CAPE Physics Answer Key
Unit 1: Mechanics, Oscillations and Waves, Thermal and Mechanical Properties of Matter

It is implied, unless otherwise stated, that SI base units are used throughout these explanations in equations involving various quantities.

Module 1: Mechanics

1.1.1: Physical Quantities, SI Units and Vectors

No.	Answers	Further explanations
1	D	
2	B	Quantities: $R = \frac{pV}{nT} = \frac{FV}{AnT}$ Units: $\frac{\text{kg m}}{\text{s}^2} \ \frac{\text{m}^3}{1} \ \frac{1}{\text{m}^2} \ \frac{1}{\text{mol}} \ \frac{1}{\text{K}} = \text{kg m}^2 \ \text{s}^{-2} \ \text{K}^{-1}\text{mol}^{-1}$
3	C	The SI base units are: kilogram (kg), metre (m), second (s), ampere (A), kelvin (K), mole (mol), candela (cd)
4	C	
5	A	Quantities: $\frac{F^2}{WA\rho}$ Units: $\frac{\text{kg}^2\text{m}^2}{\text{s}^4} \ \frac{\text{s}^2}{\text{kg m}^2} \ \frac{1}{\text{m}^2} \ \frac{\text{m}^3}{\text{kg}} = \frac{\text{m}}{\text{s}^2}$ = unit of acceleration
6	B	
7	C	$\frac{P}{Q} = \frac{20.0\times10^6}{5.0\times10^{-3}} = 4.0\times10^9 \quad \therefore P = 4.0\times10^9 Q$
8	C	The uncertainty of EACH measurement is ±1 kg. (46 – 42) kg ± 2 kg = 4 kg ± 2 kg = (4 ± 2) kg

No.	Answers	Further explanations
9	A	$\frac{\pm 2}{4} = \pm 0.5$ or $\pm 50\%$
10	B	Fractional error: $\frac{\Delta A}{A} = \frac{2\Delta d}{d} = \frac{2(\pm 0.1)}{5.0} = \pm 0.04$ Percentage error $= \pm 4\%$
11	B	Systematic errors cannot be reduced by finding the mean of several values.
12	A	The buoyancy force on the floating object is equal to its weight, and is equal to the weight of the water displaced. This gives the extra (displaced) volume as 8.0 cm^3 and the total volume reading as 210 cm^3 + 8 cm^3 = 218 cm^3. weight of object = weight of water displaced mass of object = mass of water displaced 8.0 = density of water × volume of water $8.0 = 1.0 \times V$ therefore $V = 8.0\ cm^3$
13	B	$n = \frac{mass}{molar\ mass} = \frac{47\ g}{235\ g\ mol^{-1}} = 0.20\ mol$
14	D	$m = \rho V = 3.5\ g\ cm^{-3} \times 2.0\ cm^3 = 7.0\ g$ $\left(Note: 3500\ kg\ m^{-3} = 3.5\ g\ cm^{-3}\right)$ $\frac{mass}{molar\ mass} = \frac{7.0\ g}{12\ g\ mol^{-1}} = \frac{7.0}{12} mol$ $no.\ of\ particles = \frac{7.0}{12} mol\left(6.02 \times 10^{23} mol^{-1}\right) = 3.5 \times 10^{23}$
15	A	The largest resultant is 30 N + 50 N = 80 N. The smallest resultant is 50 N – 30 N = 20 N
16	C	The resultant of any two of the three forces must be equal in magnitude but opposite in direction to the third. $F = \sqrt{5.0^2 + 4.0^2} = 6.4\ N$
17	C	The vectors to be added are joined head to tail but the resultant is directed from the start to the end of the chain of arrows.
18	C	$K = MN \quad M = k\frac{1}{N} \quad therefore\ M \propto \frac{1}{N}$

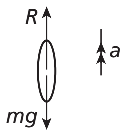
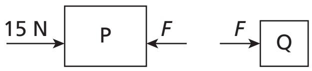
No.	Answers	Further explanations
19	B	Poor precision implies that the range of values obtained for the measurement is large. High accuracy implies that the mean value of the measurement is close to the true value.
20	B	Diameter of 2 spheres = (3.0 ± 0.2) cm − (1.0 ± 0.2) cm = (2.0 ± 0.4) cm Diameter of 1 sphere = $\frac{2.0 \pm 0.4}{2}$ cm = (1.0 ± 0.2) cm

1.1.2: Forces, Statics and Linear Motion

No.	Answers	Further explanations
1	B	For any immersed object: weight of fluid displaced = upthrust For a **floating** object: weight of fluid displaced = upthrust = weight of object.
2	B	Since the balloon is not yet in motion there is no friction and the only two forces on it are its weight (300 N) acting downward and the buoyancy force acting upward. The resultant upward force is therefore weight of air displaced − weight of balloon $F = \rho V g - 300$ $F = 1.3 \times 25 \times 9.81 - 300$ $F = 19$ N (2 sig. fig.)
3	A	The torque of a couple can be calculated as the product of one of the forces and the perpendicular distance between the forces.
4	D	
5	C	Taking clockwise moments about the hinge: $T = 25\left(\frac{1.0}{2}\sin 30\right) + 10(1.0 \sin 30)$ $T = 11$ N m (2 sig. fig.)
6	A	For vertical equilibrium: $W = 20 \cos 40° = 15.3$ N

No.	Answers	Further explanations
7	B	Perpendicular to the incline: the normal reaction cancels the effective force of the weight $mg\cos\theta$. Along the incline: the net force producing the acceleration is $mg\sin\theta - f$. Since $F = ma$, the acceleration down the incline is therefore $\frac{mg\sin\theta}{m} - \frac{f}{m} = g\sin\theta - \frac{f}{m}$
8	A	Since the velocity is constant, the kinetic energy is not changing. The gravitational potential energy is only converting to thermal energy.
9	A	$Fd = \frac{1}{2}mv^2$ $\frac{2Fd}{m} = v^2$ $\sqrt{\frac{2Fd}{m}} = v$ Since $2Fd$ is constant, $v \propto \frac{1}{\sqrt{m}}$
10	C	
11	D	Constant velocity implies zero resultant force.
12	D	$mg - R = ma \quad \therefore R = mg - ma = 45(9.81 - 4.0) = 260\text{ N}$ (2 sig. fig.)
13	B	The forces must be equal in magnitude but oppositely directed. $1.4a = m \times 3.5a$ Therefore $m = 0.40\text{ kg} = 400\text{ g}$
14	C	Exhaust: $F = \frac{m}{t}(v - 0) = \frac{200}{1}(7.5\times10^3 - 0) = 1.5\times10^6\text{ N}$ From Newton's third law, the force on the burnt fuel of the exhaust must be equal in magnitude to the force on the rocket. Rocket: $F = ma \quad m = \frac{1.5\times10^6}{15} = 1.0\times10^5\text{ kg}$
15	D	Resultant force = mass × acceleration $F - 6 = 4\times2 \quad F = 14\text{ N}$
16	B	
17	D	

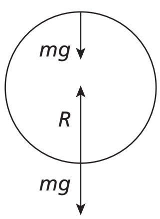
No.	Answers	Further explanations
18	C	Along the rough surface the resultant force is zero since the acceleration is zero. No forces act on the block in the direction of its motion as it slides across the smooth surface; friction is zero and the weight has no component in the direction of motion. After it leaves the edge the resultant force on it is its weight, which is constant. Downward has been taken as negative.
19	B	As it falls, its velocity increases from rest and therefore the gradient of the displacement–time graph increases. The rate of change of velocity, however, gradually decreases to zero and therefore the gradient becomes constant when the velocity is constant.
20	D	As it falls, its velocity increases, but its acceleration decreases to zero and therefore the gradient of the velocity–time graph decreases to zero.
21	D	As it falls, the acceleration decreases to zero.
22	C	As the object rises and falls, the acceleration is always constant and directed downward. The gradient is therefore always constant. At the highest point, the velocity is zero. This point is therefore at $t = 1.6$ s. The height to this point can be calculated from the area under the graph to this point: $\frac{16 \times 1.6}{2} = 12.8 = 13$ m (2 sig. fig.)
23	B	The object strikes the ground at $t = 4.0$ s. The distance travelled can be calculated from the area under the graph to this point: $\frac{40 \times 4}{2} = 80\ \text{m}$.
24	C	The density of the air is much less than that of the material from which the toy soldier is made and therefore the upthrust (bouyancy force) is negligible. For the first 12 m of the drop it cannot acquire enough speed for the frictional force to be significant. Its acceleration to this point is therefore that due to gravity. On engaging the chute, the upward force of the air quickly reduces the acceleration. This force is large enough to have an upward resultant. As the velocity reduces significantly, the upward resultant force diminishes to zero and the acceleration becomes zero.
25	B	No vector can have an effect perpendicular to itself. The horizontal velocity of the dart cannot affect its vertical motion. Applying the equation of motion $s = ut + \frac{1}{2}at^2 \quad s = 0 + \frac{1}{2}at^2 \quad t = \sqrt{\frac{2s}{a}} \quad t = \sqrt{\frac{2(1.0)}{9.81}} \quad t = 0.45\ \text{s}$

No.	Answers	Further explanations
26	B	If the object remains at rest, its acceleration must be zero. However, consider an object at its maximum height when shot vertically into the air. The force of gravity still acts on the object and therefore it still has an acceleration ($F = ma$). Although the instantaneous velocity is zero, the motion of the object is in the process of changing from upwardly directed to downwardly directed.
27	B	 Resultant force on man is $F = ma$ $R - mg = ma \qquad R = ma + mg \qquad R = m(a + g)$ Force of man on floor = force R of floor on man
28	A	 Block Q: $F = ma$ Block P: $15 - F = (4m)a$ $\therefore 15 - F = 4F \qquad 15 = 5F \qquad F = 3\text{ N}$
29	C	For the entire flight the only acceleration of the ball is the constant acceleration due to gravity. The initial vertical component of the velocity is maximum in one direction, diminishes uniformly to zero, and then increases to a maximum in the opposite direction.
30	A	The gradient of the displacement–time graph gives the velocity. Note that the initial gradient is steepest and therefore the initial velocity is greatest in magnitude.
31	C	The ball strikes the ground at W, leaves the ground at X, and reaches its rebound height at Y.
32	C	Each horizontal section of the graph represents the ball rising and then falling with the acceleration due to gravity. Since this acceleration is always constant, these sections are on the same level on the graph. The 'V' sections of the graph indicate the rebound process. The horizontal sections become smaller since the time of flight reduces after rebounding. This indicates that the ball is losing energy and is not rising as high as previously. The collision is therefore inelastic.

