 1.68×10^3 m s^{-1}

CHAPTER 10 THERMAL PHYSICS

Exercise 10.1 (pages 275,276)

1. D

2. D

3. C

4. D

5. C

6. (a) $pV = nRT$

$15 \times 10^{6} \times 3 \times 10^{-2} = n \times 8.31 \times 298 \qquad n = 181.70\ (182)$

(b) number $= n \times N_A$
number $= 181.7 \times 6.02 \times 10^{23} = 1.1 \times 10^{26}$

(c) average volume = $3 \times 10^{-2} / 1.1 \times 10^{26} = 2.7 \times 10^{-28}\ m^3$

(d) average separation $\approx (2.7 \times 10^{-28}\ m^3)^{1/3} = 5.8 \times 10^{-10}$ m.

7. the number of moles = 2 mol. $pV = nRT$ and $p = nRT/V$

$= (2\ mol \times 8.31 \times 298) / 0.2\ m^3$

$= 2.5 \times 10^{4}$ Pa.

8. (a) An **ideal gas** is a theoretical gas that obeys the **equation of state of an ideal gas exactly**. They obey the equation $pV = nRT$ when there are no forces between molecules at all pressures, volumes and temperatures.

(b) any 3 postulates of the kinetic theory of gases. These could include:

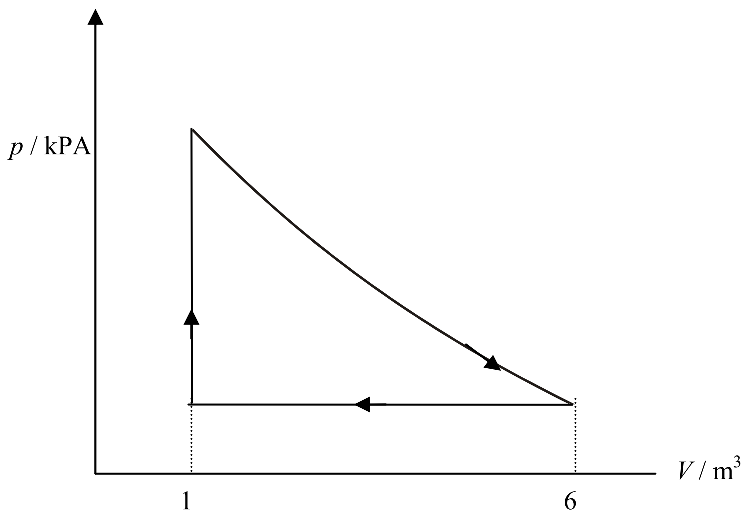
- The range of the intermolecular forces is small compared to the average separation of the molecules.
- The size of the particles is relatively small compared with the distance between them.
- Collisions of short duration occur between molecules and the walls of the container and the collisions are perfectly elastic.
- No forces act between particles except when they collide, and hence particles move in straight lines.

(c) There are no forces between molecules/atoms so there is no potential energy and therefore the internal energy = (random) kinetic energy.

CHAPTER 10 THERMAL PHYSICS

Exercise 10.2 (pages 286–288)

1. B
2. B
3. C
4. C
5. B
6. A
7. C
8. 1.29×10^6 J
9. $\Delta U = -6.4 \times 10^5$ J.
10.



11. $\Delta U = -3.8 \cdot 10^4$ J, new temp = 72 °C.
12. (a) $Q = 0$ (b) $\Delta U = Q - W = -1750$ J. i.e., Internal energy drops, so temp falls
13.

Process	*Q*	*W*	ΔU
Isobaric compression of an ideal gas	–	0	+
Isothermal compression of an ideal gas	–	–	0
Adiabatic expansion	0	+	–
Isochoric pressure drop	–	0	–
Free expansion of a gas	0	0	0

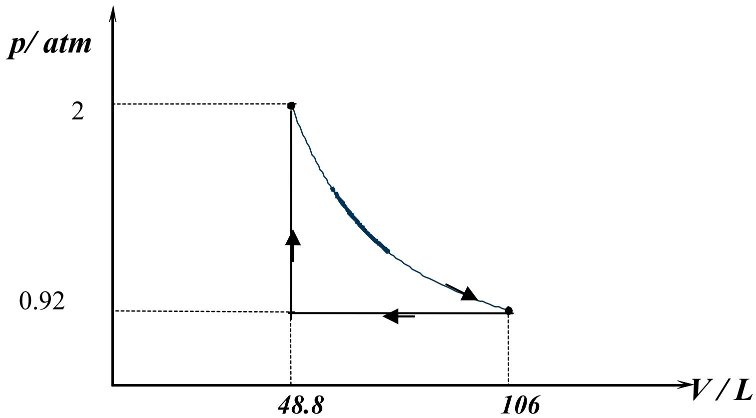
14. (a) $PV = nRT$, $2 \times 101.3 \times 10^3$ Pa $\times 48.8 \times 10^{-3}$ m^3 = n $\times$ 8.31 JK^{-1}mol^{-1} $\times$ 312 K

n = 3.8133 = 3.8 mol.

(b) Temperature the same for an isotherm. So, use $PV = nRT$ $\quad P = nRT / V$

P = 3.8133 × 8.31 × 312 / 106 × 10^{-3} = 9.3 × 10^4 Pa = 0.92 atm

(c)



(d) Work = area under the curve = area of triangle + area of rectangle

= [½ (106 – 48.8) × 10^{-3} × 1.08 × 101.3 × 10^3] + [0.92 × 101.3 × 10^3 × 57.2 × 10^{-3}]

= 3128.9 + 5330.8 = 8.5 kJ.

(e) –5.3 kJ.

(f) 0 J

(g) 8.5 – 5.3 = 3.2 kJ

(h) $T = PV / nR$ = 9.3 × 10^4 × 48.8 × 10^{-3} / 3.8133 × 8.31 = 144 K.

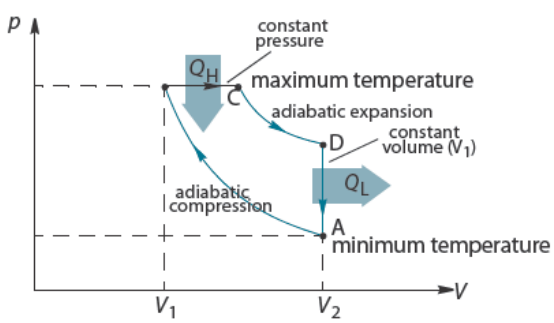
15. (a) isothermal: takes place at constant temperature. adiabatic: no energy exchange between gas and surroundings

(b) (i) neither

(ii) $\Delta W = P\,\Delta V$ = 1.5 × 10^5 × 0.06 = 6.0 × 10^3 J;

(iii) $\Delta Q = \Delta U + \Delta W$. ΔU = 7 × 10^3 – 6.0 x 10^3 = 1.0 × 10^3 J.

16.



CHAPTER 10 THERMAL PHYSICS

Exercise 10.3 (page 291, 292)

1. C
2. B
3. Suck is the induction stroke, squeeze is the compression stroke, bang is the expansion (power) stroke, and blow is the exhaust stroke.
4. External – fuel is burnt outside the engine eg. Steam engine. Internal – fuel is burnt inside the engine eg. Motor car engine.
5. (a) 2.35×10^4 J (b) 1.55×10^4 J
6. The temperature would increase. A net amount of work has to be done to remove heat from the lower temperature reservoir. Both the heat and work are expelled as heat at the back of the fridge
7. Coal 63% nuclear 50%
8. 448 K = 175°C
9. 410 J K^{-1}
10. The development of an individual from a single cell to a grown person is a process of increasing order. However, the metabolism required for this growth expels waste materials into the environment that have greater disorder. Entropy increases and the ageing process goes forward as suggested by the arrow of time
11. There are 64 possible outcomes (microstates). e.g., One macrostate might be 2H and 4T. The microstates for this are: HHTTTT, HTHTTT, TTTHHT, etc.
12. Energy degradation means a trend towards less useful forms of energy, with thermal energy the most disordered state.
13. There is strictly speaking, no reason why heat cannot flow from a cold object to a hot object – that is, the hot object getting hotter and the cold object getting colder. However, the probability of this happening is very small indeed.
14. "Heat death" – all natural processes have disorder. Hence, as time goes on, the entropy (disorder) of the Universe increases until maximum disorder occurs with all objects at the same temperature. So all the energy of the Universe becomes thermal energy and no work can be done. This is the point of the "heat death" of the Universe.

CHAPTER 11 WAVE PHENOMENA

Exercise 11.1 (a) (page 295)

See figure 1106 directly above the exercise!