No.	Answers	Further explanations
33	D	As the velocity increases, the gradient of the x–t graph increases. When the velocity is constant, the gradient of the x–t graph is constant, and when the velocity decreases, the gradient of the x–t graph decreases. Note that the gradient of the x–t graph is at no time zero, since the velocity is at no time zero.

1.1.3: Forces and Non-linear Motion

No.	Answers	Further explanations
1	C	Since the acceleration is downward, only the vertical velocity can change; there is no change in velocity horizontally. The acceleration is that due to gravity and is constant at every point in the motion.
2	B	$\frac{mv^2}{r} = \frac{GMm}{r^2}$ Therefore $v^2 = \frac{GM}{r}$ and v is independent of m. Since it changes direction, its velocity changes and it therefore accelerates. To stay above the same point on the Earth, it must have the same angular speed as the Earth. $\frac{GMm}{r^2} = mr\omega^2$ $\frac{GM}{r^3} = \omega^2$ Since G and M are constant, $\omega^2 \propto \frac{1}{r^3}$
3	B	$\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi}{60\ \text{s}} = 0.105\ \text{rad s}^{-1}$ The 2.00 cm is irrelevant.
4	D	$mg = \frac{GMm}{r^2}$ $g \propto \frac{M}{r^2}$ (Since G is constant) $\frac{g_p}{g_E} = \frac{M_p}{M_E}\frac{r_E^2}{r_p^2}$ $\therefore g_p = \frac{2M}{M}\frac{r^2}{(4r)^2}9.8 = \frac{9.8}{8} = 1.2\ \text{m s}^{-2}$
5	B	$mg = \frac{GMm}{r^2}$ $g \propto \frac{M}{r^2}$ (Since G is constant) $\frac{g_y}{g_x} = \frac{M_y}{M_x}\frac{r_x^2}{r_y^2}$ $\frac{g_y}{g_x} = \frac{\frac{4}{3}\pi r_y^3\rho_y}{\frac{4}{3}\pi r_x^3\rho_x}\frac{r_x^2}{r_y^2}$ $\frac{g_y}{g_x} = \frac{\rho_y}{\rho_x}\frac{r_y}{r_x}$ $r_x = \frac{\rho_y r_y}{\rho_x}\frac{g_x}{g_y} = \frac{2r}{1}\frac{1}{4} = \frac{r}{2}$
6	B	

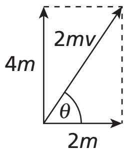
No.	Answers	Further explanations
7	B	At the top of the circle the resultant force is 200 N downward and is providing the centripetal force. When the force of 200 N suddenly acts upward, the resultant force becomes zero and at this point the body will continue its motion in a straight line (i.e. a tangent to the circle) in accordance with Newton's 1st law of motion.
8	B	Frictional force $F = \frac{mv^2}{r}$ $Fr = mv^2$ But Fr is constant $\therefore mv^2$ is constant $\therefore \frac{1}{2}mv^2 = E_k$ is constant
9	C	$v = r\omega = r\frac{\Delta\theta}{\Delta t} = 2.0 \times \frac{1.57}{0.40} = 7.9\ \text{m s}^{-1}$
10	D	A centripetal force is needed for circular motion in order to change the direction of the velocity. Note: acceleration $= r\omega^2 = r\frac{4\pi^2}{T^2}$ NOT $\frac{4\pi r^2}{T^2}$. Since the force is perpendicular to the motion along the arc, work $= F(\cos 90)x = F(0)x = 0$
11	D	$a = r\omega^2 = r\frac{4\pi^2}{T^2}$ $\therefore T = \sqrt{\frac{r4\pi^2}{a}} = \sqrt{\frac{1.2 \times 4\pi^2}{4.0}} = 3.4\ \text{s}$
12	B	Weightlessness occurs at the highest point, when the reaction force is zero. Centripetal force at top = centripetal force at bottom. $mg = R - mg$ $\therefore R = 2mg = 2 \times 50 \times 9.81 = 981\ \text{N}$ (980 N to 2 sig. fig.) Using the equation for the top: $\frac{mv^2}{r} = mg \therefore v = \sqrt{rg} = \sqrt{10 \times 9.81} = 9.9\ \text{m s}^{-1}$ 
13	C	At the brim of the hill: $mg - R = \frac{mv^2}{r} \therefore R = mg - \frac{mv^2}{r}$

No.	Answers	Further explanations
14	A	Reduced by 80% implies reduced to 20%. $\frac{mv_2^2}{r} = 0.20\frac{mv_1^2}{r}$ $v_2^2 = 0.20v_1^2$ $v_2 = v_1\sqrt{0.20} = 25\times\sqrt{0.20} = 5\sqrt{5}$ m s^{-1}
15	D	At the lowest point $T - mg = \frac{mv^2}{r}$ $9.0 - 0.5\times 9.81 = \frac{0.5v^2}{2.0}$ $4.1 = 0.25v^2$ $v = \sqrt{\frac{4.1}{0.25}} = 4.0$ m s^{-1}
16	C	Note: 1.5 times the diameter above the surface implies 3 times the radius above the surface. i.e. radius of orbit = 3 + 1 = 4 times radius of Earth. $g \propto \frac{1}{r^2}$ $\frac{g_2}{g_1} = \frac{r_1^2}{r_2^2}$ $\frac{g_2}{g_1} = \frac{r_1^2}{(4r_1)^2}$ $g_2 = \frac{1}{16}\times 9.81$ $\therefore mg_2 = 500\times\frac{9.81}{16} = 307$ N
17	A	$\frac{mv^2}{r} = \frac{GMm}{r^2}$ Since GM is constant $\therefore v^2 \propto \frac{1}{r}$ $\frac{R_y}{R_x} = \frac{v_x^2}{v_y^2}$ $R_y = \frac{4^2}{1^2}R_x = 16R_x$
18	C	$g = \frac{GM}{R^2}$ $g \propto \frac{1}{R^2}$ (Since GM is constant) $\therefore \frac{g_s}{g} = \frac{R^2}{(R+r)^2}$ $g_s = \frac{R^2}{(R+r)^2}(g)$ $mg_s = (mg)\frac{R^2}{(R+r)^2}$

1.1.4: Forces, Momentum and Energy

No.	Answers	Further explanations
1	D	The velocity is not constant since it changes direction. Uniform circular motion implies that the speed v is constant. Since the mass m and radius r are also constant, the centripetal force $\frac{mv^2}{r}$ (resultant force) and the kinetic energy $\frac{1}{2}mv^2$ must be constant. Since the resultant forces at the top and bottom are the same, $T_t + mg = T_b - mg$ and therefore $T_t \neq T_b$ (where T is the tension).

No.	Answers	Further explanations
2	A	The velocity **increases** each second but not by as much as in the previous second. This continues until the velocity no longer increases and hence the kinetic energy no longer increases.
3	C	Any change in gravitational potential energy has a corresponding negative change in kinetic energy. Since the vertical distance is directly proportional to change in potential energy ($mg\Delta h$), the relation is linear. Distance is a scalar quantity and therefore as the ball rises, and as it falls, the vertical distance travelled increases. As it rises, the potential energy increases (kinetic energy decreases). The opposite occurs as it falls. The horizontal component of the velocity is constant and therefore the kinetic energy is never zero.
4	D	$\frac{1}{2}mv^2 = FD \quad D = \left(\frac{1}{2}\frac{m}{F}\right)v^2$ But $\left(\frac{1}{2}\frac{m}{F}\right)$ is constant $\therefore v^2 \propto D \quad v \propto \sqrt{D} \quad p = mv \propto \sqrt{D}$
5	B	
6	B	Impulse $= Ft = 20 \times 0.50 = 10\ \text{N s} = 10\ \text{kg m s}^{-1}$
7	C	$Ft = mv - mu \quad 10 = 4.0v - 4.0 \times 2.0 \quad 10 + 8.0 = 4.0v \quad v = 4.5\ \text{m s}^{-1}$
8	B	$Ft = mv - mu$ area of trapezium $= mv - 0 \quad 6.0 \times 8.0 = m \times 4.0 \quad m = 12\ \text{kg}$
9	B	
10	B	Taking direction north as + results in total momentum before = total momentum after $mu - (4m \times 2u) = 5mv \quad u - 8u = 5v \quad -7u = 5v \quad v = -\frac{7}{5}u$ The negative sign indicates that the direction of motion is south.
11	C	$F = \frac{m(v-u)}{t} \quad t = \frac{m(v-u)}{F} = \frac{4.0(2.0-0)}{50} = 0.16\ \text{s}$
12	C	Force is the rate of change of momentum = 50 N

No.	Answers	Further explanations
13	B	No vector can have an effect perpendicular to itself and therefore the vertical force has no effect on the horizontal motion. The reaction force of the driver's ejection on the car has no effect on the motion of the car, because this is perpendicular to the car's motion. So the car's velocity remains the same. Although ejected vertically, the driver will retain his forward momentum.
14	D	 The adjacent sides of the figure represent the initial momentums. The diagonal represents the final momentum. $\sum$initial momentum = $\sum$final momentum y axis: $4m = (2m)v\sin\theta$ x axis: $2m = (2m)v\cos\theta$ Dividing the equations yields $2 = \tan\theta$ $\theta = 63°$
15	D	$E_{\text{kY}} = \frac{1}{2}mv^2 \quad E_{\text{kX}} = \frac{1}{2}\left(\frac{1}{2}m\right)(4v)^2 = 4mv^2 \quad \therefore E_{\text{kX}} = 8E_{\text{kY}}$
16	B	$P = Fv \quad F = \frac{P}{v} = \frac{500}{2.0} = 250\ \text{N}$
17	A	$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} = \frac{2.0\times10^3 - (40\times30)}{2.0\times10^3}$ $= \frac{800}{2000} = 0.40$ or 40%
18	D	$P = \frac{E_\text{k}}{t} = \frac{1}{2}\frac{mv^2}{t} \quad v = \sqrt{\frac{2Pt}{m}}$
19	A	As the spring stretches, the force changes from 0 to the tension T. The average force is $T/2$. $\frac{T}{2}\times0.10 = \frac{1}{2}mv^2 \quad T\times0.050 = \frac{1}{2}(0.0050)6.0^2 \quad T = 1.8\ \text{N}$