Exercise 11.1 (b) (page 297)

(a) (i) 384 Hz, 640Hz
(ii) 256 Hz, 384 Hz
(iii) 2:1

(b) HINT: consider relative lengths of the pipes

Exercise 11.2 (a) (page 299)

(a) 64.7 m s^{-1} (b) 512 Hz

Exercise 11.2 (b) (page 300)

6.91×10^{-7} m

Exercise 11.3 (page 303)

2.0×10^{-3} rad, 3.0 cm 2. 430 nm

Exercise 11.4 (a) (page 306)

$\approx 10^{-9}$ rad

Exercise 11.4 (b) (page 307)

Yes, separation of images is 12×10^{-6} m

Exercise 11.4 (c) (page 307)

1.6 m

Exercise 11.5 (a) (page 311)

A $\cos^2$ graph should be drawn

Exercise 11.5 (b) (page 312)

1. 1.51°
2. See the procedure is section 11.5.6–9 and the use of a polarimeter.
3. See Page 312

CHAPTER 12 ELECTROMAGNETIC INDUCTION

Exercise 12.1 (page 319–321)

1. A
2. D
3. C
4. D
5. B. ($F = BIl \qquad B = F / Il = ma / Il = \text{kg m s}^{-2}\text{A}^{-1}\text{m}^{-1}$)
6. D
7. A
8. Speed of movement, strength of the magnetic field, the number of turns and the area of the coil
9. When the coil is moved towards the north pole of the magnet, an induced current is produced that moves anti–clockwise at that end of the coil. When the coil is stationary, there is no induced current. When the coil is moved in the opposite direction, the induced current direction is clockwise. But remember, it is the relative motion that is important – so in effect, there is no difference.
10. (a). double e.m.f (b). quarter e.m.f (c). no difference
11. A magnetic field has a flux density B of one tesla if there is one line of magnetic induction of one weber passing through an area A of one square metre. The magnetic flux Φ is the total magnetic flux through an area and is given by $\Phi = BA$
12. 1.7×10^3 V
13. 1.6 V
14. 0.05 Wb
15. 7.0 T
16. (a) $\Phi = BA = 0.2 \text{ T} \times 5 \times 10^{-4} \text{ m}^2 = 1 \times 10^{-4}$ Wb

    (b) Parallel so $\Phi = 0 \ Wb$

    (c) $\Phi = BA \cos 60 = 0.2 \text{ T} \times 5 \times 10^{-4} \text{ m}^2 \times 0.5 = 5 \times 10^{-5}$ Wb
17. $\varepsilon = B.l.v = (4.0 \times 10^{-3} \text{ T}) \times (2.5 \text{ m}) \times (35 \text{ m s}^{-1}) = 0.35$ V
18. $\Phi = \boldsymbol{A}.\boldsymbol{B} \cos\theta = (0.05 \text{ m})^2 \times (0.60 \text{ T}) = 1.5 \times 10^{-3}$ Wb

    $\varepsilon = -N\,\Delta\Phi / \Delta t = -(120 \text{ turns}) \times (0-1.5\ .10^{-3} \text{ Wb}) / (3.0 \text{ s}) = 0.060$ V.
19. $\phi = BA = (45 \times 10^{-4} \text{ m}^2)(0.65 \text{ T}) = 2.925 \times 10^{-3}$ Wb

    e.m.f. $= -N\Delta\phi / \Delta t = -1500\,(0 - 0.002925) / 5 = 0.88$ V
20. area $= 3.14 \times (1.5)^2 \times 10^{-2} = 7.1 \times 10^{-2} \text{ m}^2$
    rate of flux change $= 7.1 \times 10^{-2} \text{ m} \times 1.8 \times 10^{-3}$ = emf $= 1.278 \times 10^{-4}$ V
    current $= 1.278 \times 10^{-4} \text{ V} / 2.0 \times 10^{-2}\ \Omega = 6.4$ mA.

CHAPTER 12 ELECTROMAGNETIC INDUCTION

Exercise 12.3 (Page 330, 331)

1. C

2. C

3. B. ($n_p / n_s = V_p / V_s$ 5000 / 250 = 240 / V_s V_s = 12V

   $P = VI$ = 24 / 12 = 2A

   $V_p / V_s = I_s / I_p$ 240 / 12 = 2 / I_p I_p = 0.1A)

4. D. ($V_{rms} = V_{peak} / \sqrt{2}$ = 12 / √2 (√2 / √2) = 12√2 / 2 = 6√2)

5. D

6. A

7. To increase the magnetic field strength. It is also soft and easy to laminate – to increase efficiency and reduce eddy currents. It doesn't become a permanent magnet and there is less hysteresis losses.

8. We need a changing magnetic flux to induce an e.m.f, therefore we need ac.

9. (a). 60 V (b). 180 V (c). 360 V

10. 0.29 T

11. Find the total of the square of each term = 372

    Find the average = 37.2 then find the square root of 37.2 = 6.1 A

12. $V_p = 1.414 \times 230\ V = 325.22$ V

    $I_p = V / R = 325.22\ V / 2.4 \times 10^3\ \Omega$ =0.136 A

13. (a) Yes, provided high voltages are used there is no difference between a.c and d.c transmission.

    (b) For 1 000 V For 100 000 V $P = VI$

$I = 1 \times 10^4$ W / 1 000 V	I = 1×10^4 W / 100 000 V
= 10 A	= 0.1 A

    Power dissipated in cable: $P = I^2R$

P = 100 A × 5.0 Ω	P = 0.01 A × 5.0 Ω
P = 500 W	P = 0.05 W

    The higher the voltage, the less power loss occurs in the cables.

    (c)To minimise the eddy currents, the yoke of the transformer is laminated

    (d) $I = P/V$ = 60 W / 110 V = 0.55 A

    Total # of lamps = max current / current in each lamp = 8 A / 0.55 A

    = 14.5 lamps = 14 lamps

(e) $Q = VIt = mc\Delta T_{\text{water}} + mc\Delta T_{\text{stainless steel}}$

110 V . 30.2 A × 2.5 min × 60 s = 4.983×10^5 J

4.983×10^5 J = 1.5 kg × 4180 J.kg^{-1}.K^{-1} × 73 K + 0.72 kg × c × 73 K

= 4.577×10^5 J + 25.55 × c

4.06×10^4 J = 52.56 c

$c = 7.7245 \times 10^2 = 7.7 .10^2$ J.kg^{-1}.K^{-1}

(f) Energy consumed = 6kW + (2 × 300 W) + (5 × 100 W) = 7.1 kW

Cost = 7.1 × 10.5 × 1 h = 74.6 cents

14. (1) The speed of the movement (2) The strength of the magnetic flux density

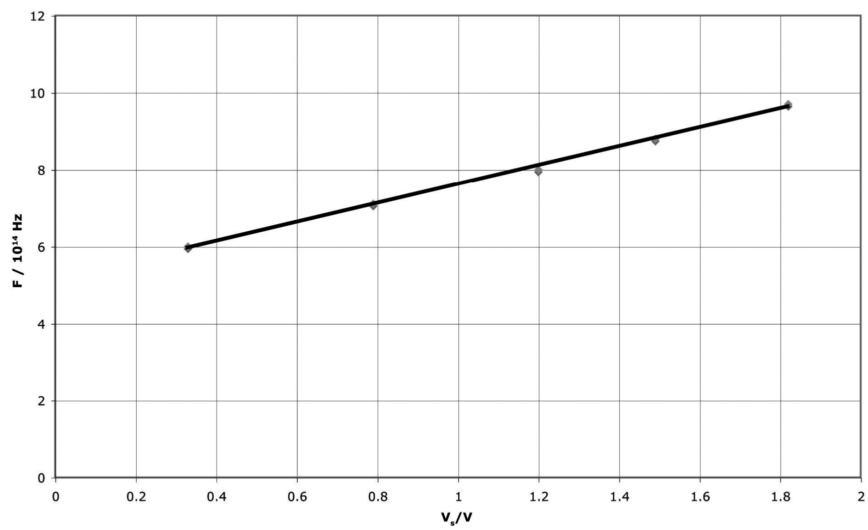
(3) The number of turns on the coil (4) The area of the coil

15. Power loss (the reduction of which is our aim) is proportional to the square of induced voltage. Induced voltage is proportional to the rate of change of flux, and each of our laminations carries one quarter of the flux. So, if the voltage in each of our four laminations is one quarter of what it was in the solid core, then the power dissipated in each lamination is one sixteenth the previous value.

CHAPTER 13 QUANTUM PHYSICS AND NUCLEAR PHYSICS

Exercise 13.1 (a) (page 336)

1. 8.3 eV
2. See Figure 1303 on p335 for answer.
3.



(i) 6.4 (± 0.1) × 10^{-34} J s,

(ii) 2.0 (±0.1) eV

Exercise 13.1 (b) (page 338)

1. 3.3 × 10^{-12} m
2. 44

Exercise 13.2 (page 344)

1. 256 Bq
2. 13 days
3. 1.0 x 10^{9} years

CHAPTER 14 DIGITAL TECHNOLOGY

Exercise 14.1 (a) (page 346)

1. 1111, 111110
2. 67

Exercise 14.1 (b) (page 348)

1. 1.2
2. 160 nm

Exercise 14.2 (page 352)

1. 5.0×10^4
2. (a) 2.2×10^{-2}

   (b) 1.1×10^{-6}

   (c) separation on CCD = 4.4×10^{-6} m, which covers 4 pixels, therefore images will be resolved.
3. Light intensity and frequency vary across image area hence number of photons per second and photon energy varies.