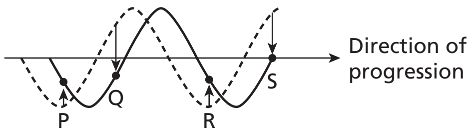
Module 2: Oscillations and Waves

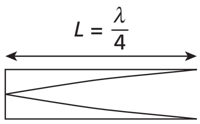
1.2.1: Harmonic Motion

No.	Answers	Further explanations
1	D	$2\pi f = 0.50\pi \qquad f = 0.25\text{ Hz}$
2	C	
3	A	$T_x = 2\pi\sqrt{\frac{m}{k}} \quad T_y = 2\pi\sqrt{\frac{4m}{k}} \quad T_y = 2\times 2\pi\sqrt{\frac{m}{k}} \quad T_y = 2T_x \quad \therefore \frac{T_x}{T_y} = \frac{1}{2}$
4	C	$\omega = \frac{2\pi}{T} = \frac{2\pi}{2\pi\sqrt{\frac{m}{k}}} = \sqrt{\frac{k}{m}} \quad v_{max} = A\omega = A\sqrt{\frac{k}{m}} \quad a_{max} = A\omega^2 = A\frac{k}{m}$
5	C	$v_{max} = A\omega = 0.020(4.0\pi) = 0.080\pi\text{ m s}^{-1}$ $a_{max} = A\omega^2 = 0.020(4.0\pi)^2 = 0.32\pi^2\text{ m s}^{-2}$
6	A	$v_{max} = A\omega = A\frac{2\pi}{T} = 1.2\frac{2\pi}{2.0} = 1.2\pi\text{ m s}^{-1}$
7	C	
8	B	For SHM, $a = -\omega^2 x$ Comparing with $a = -\left(\frac{2k}{m}\right)e$ we see that $\omega^2 = \frac{2k}{m}$ $E_{kmax} = \frac{1}{2}mv^2 = \frac{1}{2}mA^2\omega^2 = \frac{1}{2}mA^2\left(\frac{2k}{m}\right) = kA^2$ When the kinetic energy is at a maximum, the potential energy is zero, and therefore this maximum kinetic energy is equal to the total energy.
9	D	$T = 2\pi\sqrt{\frac{l}{g}} \qquad T^2 = 4\pi^2\frac{l}{g} \qquad \therefore T^2 \propto \frac{1}{g} \qquad \therefore \frac{g_y}{g_x} = \frac{T_x^2}{T_y^2} \qquad g_y = \frac{T_x^2}{T_y^2}g_x$
10	B	$T_E = \frac{4.0}{20} = 0.20\text{ s} \quad T_X = \frac{4.0}{40} = 0.10\text{ s} \qquad T^2 = 4\pi^2\frac{l}{g} \qquad \therefore T^2 \propto \frac{1}{g}$ $\therefore \frac{g_X}{g_E} = \frac{T_E^2}{T_X^2} \qquad \therefore g_X = \frac{0.20^2}{0.10^2}\times 9.81 = 39\text{ m s}^{-2}$ (2 sig. fig.)
11	D	The period of the mass–spring system is not affected by gravity. $T = 2\pi\sqrt{\frac{m}{k}} = 0.20\text{ s}$

No.	Answers	Further explanations
12	A	The velocity varies as a sinusoid. In this case, the graph is that of a cosine curve, since timing is started at the centre of the oscillation where the velocity is at a maximum.
13	D	The kinetic and potential energy curves should be swapped.
14	B	Less damping implies less energy loss and therefore greater amplitude of vibration. The resonant frequency is not affected.
15	C	
16	B	
17	D	
18	B	
19	C	Since $T = 2\pi\sqrt{\frac{l}{g}}$, the pendulum with a length equal to that of the large driving pendulum will oscillate with the same frequency and hence is the one to resonate.
20	D	
21	B	
22	C	When $t = 0$ at **end** of oscillation, $y = A\cos\omega t$ $y = 0.040\cos(10\pi \times 0.015) = 0.036\ \text{m}$
23	C	When $t = 0$ at **end** of oscillation, $v = -A\omega\sin\omega t$ $= -0.040 \times 10\pi\sin(10\pi \times 0.015) = -0.57\ \text{m s}^{-1}$ For questions 22 and 23 switch your calculator to radian measure. Note also, that if instead, $t = 0$ at the centre of the oscillation, then $y = A\sin\omega t$ and $v = A\omega\cos\omega t$.

1.2.2: Properties of Waves 1

No.	Answers	Further explanations
1	B	One complete oscillation represents a phase angle of 2π radians. The waves are $\frac{1}{4}$ of an oscillation apart and therefore the phase difference is $\frac{1}{4}(2\pi) = \frac{\pi}{2}$ radians.
2	A	$\lambda = \frac{v}{f} = \frac{16.0}{2.0} = 8.0\ \text{m}$. Since the points are 3.0 m apart, the phase difference is $\frac{3}{8}2\pi = \frac{3}{4}\pi$ radians.
3	B	 The broken line represents the position of the vibrations at a small interval of time earlier. Since the motion of the particles is only vertical, P and R are moving upward and Q and S are moving downward.
4	B	
5	D	
6	C	Each segment represents a half wavelength. $12 = 8\left(\frac{\lambda}{2}\right) = 4\lambda \quad \therefore \lambda = \frac{12}{4} = 3\ \text{m}$ $v = \lambda f = 3 \times 10 = 30\ \text{m s}^{-1}$
7	A	$8\left(\frac{\lambda}{2}\right) = 1.2 \quad 4\lambda = 1.2 \quad \lambda = \frac{1.2}{4} = 0.30\ \text{m}$ $v = \lambda f \quad 360 = 0.30 f \quad f = \frac{360}{0.30} = 1200\ \text{Hz}$

No.	Answers	Further explanations
8	D	From the diagram, the fundamental resonant frequency occurs when $L = \frac{\lambda}{4}$. $\lambda = \frac{v}{f} = \frac{340}{170} = 2.0\ \text{m}$ $\quad L = \frac{\lambda}{4} = \frac{2.0}{4} = 0.50\ \text{m}$ 
9	C	The ratio of wavelengths is inversely proportional to the ratio of frequencies, since the speed is the same for all. <table><tr><td></td><td>**X**</td><td>**Y**</td><td>**Z**</td></tr><tr><td>**λ ratio**</td><td>4</td><td>4/3</td><td>2</td></tr><tr><td>***f* ratio**</td><td>1/4</td><td>3/4</td><td>1/2</td></tr><tr><td>***f* ratio (×4)**</td><td>1</td><td>3</td><td>2</td></tr></table>
10	D	
11	A	Note that this is a STATIONARY wave (not a progressive wave). Within a particular segment each particle vibrates in phase. Within adjacent segments particles vibrate in anti-phase relative to the particles in the neighbouring segments. X is at the mean position and therefore has zero acceleration. Y is at the maximum displacement and is therefore at a displacement anti-node.
12	B	$\frac{\lambda}{4} = D + e \quad \lambda = 4D + 4e \quad v = (4D + 4e)f \quad \therefore\ \frac{1}{f} = \frac{4}{v}D + \frac{4e}{v}$ $\therefore\ gradient = \frac{4}{v}$
13	D	Note: A displacement antinode always exists at the open end. W is a displacement node since the particles there are stationary. It is also a pressure antinode since repeated compressions and rarefactions occur at this point.
14	B	$\frac{y_{\max 2}}{y_{\max 1}} = \frac{r_1}{r_2} \quad y_{\max 2} = \left(\frac{r_1}{r_2}\right) y_{\max 1} = \left(\frac{5.0\ \text{m}}{20\ \text{m}}\right) 0.20\ \text{mm} = 0.050\ \text{mm}$

No.	Answers	Further explanations
15	C	$\frac{(y_{\max 2})^2}{(y_{\max 1})^2} = \frac{I_2}{I_1} \quad (y_{\max 2})^2 = \frac{I_2}{I_1}(y_{\max 1})^2$ $y_{\max 2} = \sqrt{\frac{I_2}{I_1}(y_{\max 1})^2} = \sqrt{\frac{22.5\ \text{W m}^{-2}}{5.0\ \text{W m}^{-2}}(2.0\ \text{mm})^2} = 4.2\ \text{mm}$
16	D	$I = \frac{P}{A} = \frac{P}{4\pi r^2} = \frac{5.0}{4\pi(2.0)^2} = 0.10\ \text{W m}^{-2}$
17	D	$\frac{I_2}{I_1} = \frac{(r_1)^2}{(r_2)^2} \qquad I_2 = \frac{(r_1)^2}{(r_2)^2}(I_1) \qquad I_2 = \left(\frac{5.0^2}{3.0^2}\right)20 = 56\ \text{W m}^{-2}$
18	D	
19	A	$v = \lambda f \quad v = \frac{\lambda}{T} = \frac{0.080}{0.040} = 2.0\ \text{m s}^{-1}$
20	D	Length of pulse: $D = vt = 3.00 \times 10^8 \times 21 \times 10^{-3} = 6.3 \times 10^6$ m $N\lambda = 6.3 \times 10^6 \quad N = \frac{6.3 \times 10^6}{7.0 \times 10^{-7}} = 9.0 \times 10^{12}$
21	A	
22	A	$\frac{v_Q}{v_P} = \frac{\eta_P}{\eta_Q} \qquad v_Q = \frac{2.0}{1.6}(1.5 \times 10^8) = 1.9 \times 10^8\ \text{m s}^{-1}$
23	B	$\frac{\lambda_Q}{\lambda_A} = \frac{v_Q}{v_A} \qquad \lambda_Q = \frac{1.8 \times 10^8}{3.0 \times 10^8}(5.0 \times 10^{-7}) = 3.0 \times 10^{-7}\ \text{m}$
24	C	In the period between the blasts heard by B, sound travels from B to the cliff and back to B. $v = \frac{D}{t} \qquad t = \frac{D}{v} = \frac{2 \times 350}{350} = 2.0\ \text{s}$
25	A	If the speed decreases, so does the wavelength and the angle of refraction according to the relation: $\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{\sin\theta_1}{\sin\theta_2}$ Light waves decrease in speed when travelling from air to a **denser** medium such as water. Sound waves, on the other hand, increase in speed when travelling from air to the denser medium water.