CHAPTER 15 SIGHT AND WAVE PHENOMENA

Exercise 15.1 (page 356)

1.

COMPONENT OF THE EYE	COMPONENT OF THE CAMERA
Cornea	Aperture for admitting light
Iris	Aperture diaphragm
Pupil	Hole in the diaphragm
Lens	Camera lens
Retina	Film
Choroid	Black lining
Sclera	Camera case

2. (a) The image is real, inverted and diminished.
(b) the retina.
(c) the iris.
(d) the ciliary muscles control the focal length of the eye lens. When they are relaxed, the focal length is shorter and when they are pulled, the focal length increases.

3. The **near point** is the position of the closest object that can be brought into focus by the unaided eye. The near point varies from person to person but it has been given an arbitrary value of 25 cm. The **far point** is the position of the furthest object that can be brought into focus by the unaided eye. The far point of a normal eye is at infinity.

4. The retina contains two photoreceptors called **rods** and **cones** that have complementary properties. Rods have fast response rates, and are sensitive at low light levels but they are insensitive to colour. There are around 120 million of them. On the other hand, cones have slow response rates, and are insensitive at low light levels but are sensitive to particular wavelengths of light, and give us our colour vision. There are around 6.5 million of them. It is believed that the cones can be divided into three colour groups – red cones (64%), green cones (32%), and blue cones (2%).

5. Rods are responsible for **scotopic vision** which is the ability to see at low light levels or vision “in the dark”. They do not mediate colour and are sometimes termed “colour blind”. They are excellent photoreceptors because of their high sensitivity. Their single absorption maximum is 1700 lumens per watt (unit for luminous flux) at 507 nm. This is in the blue region of visible light and this is the reason why the rods do not mediate colour, and are more sensitive to blue in the night. Cones are responsible for **photopic vision** or high light–level vision, that is, colour vision under normal light conditions during the day. The pigments of the cones are of three types – long wavelength red, medium wavelength green and short wavelength blue. The cones are less sensitive to light than the rods with their single absorption maximum is 683 lumens per watt (unit for luminous flux) at 555 nm. The cone vision can adapt to changing levels of light more rapidly than the rods and as such they have high spatial resolution.

CHAPTER 16 OPTION E: ASTROPHYSICS

Exercise 16.2 (page 362)

Energy / m^2 / year = 4.5×10^{10} J

Assumptions include:

- the intensity of the radiation is the same at all points on the surface of Earth
- the distance of Sun from Earth is constant

Exercise 16.3 (a) (page 367)

1 ly = 63240AU

1 pc = 206265AU

Hence 1 pc = 205265/63240 = 3.26ly

Exercise 16.3 (b) (page 369)

0.76 arc sec

Exercise 16.3 (c) (page 370)

Andromeda is 28 times brighter than the Crab Nebula

Exercise 16.6 (a) (page 387)

$1.3 \times 10^{10}\, y$

Exercise 16.6 (b) (page 389)

1. (a) 2.50×10^5 AU

   (b) 4.00×10^{-6} rad;

2. B (×100);

3 (a) Yes. Its apparent magnitude at 10 pc is +4.8 which is just within the visible limit

(b) 10^{10}

(c) Greater. At 10pc Sirius is brighter than the Sun at 10pc.

4 Refer to text.

5 Refer to text.

6. $0.216\, c / 6.50 \times 10^6$ m s^{-1}

7. Refer to text.

CHAPTER 16 OPTION E: ASTROPHYSICS

General Exercises (page 389)

1. 500 nm
2. (a) See Figure 1608.

   (b) See Figure 1608.

   (c) Vega/ Barnard's star
3. Refer to text.
4. Refer to text.

CHAPTER 17 COMMUNICATIONS

Exercise 17.1 (a) (page 395)

2 ms

Exercise 17.1 (b) (page 396)

1. 120
2. 530 kHz to 534.95 kHz, 535 kHz, 534.96 kHz to 540 kHz, bandwidth = 10 kHz.

Exercise 17.2 (page 400)

(a) (i) 8 kHz

(ii) 0011

(iii) 24 kb s^{-1}

(b) 15

Exercise 17.3 (a) (page 402)

48.8°

Exercise 17.3 (b) (page 404)

3.5 km

Exercise 17.3 (c) (page 405)

1. (a) 80.6°

   (b) HINT: Consider the geometry of the situation.
2. (a) 180 dB

   (b) 64 km

Exercise 17.5 (page 412)

1. HINT: Consider the putput for each input resistor connected alone.
2. (a) 4.0 V

   (b) 6.7 V

CHAPTER 18 (OPTION G) ELECTROMAGNETIC WAVES

Exercise 18.1 (page 427)

1. When electrons are accelerated in aerials or within atoms, they produce changing electric fields. These changing electric fields generate changing magnetic fields in a plane perpendicular to the electric field plane. As this process continues, a self–propagating electromagnetic wave is produced. As the charge oscillates with simple harmonic motion, the strength of the electric and magnetic vectors vary with time, and produce sine curves (sinusoidal waves) perpendicular to each other and to the direction of the wave velocity v as shown in the diagram. The waves are therefore periodic and transverse.

2. They are transverse waves. They are periodic waves. They can travel through a vacuum (or through matter). They travel at the speed of light. Characteristics such as reflection, refraction, polarisation, diffraction and interference etc. They have energy (and momentum)

3. (a) 4.3×10^{14} Hz (b) 2.8×10^{-19} J

4. Radio waves

5. Longer wavelengths can diffract more around obstacles.

6. Use the wavelengths listed in Fig 1806 (a) to calculate the range of frequencies (the wave equation) for each wave type and then construct the table.

7. The higher the frequency of x–rays, the greater the penetration.

8. **RADIO WAVES**

   Radio waves are generated by an electric circuit called an oscillator and are radiated from an aerial. A tuned oscillatory electric circuit that is part of a radio/television receiver detects the radio waves.

   MICROWAVES

   They are produced by special electronic semi–conductor devices called Gunn diodes, or by vacuum tube devices such as klystrons and magnetrons. They are detected by point contact diodes, thermistors, bolometers and valve circuits.

   INFRA–RED RADIATION

   Is generated by electrons in atoms and the bonds of hot objects. They can be detected by our skin, by thermometers, thermistors, photoconductive cells, special photographic film etc.. . The special photographic film is used to identify heat sources such as human beings trying to hide from the scene of a crime or soldiers moving in a war situation.

   VISIBLE LIGHT

   Is generated by electronic transitions in excited atoms. Visible light is detected by stimulating nerve endings of the retina of the eye or by photographic film and photocells.

ULTRA–VIOLET RADIATION

Is generated by excited atoms in the Sun and high voltage discharge tubes. Like visible light UV radiation can cause photochemical reactions in which radiant energy is converted into chemical energy as in the production of ozone in the atmosphere and the production of the dark pigment (melanin) that causes tanning in the skin. It also helps to produce vitamin D on our skin. However, too much UV radiation can cause melanoma cancers. UV radiation can be detected by photography and the photo–electric effect.

X–RADIATION

Generated in high voltage X – ray tubes. X–rays are detected by photography, the photographic plate placed beneath the body can be used to identify possible bone fractures. X–radiation can ionise gases and cause fluorescence. Because diffracted X–rays produce interference patterns when they interact with crystals in rocks and salts, the structure of these regular patterns of atoms and molecules can be determined by this process of X–ray diffraction.

GAMMA RADIATION

Generated in nuclear reactions. Gamma radiation can be detected by an ionisation chamber as found in a Geiger–Müller counter.

9. The standard unit of length, the metre, is now defined in terms of this speed. In 1960, the standard metre was defined as the length equal to 1 650 763.73 wavelengths of the orange–red line of the isotope krypton–86 undergoing electrical discharge. Since 1983, the metre has been defined as “the metre is the length of path travelled by light in a vacuum during a time interval of 1 / 299 792 458 s”. The speed of all electromagnetic waves is the same as the speed of light.

10. (a) When a narrow beam of white light undergoes refraction when it enters a prism, the light spreads out into a spectrum of colours. The colours range from red at one side of the band, through orange, yellow, green, indigo (light purple), to purple at the other side of the band. We say that the spectrum of white light is continuous because the colour bands gradually change from on e colour to the next without there being any gaps in between. The separation of the white light into its component colours is due to dispersion as shown in the diagram.

(b) The refractive index for glass is different for different wavelengths of light. The refractive index is smaller for red light than for blue light.

11. (a) The word laser is an acronym derived from Light Amplification by Stimulated Emission of Radiation.

(b) A laser is an instrument that has a power source and a light–amplifying substance. The power source provides the energy that causes atoms in the light–amplifying substance to become excited.

The operation starts with the light–amplifying substance absorbing non–coherent radiation from a power source. It then re–emits some of the energy as photons, from meta stable states in atoms by the process of stimulated emission, and produces a coherent, monochromatic beam of photons of great intensity. The light produced is a nearly perfect plane wave. The intensity is in fact increased due to the emitted waves being coherent.

(c) **technology** – bar–code scanners, laser discs ….

industry –surveying, cutting materials including fabrics and microelectronic circuits, welding and cutting materials, holes in sewing needles, the holes in the teat of a baby's bottle, and holes in metals are all produced by lasers.

medicine – treatment of tumours, in eye surgery such as retina attachment and corneal correction, cutting of tissue and blood vessels without causing bleeding, vaporising blood clots and stones, in dental examinations, in removing tattoos and some birthmarks.

Exercise 18.2 (a) (page 432)

1. $1 / d_0 + 1 / d_i = 1 / f$ $\quad 1 / 5.0\text{ cm} + 1 / d_i = 1 / 12.0\text{ cm}$ $\quad d_i = -8.57\text{ cm}$

   The image is a virtual image located 8.6 cm in front of the lens.

   $m = -d_i / d_o = -(-8.57\text{ cm}) / 5.0\text{ cm} = +1.71$

   The image is erect and has a magnification of 1.7.

2. See text Fig 1818

3. $1 / d_0 + 1 / d_i = 1 / f$ $\quad 1 / 16.0\text{ cm} + 1 / d_i = -1 / 12.0\text{ cm}$ $\quad d_i = -6.86\text{ cm}$

   The image is a virtual image located 6.0 cm in front of the lens.

   $\boldsymbol{m = -d_i / d_o} = -(-6.86\text{ cm}) / 12.0\text{ cm} = +0.57$

   The image is erect and has a magnification of 0.57.

4. $1 / d_0 + 1 / d_i = 1 / f$ $\quad 1 / 6.0\text{ cm} + 1 / d_i = 1 / 12.0\text{ cm}$ $\quad d_i = -12.0\text{ cm}$

   The image is a virtual image located 12.0 cm in front of the lens.

   $m = -d_i / d_o = -(-12.0\text{ cm}) / 6.0\text{ cm} = +2$

   The image is erect and has a magnification of 2.0.

CHAPTER 18 (OPTION G) ELECTROMAGNETIC WAVES

Exercise 18.2 (b) (page 438,439)

1. D
2. D
3. Real, inverted image, 7.5 cm on opposite side of lens to object, m = – 0.5, image height is 2 cm.
4. Image is virtual, erect, 3.8 cm from the lens on the same side as the object. m = 0.25, image is 1.0 cm high
5. All are convex except for the short– sightedness
6. Image is 30 cm from the lens on the opposite side to the object. It is real, inverted and magnified by two.
7. 6 cm from the lens
8. 0.83 m
9. 0.037 m from the concave lens and in between the two lenses.
10. 12 cm
11. –195
12. 46°
13. Yes. When the angle of incidence is equal to the critical angle.
14. An aberration is an image defect of which blurring and distortion are the most common image defects. Aberrations can occur with the use of both lenses and mirrors.

    Spherical aberration is most noticeable in lenses with large apertures. Rays close to the principal axis (called paraxial rays) are all reflected close to the principal focus. Those rays that are not paraxial tend to blur this image causing spherical aberration.

    To reduce spherical aberration, parabolic mirrors that have the ability to focus parallel rays are used in car headlights and reflecting telescopes.

    In practice it is found that a single converging lens with a large aperture is unable to produce a perfectly sharp image because of two inherent limitations:

    - spherical aberration
    - chromatic aberration

    The nonparaxial rays do not allow for a sharp image. However, with lenses, spherical aberration occurs because the rays incident near the edges of a converging lens are refracted more than paraxial rays. This produces an area of illumination rather than a point image even when monochromatic light is used. To reduce spherical aberration, a stop (an opaque disc with a hole in it) is inserted before the lens so that the aperture size can be adjusted to allow only paraxial rays to enter.

Because visible light is a mixture of wavelengths, the refractive index of the lens is different for each wavelength or colour of light. Consequently, different wavelengths are refracted by different amounts as they are transmitted in the medium of the lens. For example, blue light is refracted more than red light. Each colour must therefore have a different focal length and it further follows that focal length is a function of wavelength.

Chromatic aberration produces coloured edges around an image. It can be minimised by using an **achromatic doublet**. Since the chromatic aberration of converging and diverging lenses is opposite, a combination of these two lenses will minimise this effect.

15. D

Exercise 18.3 (page 442)

330 m s–1

Exercise 18.4 (page 444)

630 nm

Exercise 18.5 (a) (page 445)

1. 5.0 × 10–11 m
2. 6.9 × 10–11 m

Exercise 18.5 (b) (page 447)

0.40 nm

Exercise 18.6 (page 450)

110 nm

CHAPTER 19 OPTION H: RELATIVITY

Exercise 19.1 (Page 454)

(a) (i) 5.0 m s^{-1}

(ii) 1.0 m s^{-1}

(iii) 3.6 m s^{-1}

(iv) 3.6 m s^{-1}

(b) X:Y = 1 : 2.2

Exercise 19.3 (a) (Page 460)

1 $0.5c$ 1.35×10^{11} m

$0.8c$ zero

$0.95c$ 75 m

2. $0.60c$

Exercise 19.3 (b) (Page 461)

1 a) (i) 2.3×10^{9} m (ii) zero

(b) 75 m

2. $0.86c$

Exercise 19.4 (a) (Page 463)

Refer to text.

Exercise 19.4 (b) (Page 465)

$0.87c$

CHAPTER 19 OPTION H: RELATIVITY

Miscellaneous Exercises (Page 478)

1 Refer to page 456

2 HINT: Remember that the atomic mass unit is 1/12th the mass of an atom of C–12.

3. (a) 1.2 MeV c^{-2}

(b) 0.29 MeV c^{-2}

4 0.59 MeV c^{-2} and 0.85 MeV c^{-2}

5. (i) 1740 MeV c^{-2}

(ii) 0.843c

(iii) 1470 MeV c^{-1}

(iv) 1740 MeV

6. 7×10^{15} m

7. 0.628c

8. 5.5×10^{-12} m

9 Refer to the text

10 See page 471

11 See page 477

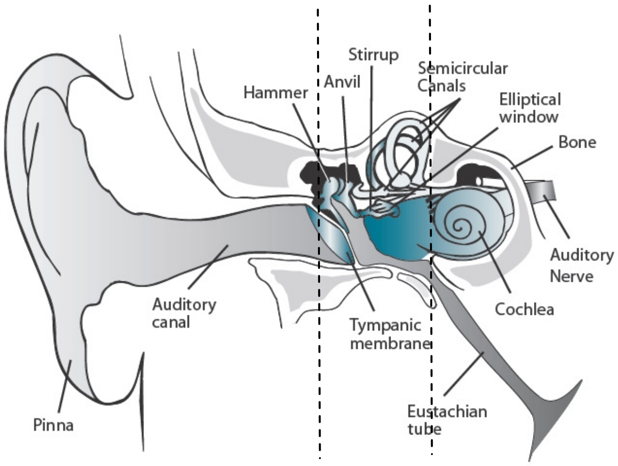
12. 500 m

13. Self evident

CHAPTER 20 (OPTION I) BIOMEDICAL PHYSICS

Exercise 20.1 (page 488, 489)

1. (a) and (b)– see diagram below and text



(c) (i) The ear–drum acts as an interface between the external and middle ear. As sound travels down the ear canal air pressure waves from the sounds set up sympathetic vibrations in the taut membrane of the ear and passes these vibrations on to the middle ear structure.

(ii) The ossicles– a chain of three bones called the malleus, incus and stapes, more commonly known as the hammer, anvil and stirrup act as a series of levers with a combined mechanical advantage of 1.3. Because of their combined inertia as a result of the ossicle orientation, size and attachments, they cannot vibrate at frequencies much greater than 20 kHz. The malleus is attached to the inner wall of the tympanic membrane and the flat end of the stapes comes up against the oval window (a membrane called fenestra ovalis). As the eardrum vibrates in step with air pressure waves of sound, the malleus vibrates also in sympathy with the eardrum. The mechanical vibrations are then transmitted by the incus and stapes to the oval membrane and then to the fluid of the inner ear.

(iii) The semi–circular canals (three fluid–filled canals) are concerned with maintaining balance and the detection of movement and position of the body. They do not contribute to the process of hearing.

(c) Most of the sound would be reflected rather than transmitted into the cochlea.

(d) High frequencies are processed near the beginning of the cochlea, low frequencies are processed further inside the cochlea.

(e) see diagram.

2. A,D,E

3. 70 dB

4. 4.8 dB

5. 1×10^{-3} Wm^{-2}

6. 6.25×10^{-6} W m^{-2}

7. The average power per unit area of a sound wave that is incident perpendicular to the direction of propagation is called the **sound intensity**. The units of sound intensity are watts per square metre, W.m^{-2}. $I = P_{av} / A$.

The intensity level of sound intensity β is defined as :

$\beta = 10 \log I / I_0$ where I is the intensity corresponding to the level β and I_0 is the threshold intensity or threshold of hearing taken as 10^{-12} W.m^{-2}. β is measured in bels B. Because the bel is a large unit, it is more convenient to use the decibel dB (one–tenth of a bel).