No.	Answers	Further explanations
26	B	Note: light travels faster in air than in water and therefore total internal reflection of light at an air–water interface occurs in the water – the denser medium. However, since sound travels faster in water than in air, total internal reflection occurs in the air – the less dense medium. **Total internal reflection always occurs in the medium in which the wave moves slower.**
27	A	$\frac{\sin\theta_x}{\sin\theta_y} = \frac{\eta_y}{\eta_x}$ $\frac{\sin c}{\sin 90°} = \frac{1.4}{1.5}$ $c = 69°$
28	B	$\frac{\lambda_x}{\lambda_a} = \frac{\sin\theta_x}{\sin\theta_a}$ $\frac{\lambda_x}{4.0\times10^{-7}} = \frac{\sin c}{\sin 90°}$ $\lambda_x = \frac{\sin 41.8°}{1}\left(4.0\times10^{-7}\right) = 2.7\times10^{-7}\ \text{m}$
29	D	The core must have the greater refractive index for total internal reflection to occur within it.

1.2.3: Properties of Waves 2

No.	Answers	Further explanations
1	C	$\lambda = \frac{v}{f} = \frac{200\ \text{mm s}^{-1}}{5.0\ \text{Hz}} = 40\ \text{mm}$ Path difference: 260 mm – 240 mm = 20 mm = $\frac{\lambda}{2}$ For waves emitted in phase, this path difference will create a phase difference of π radians. For waves emitted out of phase by π radians, the path difference will have a cancelling effect and bring them back in phase.
2	D	$\text{PX} = \frac{30}{6.0} = 5.0\lambda$ $\text{QX} = \frac{39}{6.0} = 6.5\lambda$ $\therefore$ path difference = $6.5\lambda - 5.0\lambda = 1.5\lambda$ The path difference gives a phase difference of π radians. For waves emitted out of phase by π radians, the path difference will have a cancelling effect and bring them back in phase at X, producing constructive interference. The amplitude at the point is therefore 2.0 cm.

No.	Answers	Further explanations
3	A	Since the path difference is 0λ but the waves are emitted with a phase difference of π radians, they will always have a phase difference of π radians at X. The maximum displacements of the combined waveform are (7 cm – 2 cm) = 5 cm and (2 cm – 7 cm) = –5 cm.
4	C	
5	A	
6	D	$\frac{y_{\max A}^2}{y_{\max B}^2} = \frac{I_A}{I_B}$ $\quad \frac{y_{\max A}^2}{y_{\max B}^2} = \frac{25}{9}$ $\quad \frac{y_{\max A}}{y_{\max B}} = \frac{5}{3}$
7	B	The distance x between fringes is given by $\frac{x}{D} = \frac{\lambda}{d}$. $\quad x = \frac{\lambda D}{d}$, where D is the distance between the slits and the screen and d is the distance between the slits. Note that blue light has a shorter wavelength than yellow light.
8	B	$x = \frac{\lambda D}{d}$ $\quad \therefore x_1 = \frac{4.0\times10^{-7} D}{d}$ $\quad x_2 = \frac{7.0\times10^{-7}\frac{D}{2}}{2d}$ $\frac{x_2}{x_1} = \frac{7.0\times10^{-7}}{2\times2\times4.0\times10^{-7}}$ $x_2 = \frac{7.0\times10^{-7}}{2\times2\times4.0\times10^{-7}}\left(3.0\times10^{-3}\right) = 1.3\times10^{-3}\text{ m}$
9	D	
10	A	From the central fringe to the 2nd order image, the angle subtended is $\frac{70}{2} = 35°$. $\sin\theta = m\lambda P$ $\quad P = \frac{\sin 35°}{2\left(450\times10^{-9}\right)} = 6.4\times10^5\text{ m}^{-1} = 6.4\times10^3\text{ cm}^{-1}$
11	D	Maximum angle = 90°, therefore $\sin 90° = m\lambda P$ $\quad m = \frac{\sin 90°}{\lambda P} = \frac{1}{500\times10^{-9}\times6.4\times10^5} = 3.1$ The order must be a whole number, therefore the highest order seen is 3.
12	D	$\sin\theta = m_x\lambda_x P = m_y\lambda_y P$ $\quad m_x\lambda_x = m_y\lambda_y$ $\quad \frac{m_x}{m_y} = \frac{\lambda_y}{\lambda_x} = \frac{6.0\times10^{-7}}{4.0\times10^{-7}} = \frac{3}{2}$

No.	Answers	Further explanations
13	B	$\sin\theta = m\lambda P = 3\times 4.0\times 10^{-7}\times 500\times 10^{3}$ $\theta = 37°$ (Note: 500 lines per mm = 500×10^{3} lines per m)
14	C	$\sin\theta = m\lambda P$ $P = \dfrac{\sin 40°}{3\times 500\times 10^{-9}} = 4.3\times 10^{5}\ \text{m}^{-1} = 4.3\times 10^{2}\ \text{mm}^{-1}$
15	A	From the 1st bright fringe to the 3rd dark fringe represents a spacing of $1\frac{1}{2}$ fringes. The distance between fringes is therefore $\dfrac{6.0\ \text{mm}}{1.5} = 4.0\ \text{mm}$ $\dfrac{x}{D} = \dfrac{\lambda}{d}$ $d = \dfrac{\lambda D}{x} = \dfrac{500\times 10^{-9}\times 1.2}{4.0\times 10^{-3}} = 1.5\times 10^{-4}\ \text{m} = 0.15\ \text{mm}$

1.2.4: Physics of the Ear and Eye

No.	Answers	Further explanations
1	D	
2	B	$\lambda = \dfrac{v}{f} = \dfrac{350}{50} = 7.0\ \text{m}$ $\lambda = \dfrac{v}{f} = \dfrac{350}{14\,000} = 0.025\ \text{m}$ Range: $0.025\ \text{m} \rightarrow 7.0\ \text{m}$ 0.030 m and 4.2 m are wavelengths that are both within this range.
3	C	$\Delta I_L = 10\log_{10}\left(\dfrac{I_1}{I_0}\right) - 10\log_{10}\left(\dfrac{I_2}{I_0}\right) = 10\log_{10}\left(\dfrac{I_1}{I_2}\right) = 10\log_{10}\left(\dfrac{1\times 10^{-2}}{1\times 10^{-5}}\right)$ $\Delta I_L = 10\log_{10}\left(1\times 10^{3}\right) = 30\ \text{dB}$
4	A	$I_L = 10\log_{10}\left(\dfrac{I}{1.0\times 10^{-12}}\right)$ $120 = 10\log_{10}\left(\dfrac{I}{1.0\times 10^{-12}}\right)$ $12 = \log_{10}\left(\dfrac{I}{1.0\times 10^{-12}}\right)$ $1.0\times 10^{12} = \dfrac{I}{1.0\times 10^{-12}}$ $I = 10^{0} = 1.0\ \text{W m}^{-2}$
5	B	$\Delta I_L = 10\log_{10}\left(\dfrac{I_1}{1.0\times 10^{-12}}\right) - 10\log_{10}\left(\dfrac{I_2}{1.0\times 10^{-12}}\right) =$ $10\log_{10}\left(\dfrac{I_1}{I_2}\right) = 10\log_{10}\left(\dfrac{5}{3}\right) = 2.2\ \text{dB}$
6	C	

No.	Answers	Further explanations
7	B	
8	D	
9	D	
10	B	Person has a defective 'near point' $P = \frac{1}{u} + \frac{1}{v} = \frac{1}{0.25} + \frac{1}{-0.40} = 1.5\ \text{D}$ When P and f refer to the power and focal length of a spectacle lens: u is always positive and is the normal 'near point' or 'far point'. v is always negative and is the defective 'near point' or 'far point'.
11	A	Person has a defective 'far point' $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{\infty} + \frac{1}{-1.5}$ $f = -1.5\ \text{m}$ Negative indicates that the lens is concave. Note: The focal length of the concave spectacle lens for **correcting myopia** is always the same as the persons defective 'far point'.
12	B	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\frac{1}{20} = \frac{1}{50} + \frac{1}{v}$ $\frac{1}{20} - \frac{1}{50} = \frac{1}{v}$ $v = 33.3 = 33$ cm (2 sig. fig.) Magnification $= \frac{33.3}{50.0} = 0.67$ Since v is positive, the image is inverted and on the opposite side of the lens to the object.
13	B	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\frac{1}{v} = \frac{1}{-60} - \frac{1}{15}$ $v = -12\ \text{cm}$ Since v is negative, the image is erect and on the same side of the lens as the object.
14	B	

Module 3: Thermal and Mechanical Properties of Matter

1.3.1 Design and Use of Thermometers

No.	Answers	Further explanations
1	B	$\frac{\theta}{100} = \frac{R_\theta - R_0}{R_{100} - R_0}$ $\theta = \frac{70.2 - 28.2}{75.6 - 28.2}(100) = 88.6\ °C$
2	A	525.23 – 273.15 = 252.08 °C
3	D	$\frac{\theta}{100} = \frac{L_\theta - L_0}{L_{100} - L_0}$ $\frac{75.0}{100} = \frac{L_\theta - 25.2}{87.5 - 25.2}$ $L_\theta = 71.9$ cm
4	D	A mercury-in-glass thermometer does not respond quickly since glass is a poor conductor of heat.
5	C	
6	C	$\frac{\theta}{100} = \frac{R_\theta - R_0}{R_{100} - R_0}$ $\theta = \frac{53.4 - 24.5}{87.9 - 24.5} \times 100 = 45.6\ °C$
7	B	$\frac{\theta_x}{100} = \frac{p_T - p_0}{p_{100} - p_0}$ $\theta_x = \left(\frac{p_T}{p_{100} - p_0} - \frac{p_0}{p_{100} - p_0}\right)100$ $\theta_x = \frac{100}{p_{100} - p_0}(p_T) - \frac{100p_0}{p_{100} - p_0}$ This is a straight line graph with gradient $= \frac{100}{p_{100} - p_0}$ and intercept $= -\frac{100p_0}{p_{100} - p_0}$
8	A	$\frac{T}{T_{tr}} = \frac{R}{R_{tr}}$ $T = \frac{43.52}{29.42} \times 273.16 = 404.1$ K
9	C	The constant volume and constant pressure gas thermometers, as well as the liquid-in-glass thermometer, must be read directly, and are therefore unsuitable for measurements in such remote areas. The resistance thermometer however, is comprised of an electrical circuit which can have its data transmitted to the surface to be recorded. The resistance thermometer is also very accurate when measuring slowly changing temperatures.