8. $I \propto 1/d^2$ $\quad I d^2$ = a constant $\therefore$ $I_1 d_1^2 = I_2 d_2^2$

$(5.0 \times 10^{-3}\ \text{Wm}^{-2})\ (20\ \text{m})^2 = I_2\ (40\text{m})^2$ $\quad I_2 = (5.0 \times 10^{-3}\ \text{Wm}^{-2})\ (20\ \text{m})^2 / (40\text{m})^2$

$= 1.25 \times 10^{-3}\ \text{Wm}^{-2}$

9. $\beta = 10 \log I/I_0$ dB $= 10 \log [(7.0 .10^{-4}\ \text{Wm}^{-2}) / (10^{-12}\ \text{Wm}^{-2})]$ dB = 88.451 = 88 dB.

10. $\beta = 10 \log I/I_0$ dB $\quad 96 = 10 \log I / (10^{-12}\ \text{Wm}^{-2})$

$9.6 = \log I / (10^{-12}\ \text{Wm}^{-2})$ $\quad 10^{9.6} = I / (10^{-12}\ \text{Wm}^{-2})$ $\quad 3.981 \times 10^9 = I / (10^{-12}\ \text{W.m}^{-2})$

$I = 3.9 \times 10^{-3}\ \text{Wm}^{-2}$

11. Let the original sound intensity = 10 Wm^{-2}. The sound intensity level is 130 dB.

If we double the sound intensity to 20 Wm^{-2}, $\beta = 10 \log I/I_0$ dB

$= 10 \log [(20\ \text{W.m}^{-2}) / (10^{-12}\ \text{W.m}^{-2})]$ dB = 133.01 = 133 dB

The change in decibels is 133 – 130 = 3 dB.

12. (a) $\beta = 10 \log I/I_0$ dB $= 10 \log [(1.0 \times 10^{-6}\ \text{W.m}^{-2}) / (10^{-12}\ \text{W.m}^{-2})]$ dB = 60 dB

Therefore, the frequency range is from 50 ± 10 Hz to 16 000 ± 1000 Hz

(b) minimum of the graph at about 1500 Hz (c) 250 Hz is about 20 dB and

10 000 Hz is about 30 dB. 20 dB is 10^{-10} Wm^{-2} and 30 dB is 10^{-9} Wm^{-2}, therefore 250 Hz is 10 times less intense.

13. (a) The cross–sectional area of the eardrum is about twenty times bigger than the cross–sectional area of the oval window. Therefore, the force/unit area which equals the pressure will be much greater on the oval window.

(b) Taking moments about an axis through the pivot,

$\boldsymbol{F}_1 \times l = \boldsymbol{F}_2 \times 2/3\, l$ $\quad$ So, $\boldsymbol{F}_2 = 3/2\, \boldsymbol{F}_1$

$P_2 = \boldsymbol{F}_2 / 3.0\ \text{mm}^2$ and $P_1 = \boldsymbol{F}_1 / 60\ \text{mm}^2$

$P_2 = 3/2\, \boldsymbol{F}_1 / 3.0\ \text{mm}^2 = 3/2\, P_1\ 60\ \text{mm}^2 / 3.0\ \text{mm}^2 = 30\, P_1$

The pressure amplification is 30.

14. (a) An observer is placed in a sound proof booth to listen to a pure tone. The patient indicates when the tone can be heard. The tones are reduced in intensity until they can just be heard and the hearing threshold is marked on the audiogram. This process is repeated at different frequencies.

(b) This indicates a mild hearing loss in the low frequency range where spoken vowels are heard and a severe hearing loss in the high frequencies where spoken consonants are heard. It is possible that the hearing loss is due to the effect of too much noise over a prolonged period of time, possibly an older worker in a noisy industry.

(c) from the graph, hearing loss = 35 dB. $\beta = 10 \log I / I_0$ dB

$35 = 10 \log I / (10^{-12}\ \text{Wm}^{-2})$ $3.5 = \log I / (10^{-12}\ \text{W.m}^{-2})$

$10^{3.5} = I / (10^{-12}\ \text{W.m}^{-2})$ $3.162 \times 10^3 = I / (10^{-12}\ \text{W.m}^{-2})$ $I = 3.2 \times 10^{-9}\ \text{Wm}^{-2}$.

(d) The patient has been subjected to noise over a prolonged period that has possibly caused permanent inner ear damage. A hearing aid would help to a small extent.

15. Between 50 Hz and 14 kHz.

Exercise 20.2 (page 502–504)

1. (a) to produce electrons by thermionic emission (b) to accelerate the electrons

   (c) to decelerate electrons producing heat and X–radiation

2. wavelength = 4.1×10^{-11} m frequency = 7.2×10^{18}Hz

3. To reduce the heating effect of the bombarding electrons by spreading the heat over a larger area.

4. They are very penetrating and show poor contrast.

5. (a) 4 kW (b) 2.5×10^{17}electrons per second

   (c) 1.6×10^{-14}J (d). 1.24×10^{-11} m

6. (a) 6.1×10^{1} kWm^{-2} (b) 0.144 mm^{-1} (c) 2.2×10^{-2} kWm^{2}

7. The quality of an X–ray beam is a term used to describe its penetrating power. (As the relative intensity of the X–rays is increased so too does the spectral spread. We say the X–ray quality has increased**.)** There are a number of ways that the quality of an X–ray machine can be increased.

   1. Increasing the tube voltage
   2. Increasing the tube current
   3. Using a target material with a relatively high atomic number *Z*
   4. Using filters.

8. (a) Intensity after passing through 2.4 mm would be half the initial intensity

   Intensity after passing through 4.8 mm would be a quarter of the initial intensity

   Intensity after passing through 7.2 mm would be an eighth of the initial intensity

   Intensity after passing through 9.6 mm would be one–sixteenth of the initial intensity

   New intensity = 1/16 (4.0×10^{2} kWm^{-2}) = 25 kWm^{-2}

   (b) $x_{1/2} = 0.6931 / \mu$ $\mu = 0.6931 / x_{1/2}$ = 0.6931 / 2.4 mm

   = 0.29 mm^{-1} or 2.9 x10^{2} m^{-1}

   (c) $I = I_0 e^{-\mu x}$ = 4.0 x 10^{5} Wm^{-2} $e^{-(290 \times 0.0015)}$ = 2.59 x 10^{2} kWm^{-2}

9. (a) Images of body volume are obtained. The sections produced can be cross–sections (axial) or longitudinal.

(b) (CAT) imaging uses a radial array of X–ray sources, scintillation detectors and computer technology to build up an axial scan of a section of an organ or part of the body with 256 grey shades. A patient lies on a table that passes through a circular scanning machine about 60–70 cm in diameter called a gantry. The gantry can be tilted, and the table can be moved in the horizontal and vertical directions. X–rays from the gantry are fired at the organ being scanned and attenuation occurs depending on the type of tissue being investigated. The image produced on the computer monitor is a series of sections or slices of an organ built up to create a three–dimensional image.

(c) CAT scans provide detailed cross–sectional images for nearly every part of the body including the brain and vessels, the heart and vessels, the spine, abdominal organs such as the liver and kidneys etc... They are being used in many diagnostic applications including the detection of cancerous tumours, detection of strokes and blood clots.

(d) Both use X–radiation that penetrates matter where it is absorbed to differing degrees by different tissues. Both are invasive.Conventional X–rays are limited in that they show only denser bone structures with organs having the same attenuation as skin tissue (unless a radiopharmaceutical is introduced). CAT has many more applications.The two–dimensional image produced on a computer monitor has good resolution.

10. (a) MRI uses radiation in the radio region of the electromagnetic spectrum and magnetic energy to create cross–sectional slices of the body.The patient is laid on a table and moved into a chamber containing cylindrical magnets that can produce constant magnetic fields around 2 T.

Protons in the atoms of the patient line up with the magnetic field so that the axes of their spins are parallel. Pulses of radio–frequency (RF) electromagnetic waves bombard the patient. At particular RF frequencies, the spin is tilted as the atoms in the tissues absorb energy.

When the pulse stops, the protons return to their original orientation and emit radio frequency energy. Different tissues emit different amounts of energy in this process.

This differing amounts of energy are sent to a computer that decodes the information and produces a two–dimensional or three–dimensional image on a computer monitor screen.

(b) The single proton in the hydrogen atom has a strong resonance signal and its concentration is abundant in body fluids due to the presence of water.

(c) MRI is ideal at detecting brain and pituitary tumours, infections in the brain, spine and joints and in diagnosing strokes.

(d) See text.

11. (a) Ultrasound is sound with frequencies greater than 20 000 Hz. Just as transverse electromagnetic waves interact with matter as is the case with X–radiation, CAT and MRI, so too ultrasound mechanical waves interact with matter.