1.3.2 Thermal Properties

No.	Answers	Further explanations
1	A	$P = \frac{mc\Delta T}{t} = \frac{0.500 \times 2000 \times (80 - 20)}{(5 \times 60)} = 200\ \text{W}$
2	B	$P = \frac{ml}{t}$ $\quad l = \frac{Pt}{m} = \frac{200(8 \times 60)}{0.500} = 192\,000\ \text{J kg}^{-1}$
3	B	$P = \frac{mc\Delta T}{t}$ $\quad t = \frac{mc\Delta T}{P} = \frac{30 \times 4200 \times 50}{800 \times 8 \times 0.20} = 4922\ \text{s} = \frac{4922}{60}\ \text{min} = 82\ \text{min}$
4	B	$E = ml + mc\Delta T = \left(4.0 \times 10^{-6} \times 3.34 \times 10^{5}\right) +$ $\left(4.0 \times 10^{-6} \times 4200 \times 5.0\right) = 1.4\ \text{J}$
5	B	$(mc)\Delta T = VIt$ $\quad \Delta T = \frac{120 \times 4.0 \times 30}{200} = 72\ °\text{C}$ (The mass of the resistor is not needed because its heat capacity, *mc*, is given.)
6	D	Option III: Heat flows from regions of higher to regions of lower temperature. However, body X may have a higher temperature than body Y although it possesses less thermal energy.
7	D	
8	D	
9	B	Option III: Air pockets primarily reduce **conduction** since air is a very poor conductor of thermal energy.

1.3.3 Heat Transfer

No.	Answers	Further explanations
1	D	For a constant rate of heat flow through a uniform cross-sectional area, a greater conductivity reduces the temperature gradient. $\frac{Q}{t} = -kA\frac{\Delta\theta}{\Delta x}$
2	C	
3	B	For a constant rate of heat flow through a material of uniform conductivity, a greater cross-sectional area reduces the temperature gradient. $\frac{Q}{t} = -kA\frac{\Delta\theta}{\Delta x}$

No.	Answers	Further explanations
4	A	First find equivalent resistance: $R = \left(\dfrac{x}{kA}\right)_P + \left(\dfrac{x}{kA}\right)_Q$ $R = \dfrac{0.500}{400 \times 1.00 \times 10^{-2}} + \dfrac{0.500}{200 \times 1.00 \times 10^{-2}} = \dfrac{3}{8}$ **Then** $\dfrac{Q}{t} = \dfrac{\Delta\theta}{R} = \dfrac{40 \times 8}{3} = 107\ \text{W}$
5	B	$\left(\dfrac{Q}{t}\right)_P + \left(\dfrac{Q}{t}\right)_Q = 400 \times 1.00 \times 10^{-2}\left(\dfrac{40}{0.50}\right) + 200 \times 1.00 \times 10^{-2}\left(\dfrac{40}{0.50}\right) = 480\ \text{W}$
6	A	$\dfrac{Q}{t} = -kA\dfrac{\Delta\theta}{\Delta x} \qquad 107 = 200\left(1.00 \times 10^{-2}\right)\dfrac{40}{L}$ $L = \dfrac{200\left(1.00 \times 10^{-2}\right) \times 40}{107} = 0.75\ \text{m}$
7	D	
8	C	$P = \varepsilon\sigma A\left(T_1^4 - T_2^4\right) = 0.50 \times 5.67 \times 10^{-8} \times 6\left(1.0 \times 10^{-4}\right)\left(453^4 - 293^4\right)$ $= 0.59\ \text{W}$
9	A	$P = kA\dfrac{\theta_H - \theta_C}{x} \qquad k = \dfrac{Px}{A\left(\theta_H - \theta_C\right)} = \dfrac{120 \times 0.20}{8.0 \times 10^{-4}\left(120 - 50\right)} =$ $4.3 \times 10^2\ \text{W m}^{-1}\text{K}^{-1}$
10	C	$P = \dfrac{mc\Delta T}{t} \qquad \dfrac{m}{t} = \dfrac{P}{c\Delta T} = \dfrac{120\ \text{W}}{4.2\ \text{J g}^{-1}\ \text{K}^{-1} \times 4.0\ \text{K}} = 7.14\ \text{g s}^{-1} =$ $7.14 \times 60\ \text{g min}^{-1} = 430\ \text{g min}^{-1}$
11	C	The block continues to lose thermal energy at a rate of 500 W. $P = \dfrac{mc\Delta T}{t} \qquad \dfrac{\Delta T}{t} = \dfrac{P}{mc} = \dfrac{500}{2.5 \times 380} = 0.53\ \text{K s}^{-1}$
12	C	

1.3.4 The Kinetic Theory of Gases

No.	Answers	Further explanations
1	C	
2	C	
3	A	$E_K = \frac{3}{2}kT = \frac{3}{2}\left(1.38\times10^{-23}\right)473 = 9.79\times10^{-21}\ \text{J}$
4	B	
5	A	$v_{rms} = \sqrt{\frac{\left(3\times5.0^2\right)+\left(7\times6.0^2\right)+\left(8\times7.0^2\right)+\left(2\times8.0^2\right)}{20}} = 6.5\ \text{m s}^{-1}$
6	B	
7	C	$pV = nRT \qquad p = n\frac{RT}{V} = \frac{m}{M_0}\frac{RT}{V}$ $P \propto m$ since M_0, R, T and V are constant. Therefore gradient = $\frac{RT}{M_0V}$
8	C	$pV = nRT \quad n = \frac{pV}{RT} = \frac{\left(3.00\times10^6\right)\left(1.00\times10^{-3}\right)}{8.31\times300} = 1.2\ \text{mol}$ $N = nN_A = 1.2\times6.02\times10^{23} = 7.2\times10^{23}$
9	C	$n = \frac{N}{N_A} \quad N = nN_A = 4.0\times6.02\times10^{23} = 2.41\times10^{24}$
10	A	$p = \frac{1}{3}\rho\left\langle c^2\right\rangle \qquad \rho = \frac{3p}{\left\langle c^2\right\rangle} = \frac{3\left(2.00\times10^5\right)}{800^2} = 0.938\ \text{kg m}^{-3}$
11	C	$pV = nRT \qquad p \propto n$ (since R, T and V are constant) $\frac{p_2}{p_1} = \frac{n_2}{n_1} \qquad \frac{p_2}{p_1} = \frac{N+3}{3} \qquad \frac{2.0\times10^6}{6.0\times10^5} = \frac{N+3}{3} \qquad \therefore N = 7$
12	A	$pV = nRT = \frac{N}{N_A}RT \qquad T = \frac{pVN_A}{NR} = \frac{4.0\times10^5\times2.0\times10^{-3}\times6.02\times10^{23}}{1.5\times10^{23}\times8.31}$ $= 386\ \text{K} = (386-273)\ ^\circ\text{C} = 113\ ^\circ\text{C}$ (110 °C, to 2 sig. fig.)

No.	Answers	Further explanations
13	D	
14	D	
15	B	$\langle c^2 \rangle = \frac{3RT}{M_0}$ $\sqrt{\langle c^2 \rangle} = \sqrt{\frac{3RT}{M_0}} = \sqrt{\frac{3 \times 8.31 \times 100}{0.0040}} = 790 \text{ m s}^{-1}$
16	C	$\langle c^2 \rangle = \frac{3RT}{M_0}$ $\therefore \langle c^2 \rangle \propto T$ $\frac{\langle c^2 \rangle_2}{\langle c^2 \rangle_1} = \frac{T_2}{T_1}$ $\frac{(3v)^2}{(v)^2} = \frac{T_2}{(273+50)}$ $\frac{9v^2}{v^2} = \frac{T_2}{323}$ $T_2 = 2907\text{ K} = (2907 - 273)\,°\text{C} = 2634\ °\text{C}$ (2630 °C, to 3 sig. fig.)