(b) Ultrasound from 20 000Hz to several billion hertz can be produced by ultrasound transducers (a device that converts energy from one form to another) using mechanical, electromagnetic and thermal energy. (Normal sound waves are not useful for imaging because their resolution is poor at long wavelengths. Medical ultrasound uses frequencies in the range greater than 1 MHz to less than 20 MHz. In this range with speeds around 1500 $m.s^{-1}$ in body tissue the wavelengths are about 1–2 mm).The common transducer used in ultrasound is the piezoelectric crystal transducer. When ultrasound meets an interface between two media, the ultrasound wave can undergo reflection, transmission, absorption and scattering. In ultrasound imaging, it is the reflected portion of the ultrasound beam that is used to produce the image. The greater the difference in the characteristics of the media boundary, the more energy will be reflected to give an echo.

(c) (i)

MEDIUM	**VELOCITY** $m.s^{-1}$	**DENSITY** $kg.m^{-3}$	**ACOUSTIC IMPEDANCE** $kg.m^{-2}.s^{-1} \times 10^{6}$
Air (20 ^{0}C, 101.3 kPa)	344	1.21	0.0004
Water (20 ^{0}C)	1482	998	1.48
Whole blood (37 ^{0}C)	1570	1060	1.66
Brain	1541	1025	1.60
Liver	1549	1065	1.65
Kidney	1561	1038	1.62
Skull bone	4080	1912	7.80
Muscle	1580	1075	1.70

(ii) Ultrasound could not be used to obtain images of lung tissue.

The greater the difference in acoustic impedance between two materials, the greater will be the reflected proportion of the reflected pulse.

Lung tissue is encased by the rib cage and contains air – strong reflections from these media would obscure images of the lung tissue.

(d) In a typical ultrasound scan, a piezoelectric transducer is placed in close contact with the skin. To minimise the acoustic energy lost due to air being trapped between the transducer and the skin, a gel is applied between the transducer and the skin.

(e) If the ultrasound beam is reflected, transmitted, absorbed and scattered the intensity (attenuation) will decrease. IF the frequency of the source is increased too much, the attenuation in fact decreases as does the penetration depth. Furthermore, the resolution also decreases if the frequency is increased beyond an optimum point. In a typical pulse–echo diagnostic procedure, the maximum mean ultrasound power delivered is about 10^{-4} W, and the frequency is in the range 1–5 MHz.

(f) A scan produced by a single transducer when a single bit of information with a one–dimensional base is displayed is called an **A–scan** (amplitude mode). The transducer scans along the body and the resulting echoes are plotted as a function of time. The A–mode measures the time that has elapsed between when the pulse is sent and the time the echo is received. The first echo is from the skin, the second and third pulses are from either side of the first organ, the fourth and fifth echo is from either side of the second organ. The pulse intensity decreases due to attenuation. This mode is seldom used but when it is, it measures the size and distance to internal organs and other organs such as the eye. In the B–scan mode (brightness scan), an array of transducers scan a slice in the body. Each echo is represented by a spot of a different shade of grey on an oscilloscope. The brightness of the spot is proportional to the amplitude of the echo. The scan head containing many transducers is arrayed so that the individual b–scans can be built up to produce a two–dimensional image. The scan head is rocked back and forth mechanically to increase the probability that the pulse will strike irregular interfaces.

(g) see text.

12. (i) Ultrasound because it gives reasonably clear images in the womb without harmful radiation.

(ii) X–rays because they can easily distinguish between flesh and bone to get a clear image of the fracture.

(iii) CAT or MRI because they are able to detect tumours of the brain.

13. (a) 0.09mm

(b) the half–value thickness is that thickness of lead which (for this particular beam) reduce the intensity of the (transmitted) beam by 50 %.

(c) the half–value thickness corresponds to an intensity of 10 units; This value would be at an intensity of 10. So the half–value thickness would be 2 mm.

(d) the transmitted intensity = 40% × 20 = 8. This corresponds to a thickness of about 2.5 mm.

(e) the transmitted intensity would be (1 – 0.8) × 20 = 4 units. 4×10^{-3}m = 0.6931 / μ. $\mu = 0.6931 \times 4 \times 10^{-3}$ m $= 1.73 \times 10^{2}$ m^{-1}.

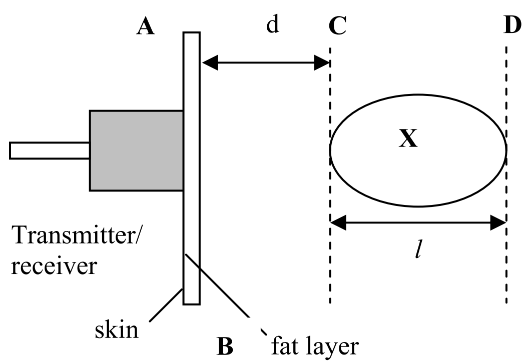
So $I = I_0 e^{-\mu x}$, $4 = 20 \times (e)^{-\mu x}$. So $0.2 = e^{-173\,x}$.

That is $-\ln 0.2 = 173x$.

Therefore, $x =$ 0.015 m = 10.5 mm.

14. (a)1 MHz → 20 MHz.

(b)(i)



(ii) The pulse takes 50 μs to travel 2*d*.

So $d = vt / 2 = 2.0 \times 10^3\ ms^{-1} \times 50 \times 10^{-6}\ \mu s / 2 = 50$ mm,

and $l = vt / 2 = 2.0 \times 10^3\ ms^{-1} \times (275 - 100) \times 10^{-6}\ \mu s / 2 = 175$ mm.

(c) A–scan. A–mode measures the time lapsed between when the pulse is sent and the time the echo is received. A B–scan gives a three–dimensional image.

Exercise 20.3 (page 512,513)

1. 68 Gy
2. 750 mJ
3. 4.1 m
4. 5.8 days
5. (a) The stable isotopes of chemicals in the body carry out their physiological processes in a normal fashion on most occasions. However, when these normal functions are disrupted various illnesses are generated at both the cellular and organ level. If a specific radioisotope is introduced into the body generally by intravenous injection, it should behave in the same manner as the equivalent stable isotope of the same element. The path or accumulation of the radioactive tracer can then be pinpointed with the use of a detecting device.

(b) If the radioactive tracer is of the preferred gamma–emitter type, its path can be detected by a gamma camera (a scintillation counter) that is traced over the body system or an organ and the activity of the tracer can be “imaged”. For example, a gamma camera scan (scintigram) of the heart could be taken and abnormalities in heart function could be analysed on the lack of uptake (a cold spot) or the excessive uptake (a hot spot) of the radioactive tracer. α–emitters and β–emitters do not pass far enough through the body to be easily detected. However, blood and fluid samples can be taken and the radioactive tracer activity can be detected and measured with other radiation detectors.

(c) Some examples include iodine in the thyroid gland, calcium and strontium isotopes in the bone or potassium and rubidium in the muscles. By attaching radioisotopes to these chemicals, the tracer can be directed to the organ of interest.

(d) It is important that any radioactive tracer used has a short half–life in the order of minutes, hours or a day as long half–life radioisotopes would emit potentially dangerous radiation for too long a time.

(e) ^{99m}Tc produces radiation at detectable levels for over a week before it needs to be replenished in the target organ of the patient for subsequent imaging. It is an excellent tracer for many diagnostic purposes. The gamma ray emission energy corresponds to the maximum sensitivity of the crystal detector of the gamma camera. And because it is non–toxic it is relatively harmless to the patient.

6. If the biological half–life is long then the tracer can do a lot of damage to healthy cells. With a short biological half–life and long physical half–life the tracer will have a high activity during the time it is in the body.

7. Dose equivalent D = absorbed dose H x quality factor Q. So. $H = D/Q$

$H = 250$ Jkg $^{-1}$ / 11 = 22.7 Jkg^{-1}. The total energy absorbed = 22.73 $\times$ 0.10 = 2.27 J.

The total energy absorbed = energy per proton × number per second × time.

Therefore, $t = 2.27 / (1.9 \times 10^{10} \times 4.2 \times 10^{6} \times 1.6 \times 10^{-19}) = 178$ s

8. (a) When ionising radiation penetrates living cells at the surface or within the body, it may transfer its energy to atoms and molecules through a series of random collisions. The most acute damage is caused when a large functioning molecule such as DNA is ionised leading to changes or mutations in its chemical structure. If the DNA is damaged it can cause premature cell death, prevention or delay of cell division, or permanent genetic modification. If genetic modification occurs, the mutated genes pass the information on to daughter cells. Ionising radiation appears to effect different cells in different ways. Cells of the reproductive organs are very radiation–sensitive and sterility is a common outcome after radiation exposure. Bone and nerve cells are relatively radiation–resistant. However, radiation of bone marrow leads to a rapid depletion in stem cells that can then induce anaemia or even leukemia. Exposure to radiation results in a range of symptoms including skin burns, radiation sickness (nausea, vomiting, diarrhoea, loss of hair, loss of taste, fever, loss of hair etc..) and cancer, leukemia and death.

(b)The term *exposure X* is defined for X–radiation and γ–radiation as the total charge Q of ions of one sign (either electrons or positrons) produced in air when all the β–particles liberated by photons in a volume of air of mass m are completely stopped in air

$X = Q / m$. It can be seen that the units for exposure are C kg^{-1}.