1.3.5 First Law of Thermodynamics

No.	Answers	Further explanations
1	C	ΔW = work done ON the gas. ΔU can change without heat entering or leaving the system if the gas is compressed or expanded. $\Delta W = -p\Delta V$ for work done ON the gas.
2	D	
3	A	No work is done during XY since there is no change in volume. Work done **by** gas during YZ: $\Delta W = p\Delta V = 1.0 \times 10^5 \times (1.0 - 5.0) =$ -4.0×10^5 J
4	C	Work done **on** the gas along WX and YZ: $\Delta W = -p\Delta V = \left(-3.0 \times 10^5 \times (5.0 - 1.0)\right) + \left(-1.0 \times 10^5 \times (1.0 - 5.0)\right)$ $= -8.0 \times 10^5$ J
5	C	For a cyclic process p, V and T return to their original values. Since T is unchanged, $\Delta U = 0$. Work BY gas $= 8.0 \times 10^5$ J $\therefore$ Work ON gas $= -8.0 \times 10^5$ J $\Delta U = \Delta Q + \Delta W$ $0 = \Delta Q + \left(-8.0 \times 10^5\right)$ $\Delta Q = 8.0 \times 10^5$ J
6	A	$\Delta Q = nC_p\Delta T = 8.0 \times 29 \times 100 = 2.3 \times 10^4$ J

No.	Answers	Further explanations
7	B	Work done **by** gas: $\Delta W = p\Delta V = 1.0 \times 10^5 \times 1.7 \times 0.050 = 8.5 \times 10^3$ J
8	B	For a monatomic gas, C_V is $\frac{3}{2}R$ and C_P is $\frac{5}{2}R$.
9	C	Note that during Z, the temperature will stay the same if the curve is an isotherm, or will fall or rise depending on whether the curve is less steep or steeper than the isotherm.
10	D	Note that an adiabatic curve is steeper than an isothermal curve. **isothermal:** constant temperature/no change in internal energy/$\Delta U = 0$ **isovolumetric:** constant volume/no work done/$\Delta W = 0$ **isobaric:** constant pressure **adiabatic:** no heat added or removed/$\Delta Q = 0$
11	A	$\Delta W = -p\Delta V = -1.2 \times 10^5 \times 0.0020 = -240$ J $\Delta U = \Delta Q + \Delta W = 500 - 240 = 260$ J
12	B	$\Delta Q = 0$ for an adiabatic change. Expansion implies that work is done BY the gas.
13	C	
14	A	$pV = nRT$ $\therefore$ *largest* pV *indicates highest* T. X: $pV = 20 \times 10^4 \times 0.1 = 2 \times 10^4$ Y: $pV = 5 \times 10^4 \times 0.1 = 5 \times 10^3$ Z: $pV = 5 \times 10^4 \times 0.5 = 2.5 \times 10^4$
15	D	Q_2 is wasted and so the useful output is $Q_1 - Q_2$. $\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} = \frac{Q_1 - Q_2}{Q_1}$
16	B	$\Delta W = p\Delta V = 1.00 \times 10^5 \left(0.300^3 - 0.100^3\right) = 2.60 \times 10^3$ J

1.3.6 Mechanical Properties of Materials

No.	Answers	Further explanations
1	C	$\rho = \frac{m}{V} \quad V = \frac{m}{\rho} = \frac{27.0\text{ g}}{6.02\times10^{23}}\frac{1}{2.70\text{ g cm}^{-3}} = 1.66\times10^{-23}\text{ cm}^3$
2	A	Letting mass of Y = M $V_x = \frac{2M}{9000} = \frac{M}{4500} \quad V_y = \frac{M}{5000} \quad \rho = \frac{\text{total mass}}{\text{total volume}} = \frac{3M}{\left(\frac{M}{4500}+\frac{M}{5000}\right)}$ $= \frac{3}{4.222\times10^{-4}} = 7105\text{ kg m}^{-3}$
3	C	Mass of small cube = mass of increase in liquid displaced. $m = \rho_L V_L = \rho\left(L^2\frac{L}{4}\right) = \frac{\rho L^3}{4}$
4	A	$\rho_{sc} = \frac{m}{\left(\frac{L}{3}\right)^3} = \frac{27m}{L^3}$
5	B	$p = 1.04\times10^5 + (2.00\times1050\times9.81) = 1.25\times10^5\text{ Pa}$
6	D	$p = h\rho g = \frac{F}{A} \quad F = h\rho gA = 0.10\times1000\times9.81\times\pi(0.060)^2 = 11\text{ N}$
7	A	p = atmos. press. + excess press. $= 1.02\times10^5 + (0.60\times7.5\times10^3\times9.81) =$ 1.5×10^5 Pa (2 sig. fig.)
8	A	$h_x\rho_x g = h_y\rho_y g \quad \rho_x = \frac{h_y}{h_x}\rho_y = \frac{0.10}{0.15}\rho_y = \frac{2}{3}\rho_y$
9	A	$p_A = p_x + h_y\rho_y g \quad p_x = p_A - h_y\rho_y g = p_A - 0.10\rho_y g$

No.	Answers	Further explanations
10	A	Option I: The pressure at the top of each column is the common pressure p_x. Option II: The pressure at the base of each liquid column is atmospheric pressure since it is at the same level as the surface of the liquid in the dish which is exposed to the atmosphere. Option III: Since the pressure at the same level at the base of each column is the same (atmospheric pressure) but the liquids are of **different densities,** there can be no other pair of points on the same level in the two columns at which the pressures are equal.
11	D	$\frac{p_t V_t}{T_t} = \frac{p_b V_b}{T_b} \quad p_b = \frac{p_t V_t}{T_t} \frac{T_b}{V_b} = \frac{1.0 \times 10^5 \left(\frac{4}{3}\pi(2r)^3\right) 283}{293\left(\frac{4}{3}\pi r^3\right)} = 7.7 \times 10^5 \text{ Pa}$
12	D	$p_b = p_t + h\rho g \quad h = \frac{p_b - p_t}{\rho g} = \frac{(5.0 - 1.0) \times 10^5}{1.1 \times 10^3 \times 9.81} = 37 \text{ m}$
13	B	If similar springs are placed in parallel, the total force constant is twice that of a single spring. Parallel springs: $k = 20.0 \text{ N}/5.0 \text{ cm} = 4.0 \text{ N cm}^{-1}$.
14	D	If similar springs are placed in series, the total force constant is half that of a single spring. Series springs: $k = 20.0 \text{ N}/5.0 \text{ cm} = 4.0 \text{ N cm}^{-1}$.
15	A	P: $F = ke \quad e_P = \frac{20.0 \text{ N}}{4.0 \text{ N cm}^{-1}} = 5.0 \text{ cm}$ Q: $e_Q = 7.0 \text{ cm} - 5.0 \text{ cm} = 2.0 \text{ cm} \quad k_Q = \frac{F}{e_Q} = \frac{20.0 \text{ N}}{2.0 \text{ cm}} = 10 \text{ N cm}^{-1}$
16	C	The work done by the external agent in loading the spring is the area under the graph to the *x*-axis. The work done by the external agent on unloading is also the area under the graph to the *x*-axis, but is negative. The total work done expresses itself as the energy lost as heat and is therefore the area enclosed by the two curves.
17	D	
18	B	$E = \frac{stress}{strain} = \frac{F/A}{e/L} = \frac{FL}{Ae}$

No.	Answers	Further explanations
19	D	
20	C	
21	C	$k = \frac{60}{0.030} = 2000\ \text{N m}^{-1}$ $E_P = \frac{1}{2}kx^2 = \frac{1}{2}(2000)(0.030)^2 = 0.90\ \text{J}$ OR: area under curve: $E_P = \frac{1}{2}(60 \times 0.030) = 0.90\ \text{J}$
22	C	Note: the proportional limit is surpassed where the graph ceases to be a straight line. The elastic limit, which is reached after the proportional limit, has also been surpassed since the curve does not retrace its path when unloading. Permanent stretch = (2.215 – 2.200) m = 0.015 m or 1.5 cm The strain at a load of 40 N is $\frac{2.22-2.20}{2.20} = 9.1 \times 10^{-3}$
23	D	Work done = area under curve between 2.22 m and 2.23 m $= (40 \times (2.23 - 2.22)) + \frac{(20 \times (2.23 - 2.22))}{2} = 0.50\ \text{J}$
24	A	$E = \frac{stress}{strain} = \frac{F/A}{e/L} = \frac{FL}{Ae} = \frac{60.0 \times 0.30}{\pi(2.5 \times 10^{-3})^2 \times 9.0 \times 10^{-3}} = 1.0 \times 10^8\ \text{Pa}$
25	C	$S = \frac{F}{A} = \frac{F}{\pi r^2}$ $S_2 = \frac{\frac{1}{4}F}{\pi(2r)^2} = \frac{F}{16\pi r^2} = \frac{S}{16}$

Answer Key
Unit 2: Electricity and Magnetism, A.C. Theory and Electronics, Atomic and Nuclear Physics

Module 1: Electricity and Magnetism

2.1.1 Electrical Quantities

No.	Answers	Further explanations
1	C	
2	C	
3	C	$P = VI \quad \therefore V = \frac{P}{I} = \frac{4.0}{0.20} = 20\text{ V} \qquad P = \frac{E}{t} \quad \therefore E = Pt = 4.0 \times 5.0 = 20\text{ J}$
4	D	$P = I^2 R \quad \therefore R = \frac{P}{I^2} = \frac{4.0}{(0.20)^2} = 100\ \Omega \qquad Q = It = 0.20 \times 5.0 = 1.0\text{ C}$
5	B	$R \propto \frac{l}{\pi r^2} \quad R \propto \frac{l}{r^2} \quad \therefore \frac{R_P}{R_Q} = \frac{l_P}{l_Q}\frac{r_Q^2}{r_P^2} = \frac{3l}{l}\frac{r^2}{(3r)^2} = \frac{1}{3} \qquad \therefore \frac{R_P}{R_T} = \frac{1}{3+1} = \frac{1}{4}$ Since $\frac{V_P}{V_T} = \frac{R_P}{R_T} \quad \therefore \frac{V_P}{V_T} = \frac{1}{4}$
6	D	
7	C	$R = \frac{\rho l}{A} \quad \therefore l = \frac{RA}{\rho} = \frac{10 \times 1.5 \times 10^{-6}}{1.5 \times 10^{-6}} = 10\text{ m}$
8	B	$R \propto \frac{l}{r^2} \qquad \therefore \frac{R_2}{R} = \frac{2l}{l}\frac{r^2}{(2r)^2} = \frac{1}{2} \qquad R_2 = \frac{R}{2}$
9	A	$\frac{V}{I} = \frac{\rho l}{A} \quad \therefore I = \frac{VA}{\rho l} = \frac{8.0 \times 4.0 \times 10^{-6}}{2.0 \times 10^{-6} \times 1.6} = 10\text{ A}$
10	D	

No.	Answers	Further explanations
11	C	$I = nAve = 2.5\times10^{21}\times10^{9}\left(\pi\left(1.0\times10^{-3}\right)^{2}\right)\times0.40\times10^{-3}\times1.6\times10^{-19}$ $= 5.0\times10^{2}\text{ A}$
12	A	$\frac{V}{R} = nAve \quad V = RnAve \quad \therefore V \propto v$ since n, A, e and R are constant

2.1.2 Electrical Circuits

No.	Answers	Further explanations
1	C	
2	B	Ohm's law is only obeyed by Y; it is the only line which is directed straight through the origin.
3	A	Note: the gradient of a V–I graph only gives the resistance if the straight line passes through the origin. (So only for Y.) To calculate the resistance at any point on the graph, divide the voltage coordinate by the current coordinate at that point.
4	A	Total power, $P_{\text{T}} = I^2(R+r)$ Power used by bulb, $P = I^2R \quad \frac{P}{P_{\text{T}}} = \frac{I^2R}{I^2(R+r)} = \frac{R}{(R+r)}$
5	C	$E = IR + Ir \qquad r = \frac{E-IR}{I} = \frac{3.0-0.50\times4.0}{0.50} = 2.0\ \Omega$
6	A	p.d. across branches is the same, therefore $1.2\times3.0 = 1.5\times I_1 \ \therefore I_1 = \frac{1.2\times3.0}{1.5} = 2.4\text{ A}$ $I_2 = 3.0 + I_1 = 3.0 + 2.4 = 5.4\text{ A} \qquad V = I_2\times5.0 = 5.4\times5.0 = 27\text{ V}$
7	C	Imagine leaving the cell in the direction of the current until the first terminal of the voltmeter. The voltmeter measures the p.d. across any components between this point and its next terminal when traversing the circuit in the direction of the current. $V = IR \ \therefore I = \frac{V}{R} = \frac{6.0}{4.0} = 1.5\text{ A} \qquad E = I(R+r) = 1.5(4.0+1.0) = 7.5\text{ V}$
8	D	The voltmeter measures the p.d. across the 4.0 Ω resistor. $I = \frac{V}{R} = \frac{4.0}{4.0} = 1.0\text{ A}$

No.	Answers	Further explanations
9	B	$E = I(R_1 + R_2) = 1.0(4.0 + 6.0) = 10.0\ \text{V}$
10	D	A: $P = I^2R = 5^2 \times 1 = 25\ \text{W}$ B: $P = I^2R = 2^2 \times 8 = 32\ \text{W}$ C: $P = VI = 2 \times 4 = 8\ \text{W}$ D: $P = \frac{V^2}{R} = \frac{4^2}{20} = 0.8\ \text{W}$
11	B	In the square section, 3 of the resistors are in one branch and 1 is on the other i.e. 6.0 Ω in parallel with 2.0 Ω. Total resistance $R = 2.0 + \frac{2.0 \times 6.0}{2.0 + 6.0} = 3.5\ \Omega$
12	B	$\frac{R}{10} = \frac{50}{20}$ $R = \frac{50}{20} \times 10 = 25\ \Omega$
13	C	$I = \frac{V}{R} = \frac{3.0}{30} = 0.10\ \text{A}$
14	A	
15	C	The LDR is in **series** with the other resistor. When the resistance of the LDR decreases, the total resistance decreases and the current therefore increases. The p.d. across the other resistor ($V = IR$) therefore increases.
16	B	The resistors are in **parallel**. As the resistance of the LDR increases, the current through it decreases. Note, however, that the other resistor is connected directly across the battery and therefore the p.d. across it is unchanged.
17	C	Assuming the battery is of negligible internal resistance: p.d. across 10 Ω resistor when rheostat set to 0 Ω: 3.0 V p.d. across 10 Ω resistor when rheostat set to 20 Ω: $\left(\frac{10}{10 + 20}\right)3.0 = 1.0\ \text{V}$
18	D	
19	A	Bottom branch: $I = \frac{V}{R} = \frac{5}{10} = 0.5\ \text{A}$ Total current = 0.5 A + 0.4 A = 0.9 A

No.	Answers	Further explanations
20	C	Resistors in parallel $= \frac{3.0 \times 2.0}{3.0 + 2.0} = 1.2\ \Omega$ $\therefore$ p.d. across parallel section $= \left(\frac{1.2}{1.2 + 0.8}\right)3.0 = 1.8\ \text{V}$ Current in $3.0\ \Omega$ resistor $I = \frac{V}{R} = \frac{1.8}{3.0} = 0.60\ \text{A}$
21	B	When no current flows, there can be no lost voltage (*Ir*). The terminal p.d. is then the e.m.f. The lost voltage at any current is the difference between the terminal voltage and the e.m.f. (3.0 V – 2.4 V = 0.6 V)
22	D	Lost voltage $= Ir \quad \therefore r = \frac{V_L}{I} = \frac{3.0 - 2.4}{1.2} = 0.5\ \Omega$
23	C	As the resistance increases, the current (and therefore the lost voltage) decreases. The terminal voltage therefore increases until it is equal to the e.m.f.
24	C	Total current entering branch point = 0. $2I_1 + I_3 - I_1 - I_2 = 0 \quad \therefore I_1 - I_2 + I_3 = 0 \quad \therefore I_2 - I_1 = I_3$

2.1.3 Electric Fields

No.	Answers	Further explanations
1	D	By definition, the electric field strength at a point is the force per unit charge it causes on a charge placed at the point.
2	B	$E = \frac{1}{4\pi\varepsilon}\frac{q}{r^2} \qquad \varepsilon = \frac{1}{4\pi}\frac{q}{r^2 E} \qquad \therefore$ unit of $\varepsilon = \text{C}\ \frac{1}{\text{m}^2}\frac{1}{\text{N}/\text{C}} = \text{C}^2\ \text{m}^{-2}\ \text{N}^{-1}$
3	B	A UNIFORM field exists between parallel plates having a p.d. between them.
4	C	$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} \quad V = \left(9.00 \times 10^9\right)\frac{q}{r}$ $\therefore q = \frac{Vr}{9.00 \times 10^9} = \frac{3.0 \times 10^3 \times 0.30}{9.00 \times 10^9} = 1.0 \times 10^{-7}\ \text{C}$
5	A	$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \quad E = \left(9.00 \times 10^9\right)\frac{q}{r^2} = \left(9.00 \times 10^9\right)\frac{5.0 \times 10^{-6}}{0.50^2} = 1.8 \times 10^5\ \text{N C}^{-1}$

No.	Answers	Further explanations
6	A	$E = \frac{F}{q} \quad F = Eq = \frac{V}{d}q = \left(\frac{1000}{0.10}\right)1.60 \times 10^{-19} = 1.6 \times 10^{-15}\ \text{N}$ (The electron's speed is irrelevant.)
7	D	If the field was magnetic, the particle would deflect in a plane perpendicular to the paper in accordance with Fleming's left-hand rule. The deflection is within the plane of motion of the particle and therefore the field is electric. The upper plate is positive since the field arrows originate there. Negatively charged electrons are attracted to the positive upper plate.
8	C	
9	C	
10	B	The field is the same everywhere between the plates. $E = \frac{V}{d} = \frac{400}{0.20} = 2.0 \times 10^{3}\ \text{V m}^{-1}$
11	C	$V = 9.00 \times 10^{9}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) = 9.00 \times 10^{9}\left(\frac{4.0 \times 10^{-6}}{0.30} + \frac{-2.0 \times 10^{-6}}{0.50}\right)$ $= 8.4 \times 10^{4}\ \text{V} \left(\text{Note: } r_2 = \sqrt{0.30^2 + 0.40^2}\right)$
12	B	Using $+ \rightarrow$: $E = 9.00 \times 10^{9}\left(\frac{\vec{q_1}}{r_1^2} + \frac{\vec{q_2}}{r_2^2}\right) = 9.00 \times 10^{9}\left(\frac{4.0 \times 10^{-6}}{0.80^2} + \frac{-2.0 \times 10^{-6}}{0.40^2}\right)$ $= -5.6 \times 10^{4}$ $5.6 \times 10^{4}\ \text{N C}^{-1}$ directed to the left.
13	C	$F = 9.00 \times 10^{9}\left(\frac{q_1 q_2}{r^2}\right) = 9.00 \times 10^{9}\ \frac{(4.0 \times 10^{-6} \times 2.0 \times 10^{-6})}{0.40^2} = 0.45\ \text{N}$ (The negative sign of q_2 is ignored in the calculation. The charges attract each other since they are of opposite sign.)
14	A	From a point charge: $V \propto \frac{1}{r}$ and $E \propto \frac{1}{r^2}$ $\therefore$ if r doubles V becomes $\frac{V}{2}$ and E becomes $\frac{E}{2^2} = \frac{E}{4}$
15	C	$E = \frac{V}{d} = \frac{1200}{0.06} = 2.0 \times 10^{4}\ \text{V m}^{-1}$ at all points between the plates. The top plate is positive with respect to the lower plate.

No.	Answers	Further explanations
16	D	
17	B	

2.1.4 Capacitors

No.	Answers	Further explanations
1	C	Since $C = \frac{Q}{V}$ the SI unit of capacitance is CV^{-1}
2	B	
3	A	$E = \frac{1}{2}CV^2 = \frac{1}{2}\left(200\times10^{-6}\right)500^2 = 25\text{ J}$
4	A	$E = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{\left(5.0\times10^{-6}\right)^2}{200\times10^{-6}} = 6.3\times10^{-8}\text{ J}$
5	A	$Q = CV \quad \therefore Q \propto V \quad \therefore \frac{Q_2}{Q_1} = \frac{V_2}{V_1} \qquad Q_2 = \left(\frac{V_2}{V_1}\right)Q_1$ $Q_2 = \left(\frac{125}{500}\right)3.0 = 0.75\text{ C}$
6	C	$C = \varepsilon\frac{A}{x} = \varepsilon\frac{\pi r^2}{x} \quad \therefore C \propto \frac{r^2}{x}$ $\therefore$ if radius doubled and x halved: $C_2 = \varepsilon\frac{(2r)^2}{x/2} = 8\varepsilon\frac{r^2}{x} = 8C$
7	C	The new arrangement is of 2 capacitors in parallel. $C = \varepsilon_0\frac{A}{d} \qquad C_2 = \varepsilon_0\frac{A/2}{d} + 2\varepsilon_0\frac{A/2}{d} = \frac{3}{2}\varepsilon_0\frac{A}{d} = \frac{3}{2}C$
8	A	A: $\frac{C\times C}{C+C} = \frac{C^2}{2C} = \frac{C}{2}$ B: $C + C + C = 3C$ C: $2\left(\frac{C}{2}\right) = C$ D: C