Absorbed dose D is defined as the amount of energy E transferred to a particular unit mass m. $D = E / m$. The SI unit of absorbed dose is $J.kg^{-1}$ otherwise known as the gray Gy.

D*ose equivalent* $H = Q\ D$ where Q is a dimensionless quantity called the **quality factor** of the radiation.

The unit of dose equivalent is the sievert Sv and 1Sv = 1 J kg^{-1}.

The millisievert mSv is the more common measure of dose equivalent.

(c) dose equivalent is the amount of energy absorbed but a quality factor is introduced to describe the effects of different types of radiation. α is absorbed more that γ radiation and so has a much higher Q factor;

(d) Average ionisation energy in air = 34 eV. Exposure of one unit = 1 C kg^{-1}

Energy absorbed = 34e / e = 34 J kg^{-1}

Absorbed dose = E / m = 34 J / 1kg = 34 Gy

(e) $H = Q\,D\,N$ where $N = 1$ $H_1 = D$ ½ (30) = 15 $mJkg^{-1}$

$H_2 = D \times 1/6\ (30) = 5$ mJ kg^{-1}

Energy absorbed by 50 kg = 50 kg × 20 $mJkg^{-1}$ = 1 J

(f) The type of radiation, the strength of the source, the distance from the source, the exposure time, the origin of the source (external or internal), the portion of the body being radiated and the general health to the individual all need to be monitored carefully.

As the intensity of the radiation obeys the inverse square law for distance from the source, keeping a safe distance from the source is the best means of protection.

All radioactive sources must be completely contained to prevent the spread of contamination. Radiation detectors such as a film badge or a thermoluminescent dosimeter (TLD) are worn by all workers employed in any industry using ionising radiation.

For the patient, it is known that radiation doses to the bone marrow in the order of

3 000 to 4 000 mSv have lethal effects within a month in about half of the exposed people in the absence of specialised medical treatment. Single doses over 2 000 mSv absorbed by the testes or 3 000 mSv absorbed by the ovaries can cause permanent sterility. The specialised medical treatment in the case of doses up to 10 000 mSv would include isolation of the patient in a sterile environment, selective treatment with antibiotics and stimulation of leukocyte production in order to offset damage to white blood cells. Bone marrow transplant may also be necessary. So you can see that protection is paramount in any medical diagnosis or therapy.

(g) The **biological half–life** T_B of a material is the time taken for half the radioactive substance to be removed from the body by biological processes.

The **physical half–life** T_R of a radioactive nuclide is the time taken for half the nuclei present to disintegrate radioactively.

The **effective half–life** T_E of the radioactive substance will be less than the physical half–life due to the biological half–life component.

If λ_R and λ_B are the fractions of the radioisotope removed per second by the physical decay and the biological processes respectively, then the total fraction removed per unit time λ_E is given by $1 / T_E = 1 / T_R + 1 / T_B$

(h) **(i)** $1 / T_E = 1 / T_R + 1 / T_B$

$= 1/8 + 1/20 = 0.175$

$T_E = 5.714 = 5.7$ days

(ii) 40 days = 2 biological half–lives

40 days = 5 physical half–lives

amount remaining = $(0.5)^7 = 0.008 \times 100 = 0.8\%$

(i) It is often useful for some medical conditions to destroy or weaken malfunctioning cells using radiotherapy because rapidly dividing cells are particularly sensitive to damage by radiation. For this reason, some cancerous growths can be controlled or eliminated by irradiating the area containing the growth. Depending on the cancerous growth, the radiotherapy administered can be of three different types:

1. Internal radiotherapy–where the radioisotope is localised in the affected organ.
2. External radiotherapy (teletherapy and X–ray theraphy)–where the radioactive source used is outside the body.
3. **Brachytherapy**–where the radioactive source is temporarily implanted in the body at the site to be irradiated.

External radiotherapy called **teletherapy** commonly uses the isotope cobalt–60 as a source of γ–radiation. It is produced by neutron bombardment of the common isotope cobalt–59 in a cyclotron. It produces penetrating gamma rays of sufficiently high energy around 1.25 MeV. This is equivalent to X–rays generated at 3 MV. The equipment requirements for teletherapy is simpler than X–rays and does not have high voltage hazards associated with X–rays. The tumour to be irradiated is pinpointed using laser beams. The cobalt–60 source is located near the centre of a lead–filled steel container known as a head. During therapy, a shutter is opened by a motor and the emerging gamma rays are collimated before striking the patient. In order to minimise the impact on healthy tissue, multiple–beam and rotational therapy are used for deep tumours. Either the radioactive source is rotated or the patient is rotated. Unfortunately, the radioactivity of cobalt–60 cannot be switched off like an X–ray. Cobalt–60 therapy is losing favour these days with preference in developed countries to linear accelerators (betatrons or linacs) that use X–rays or high–energy protons. The results for cancers of the pelvis, cervix, larynx and pituitary gland have been more successful than cobalt–60.

Iridium–192 implants (brachytherapy) that emit β–particles and low energy γ–radiation are now commonly used to treat breast cancer and cancers of the mouth. These are produced in wire form and are introduced through a catheter to the target area – usually in the head or breast. After a time period calculated to give the correct dose, the implant wire is removed to shielded storage. This procedure gives less overall radiation to the body, is more localised to the target tumour and is cost effective.

CHAPTER 21 (OPTION J) PARTICLE PHYSICS

Exercise 21.1 (pages 528,529)

1. Particles are called **elementary particles** if they have no internal structure, that is, they are not made out of any smaller constituents. The elementary particles are the leptons, quarks and exchange particles. Composite particles such as the proton are composed of elementary particles. (For the proton, uud quarks).

2. Hadrons (mesons and baryons) are associated with the strong nuclear force. They decay via the hadrionic interaction in 10^{-10}s. Leptons are particles that interact or participate in the weak interaction.

3. (a) Neutrino travels at the speed of light. It has no charge, spin of ½ ,and their mass is much much less than the rest mass of the electron.

   (b) In beta–decay n → p + e^- + ?. The energy of the beta particle is lower than expected. The law of conservation of energy seemed to be violated. Fermi suggested that the missing energy could be accounted for by predicting and ultimately finding the neutrino.

4. C

5. C

6.

1. positron, charge +1, lepton.	2. down quark, charge –1/3.
3. plus pion, charge +1, meson.	4. electron neutrino, charge 0, lepton.
5. lamda, charge 0, baryon.	6. sigma–plus, charge +1, baryon.
7. antitau, charge +1, lepton.	8. xi–zero, charge 0, baryon.
9. minus–kaon, charge –1, meson.	10. gluon, charge 0, gauge boson.
11. omega–minus, charge –1, baryon.	12. photon, charge 0, gauge boson.
13. antimuon, charge +1, lepton.	14. Z gauge boson, charge 0.
15. muon neutrino, charge 0, lepton.	16. anti–up, charge –2/3, quark.
17. tau, charge –1, lepton.	18. charm, charge +2/3, quark.

7. (a) conserved (b) conserved (c) not conserved (d) not conserved.

8. (a) The Pauli exclusion principle states that an orbital can only contain a maximum of two electrons and when the 2 electrons occupy an orbital they have opposite spin.
   (b) This principle is also extended to the shell model that explains nuclear energy states.

9. 1. ½ 2. ½ 3. 0 4. ½ 5. ½ 6. ½ 7. ½ 8. ½ 9. 0 10. 1 11. 3/2 12. 1 13. ½ 14. 1 15. ½

10. A

11. All particles have antiparticles which are identical to the particle in mass and half–integral spin but are opposite in charge to their corresponding particle. Antiparticles have antimass.

12. Baryons are usually much heavier than mesons.

13. a) neutron b) proton and electron c) proton (since it is heavier).

14. proton – uud – 2/3 + 2/3 + –1/3 = 1 neutron – ddu – –1/3 + –1/3 + 2/3 = 0.

15. (a) When matter (such as an electron) collides with its corresponding antimatter (such as a positron), both particles are annihilated, and 2 gamma rays with the same energy but with a direction at 180^0 to each other are produced. This is called **pair annihilation**.

(b) Total energy of the photons is 1.022 MeV, therefore the energy of each photon is 511keV (c) the direction is the same as the vector sum of the momentum of the electron and the positron. (d) 2.5×10^{20}Hz

16. C

17. a). 3.01×10^{-10} J b). 3.09×10^{-10} J.

18. 1.88×10^3 MeV.

19. Photons emitted by one electron cause it to recoil, as it transfers momentum and energy to the other electron. Then the second electron undergoes the same process almost immediately. The closer two charges are, the more energetic the virtual photons exchanged, while the further away two charges are, the less energetic their virtual photons. Because the exchange must be very rapid, the photons exchanged are called virtual photons, suggesting they are not observable. These virtual photons are said to carry the electromagnetic force, or in other words, to mediate the force.

20. (a) a muon neutrino interacts with a photon exchange particle to become a muon.

(b) a down quark emits an exchange particle and becomes an up quark. This is an example of a flavour change as it transforms into a member of another generation.

(c) a positive muon emits a W^+ particle and becomes an anti–muon neutrino. The W^+ particle changes to particle–antiparticle pair in the form of an positron and an electron neutrino.

(d) a positive minus–pion decays into a negative muon and a muon neutrino. The down quark and the antiup quark annihilate to produce a W^- particle. Note the backward direction of the antidown quark. The W^- then decays into a negative muon and a muon neutrino.

CHAPTER 21 (OPTION J) PARTICLE PHYSICS

Exercise 21.2 (pages 537, 538)

1. $E = mc^2 = 1.673 \times 10^{-27}$ kg $\times 9 \times 10^{16}$ m^{2}s$^{-2} \div 1.6 \times 10^{-19}$ JeV^{-1} = 0.9 GeV

   Therefore, the total energy is 30.9 GeV.

   $\lambda \approx hc / mc^2 = (6.63 \times 10^{-34}$ Js $\times 3 \times 10^8$ ms$^{-1}) \div (30.9 \times 10^9$ eV $\times 1.6 \times 10^{-19}$ JeV$^{-1})$

   $= 4.0 \times 10^{-17}$ m.

2. $B = 2\pi mf / q$

   $= (2\pi \times 2 \times 1.673 \times 10^{-27}$ kg $\times 1.5 \times 10^7$ revs$^{-1}) \div 1.6 \times 10^{-19}$ JeV^{-1} = 0.99 T

3. $\lambda = h / \boldsymbol{p} = h/m\boldsymbol{v} \approx h/mc = hc/mc^2$ where mc^2 = 1.5 GeV.

   Therefore, $\lambda = (6.63 \times 10^{-34}$ Js $\times 3 \times 10^8$ ms$^{-1}) \div (3.2 \times 10^9$ eV $\times 1.6 \times 10^{-19}$ JeV$^{-1})$

   $= 3.9 \times 10^{-16}$ m. This is less than the size of the nucleus and thus the resolution should be good.

4. Knowing that $W = qV = ½ m\boldsymbol{v}^2$, then making $\boldsymbol{v}$ the subject of the equation, we get:

   $\boldsymbol{v} = \sqrt{(2qV / m)} = \sqrt{[(2 \times 1.6 \times 10^{-19} \text{ C} \times 30 \times 10^3 \text{ V}) \div (9.11 \times 10^{-31} \text{ kg})]}$

   $= \sqrt{1.05 \times 10^{16}}$

   $\boldsymbol{v} = 1.03 \times 10^8$ ms^{-1}.

   $f = 15 \times 10^6$ Hz and so T $= 6.67 \times 10^{-8}$ s.

   The average time for the polarity to change in the tube lengths $= T/2 = 3.335 \times 10^{-8}$.

   Therefore, the length of the tube $= \boldsymbol{v}t = 1.03 \times 10^8$ ms$^{-1} \times 3.335 \times 10^{-8}$ m = 3.44 m.

5. $m\boldsymbol{v}^2 / r = qvB$ where r = 1000 m.

   If we assume that the proton beam is travelling at approximately the speed of light, then $m\boldsymbol{v}^2 / r \approx mc^2 / r$ where mc^2 = 300 GeV.

   Therefore, $\boldsymbol{B} \approx mc^2 / qcr$

   $\approx (300 \times 10^9$ eV $\times 1.6 \times 10^{-19}$ JeV$^{-1}) \div (1.6 \times 10^{-19}$ C $\times 3 \times 10^8$ ms$^{-1} \times 1000) \approx 1$ T.

6. (a) A deuteron has approximately twice the mass of a proton. Since the potential difference must reverse twice each cycle, then the period T of each cycle will be given by:

   $T = 2\pi\text{m} / q\boldsymbol{B}$ and therefore $f = q\boldsymbol{B} / 2\pi\text{m}$ and $\boldsymbol{B} = 2\pi\text{m}f / q$.

So, $\boldsymbol{B} = 2 \times \pi \times 3 \times 1.673 \times 10^{-27}$ kg $\times 15 \times 10^{6}$ s^{-1} $\div 1.6 \times 10^{-19}$ C = 1.98 T

(b) $m\boldsymbol{v}^2/r = q\boldsymbol{vB}$ and therefore $\boldsymbol{v} = rq\boldsymbol{B}$ / m.

So, $\boldsymbol{v}$ = 0.5 m × 1.6 × 10^{-19} C × 0.99 T ÷ (2 × 1.673 × 10^{-27} kg) = 2.35 × 10^{7} ms^{-1}.

$E_K = ½ m\boldsymbol{v}^2$ = 0.5 × 2 × 1.673 × 10^{-27} kg × (2.35 × 10^{7} ms^{-1})^2 = 9.3 × 10^{-13} J

= 5.8 MeV.

7. $\lambda = h / \boldsymbol{p} = h/m\boldsymbol{v} \approx h/mc = hc/mc^2$ where mc^2 = 400 GeV.

Therefore, λ = (6.63 × 10^{-34} J s × 3 × 10^{8} m s^{-1}) ÷ (370 × 10^{9} eV × 1.6 × 10^{-19} JeV^{-1})

= 3.4 × 10^{-18} m. This is equal to the resolving power attainable.

8. Assuming the particle is traveling at approximately the speed of light, c = 2πr / T and $T = 2\pi r / c$ = 2π × 4.25 × 10^{3} m / 3 ×x 10^{8} ms^{-1} = 8.9 × 10^{-5}s.

9. (a) Using a hand rule to show A is an antiproton.

(b) No, because of their different radii. Therefore, they have different speeds and thus different kinetic energy.

(c) $E_{min} = 2m_0c^2$ = 2 × 1.673 × 10^{-27} kg × (3 × 10^{8} ms^{-1})^2 = 3.01 × 10^{-10} J = 1.9 GeV.

10. (a) $E = V/d$ = 50 × 10^{3} V / 0.02m = 2.5 × 10^{6} Vm^{-1}

(b) $W = qV$ = 1.6 × 10^{-19} C × 50 × 10^{3} V = 8 × 10^{-15} J

(c) $v = \sqrt{(2W/m)} = \sqrt{(2 \times 8 \times 10^{-15} \text{ J} / 1.673 \times 10^{-27} \text{ kg})}$ = 3.1 × 10^{6} ms^{-1}.

(d) So that some of the energy is not lost due to collisions with air particles.

11. (a) 50 × 10^{6} eV × 1.6 × 10^{-19} JeV^{-1} = ½ × 1.673 × 10^{-27} kg × $\boldsymbol{v}^2$. $\boldsymbol{v}$ = 9.8 × 10^{7} ms^{-1}.

(b) Circumference = 2πr = 2π × 100 m = 628.3 m. t = d/$\boldsymbol{v}$ = 6.4 μs.

(c) $\boldsymbol{p} = m\boldsymbol{v}$ = 1.6 × 10^{-19} kgms^{-1}.

(d) q = It = 6 × 10^{-7} C ÷ 1.6 × 10^{-19} = 3.75 × 10^{12} protons.

(e) W = 12 × q V = 7.68 × 10^{-15}J = 48 keV.

(f) Total after 1 revolution = 50.048 MeV

number of revolutions = 28 × 10^{9} eV ÷ 50.048 × 10^{6} eV = 560 rev.

CHAPTER 21 (OPTION J) PARTICLE PHYSICS

Exercise 21.4 (pages 546)

1. a. $\Lambda = 0$ b. $\Sigma = 1$ c. $\pi^{+} = 1$ d. $K^{-} = -1$

2. B

3. D

4. Z^0. Neutrinos mean the weak force is involved. Because the electron remains an electron and there is charge, the Z^0 would be involved.

5. See text.

6. See text.

7. (a) ucs, ucd, utb and other combinations

   (b) dds, ddb, dsb and other combinations

   (c) uds, tsb, cdb and other combinations.

8. (a) π^0. charge has to be conserved.

   (b) π^0. Using quark conservation $\bar{u}d + uud \rightarrow udd + \bar{u}u$.

   (c) K^0. Using quark conservation $\bar{u}d + uud \rightarrow uds + \tilde{s}d$.

   (d) e^{-}. To conserve charge.

   (e) μ^{+}. To accompany the muon neutrino

9. (a) yes

   (b) no. charge and lepton number not conserved.

   (c) no. charge not conserved.

   (d) no. lepton number not conserved.

   (e) no. lepton number is not conserved.

   (f) yes.

   (g) yes.

   (h) yes. Strangeness is not conserved but it can take place via the weak interaction.

   (i) no. since this is a decay, the mass of Λ^0 must be greater than the some of the product masses. Energy is not conserved.

10. (a) uds (b) uds (c) $u\bar{u}\ \tilde{d}d$ (d) $u\tilde{s}$ (e) $\bar{u}d$.

The particle/antiparticle pairs are K^+, π^- and π^0 is its own antiparticle.

11. $n \rightarrow p + e^- + \tilde{\nu}_e$

The neutron is ddu and the proton is uud. Charge has to be conserved.

So, d (–1/3) → u (+2/3) + e^- (–1) + $\tilde{\nu}_e$ (0).

Therefore, the Feynman diagram would be