No.	Answers	Further explanations
9	A	Top branch: $\frac{C\times C}{C+C}=\frac{C^2}{2C}=\frac{C}{2}$ Bottom branch: $2C$ Combined branches: $\frac{C}{2}+2C=\frac{5C}{2}$ Total capacitance: $\frac{C\times {}^{5C}\!/_{2}}{C+{}^{5C}\!/_{2}}=\frac{\frac{5}{2}C^2}{\frac{7}{2}C}=\frac{5}{7}C$
10	C	
11	A	$V=V_0e^{-\frac{t}{RC}}$ $2.0=10e^{-\frac{t}{RC}}$ $\ln 0.20=-\frac{t}{RC}$ $t=-\ln 0.20\times\left(5.0\times10^3\times4.0\times10^{-6}\right)=3.2\times10^{-2}$ s
12	C	$Q=CV=4.0\times10^{-6}\times10=4.0\times10^{-5}$ C
13	B	$Q=Q_0e^{-\frac{t}{RC}}$ $1=4e^{-\frac{t}{RC}}$ $\ln\left(\frac{1}{4}\right)=-\frac{t}{RC}$ $RC\ln 0.25=-t$ so $t=-5.0\times10^3\times4.0\times10^{-6}\ln 0.25=2.8\times10^{-2}$ s
14	B	Time constant $=RC=5.0\times10^3\times4.0\times10^{-6}=0.020$ s
15	C	$Q=Q_0e^{-\frac{t}{RC}}$ $Q=Q_0e^{-1}$ (when $t=RC$) $Q=0.37Q_0$

2.1.5 Magnetic Fields and Forces

No.	Answers	Further explanations
1	B	$F=BIL$ Therefore $B=\frac{F}{IL}$ and the unit of B (the tesla) is N A^{-1} m^{-1}.
2	A	$B=\frac{\mu_0 I}{2\pi r}=\frac{4\pi\times10^{-7}\times2.0}{2\pi\times0.20}=2.0\times10^{-6}$ T. The right-hand grip rule reveals that the magnetic field below the wire is directed to the north.

No.	Answers	Further explanations
3	D	$B = \frac{\mu_0 NI}{2r}$ $\quad r = \frac{\mu_0 NI}{2B} = \frac{4\pi \times 10^{-7} \times 250 \times 8.0}{2\left(30 \times 10^{-3}\right)} = 0.042\ \text{m}$
4	C	$B = \mu_0 nI = 4\pi \times 10^{-7} \times 5000 \times 2.0 = 1.3 \times 10^{-2}\ \text{T}$ $\left(\text{Note: } 50\ \text{cm}^{-1} = 5000\ \text{m}^{-1}\right)$
5	A	$B = \frac{\mu_0 NI}{L}$ $\quad B_2 = \frac{\mu_0 \frac{N}{2} 2I}{L} = \frac{\mu_0 NI}{L}$ So no change.
6	D	Use of right-hand grip rule.
7	A	It is useful to note that wires carrying currents in the same direction attract each other and wires carrying currents in opposite directions repel each other. This can be verified by drawing magnetic field diagrams associated with the currents.
8	C	Use of Fleming's left-hand rule.
9	B	Use of Fleming's left-hand rule. Recall that the direction of current is opposite to the direction of electron flow.
10	A	$Bqv = \frac{mv^2}{r}$ $\quad r = \frac{mv}{Bq}$ $\quad B, q,$ and v are constant $\quad \therefore r \propto m$ Since Y has $\frac{1}{3}$ the mass of X, the radius of its path is also $\frac{1}{3}$ of the radius of X.
11	B	$Bqv = \frac{mv^2}{r}$ $\quad r = \frac{mv}{Bq}$ $\quad B, m,$ and v are constant $\quad \therefore r \propto \frac{1}{q}$ Since Y has $\frac{1}{3}$ the charge of X, the radius of its path is 3 times the radius of X.
12	A	$F = BIL \sin\theta$ When the angle between B and I is 90°, the value of $\sin\theta$ is maximum.
13	B	Using the right-hand grip rule on X reveals that the field it produces at O is in direction P. Using the right-hand grip rule on Y reveals that the field it produces at O is in direction R. The resultant of these fields is therefore in direction Q, mid-way between P and R.
14	B	The field of the coil at the location of X is upward and to the left towards the near end of the coil. Applying Fleming's left-hand rule to this field direction and to the current in X indicates that the direction of the force produced is Q.

No.	Answers	Further explanations
15	C	$F = BIl \sin\theta = 1.5 \times 5.0 \times 10^{-3} \times 0.25 \sin 30 = 9.4 \times 10^{-4}$ N
16	A	P is strongly attracted downward by Q and weakly repelled upward by R. Therefore the resultant force is down. Q is strongly attracted upward by P and strongly repelled upward by R. Therefore the resultant force is upward. R is weakly repelled downward by P and strongly repelled downward by Q. Therefore the resultant force is downward.
17	A	$mg = BIl \qquad m = \frac{BIl}{g} = \frac{50 \times 10^{-3} \times 5.0 \times 0.30}{9.81} = 7.6 \times 10^{-3}\ \text{kg} = 7.6\ \text{g}$ Fleming's left-hand rule indicates that the magnetic field is directed to the north.
18	A	$V_H = \frac{BI}{net} \qquad n = \frac{BI}{V_H et} = \frac{1.0 \times 8.0}{5.0 \times 10^{-3}\left(1.60 \times 10^{-19}\right)1.2 \times 10^{-2}} = 8.3 \times 10^{23}\ \text{m}^{-3}$
19	B	The fields are in balance. $\therefore Eq = Bqv \qquad \frac{V}{d}q = Bqv$ $B = \frac{V}{dv} = \frac{400}{0.20 \times 2.0 \times 10^{6}} = 1.0 \times 10^{-3}\ \text{T}$

2.1.6 Electromagnetic Induction

No.	Answers	Further explanations
1	D	
2	A	$\Phi = NBA = 50 \times 0.25 \times \pi\left(0.10\right)^2 = 0.39\ \text{Wb}$
3	C	$E = Blv \sin\theta = 5.0 \times 10^{-3} \times 20 \times 10^{-2} \times 4.0 \sin 30 = 2.0 \times 10^{-3}\ \text{V}$ Use of Fleming's right-hand rule indicates that current flows from X to Y within the rod. The potential at Y is POSITIVE, since point Y will then be able to push current through any external circuit which may be connected to it.

No.	Answers	Further explanations
4	B	Closing the switch will produce a magnetic field that grows towards the ring and induces a current in it. The induced current will be in such a direction as to oppose the growing flux producing it. The side of the ring facing the coil will therefore be of similar polarity, causing the ring to repel to the right (east).
5	C	On opening the switch, the magnetic field on either side of the coil diminishes, withdrawing into the coil. Currents are then induced in the rings in such a direction as to prevent the flux from diminishing. The sides of the rings facing each end of the coil will therefore be of opposite polarity, causing attraction towards the coil.
6	B	Assuming the bar magnet falls with its N-pole facing downward: as it enters the coil a N-pole is induced at the coil's upper end to oppose the entry. As it leaves the coil, a N-pole is induced at the coil's lower end to oppose the exit of the S-pole of the bar magnet. Since the polarity of the coil reverses, so does the current within it. The induced current is larger as the magnet leaves the coil since it is then cutting flux at a greater rate due to its higher speed.
7	C	
8	A	$I_s = \frac{P_s}{V_s} = \frac{3.0}{6.0} = 0.50\ \text{A}$ $\quad \frac{I_p}{I_s} = \frac{V_s}{V_p}$ $\quad \therefore I_p = \frac{V_s}{V_p} I_s = \frac{6.0}{120} \times 0.50 = 0.025\ \text{A}$ $\frac{N_p}{N_s} = \frac{V_p}{V_s}$ $\quad N_p = \frac{120}{6.0} \times 100 = 2000$
9	C	$I_s = \frac{V_s}{R_s} = \frac{30}{20} = 1.5\ \text{A}$ $\quad \text{Efficiency} = \frac{V_s I_s}{V_p I_p}$ $\quad 0.80 = \frac{30 \times 1.5}{120 \times I_p}$ $I_p = \frac{30 \times 1.5}{120 \times 0.80} = 0.47\ \text{A}$
10	B	$E = -\frac{(0 - NBA)}{t} = \frac{5 \times 2.0 \times 10^{-2}\left(2.0 \times 10^{2} \times 10^{-4}\right)}{0.25} = 8.0 \times 10^{-3}\ \text{V}$ (The velocity is not needed in the calculation.)
11	B	

No.	Answers	Further explanations
12	C	$t = 0$ in position X: The flux linkage is maximum. $\Phi = NBA \cos \omega t$, since $\cos \omega t$ is then at a maximum ($\cos 0 = 1$). The e.m.f. is zero at time $t = 0$, since the rate of change of flux is zero. $E = NBA \sin \omega t$, since $\sin \omega t$ is then zero ($\sin 0 = 0$).
13	B	The variation of e.m.f. with time is sinusoidal. In position Y, the e.m.f. is at a maximum since the rate of change of flux is at a maximum. If $t = 0$ in this position, $E = NBA\omega \cos \omega t$ ($\cos 0 = 1$).

Module 2: A.C. Theory and Electronics

2.2.1 Alternating Currents

No.	Answers	Further explanations
1	C	$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{156}{\sqrt{2}} = 110 \text{ V}$
2	A	$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.02} = 100\pi$ Amplitude = 240 V $\therefore V = 240 \sin \omega t = 240 \sin 100\pi t$
3	A	$P = \frac{V^2}{R} = \frac{\left(\frac{170}{\sqrt{2}}\right)^2}{20} = 720 \text{ W}$ (2 sig. fig.)
4	B	$I_{pp} = 14.0 \text{ A} \quad \therefore I_p = 7.0 \text{ A} \quad I_{rms} = \frac{7.0}{\sqrt{2}} = 4.9 \text{ A}$
5	A	$P = I^2 R \qquad R = \frac{P}{I^2} = \frac{500}{\left(\frac{5.0}{\sqrt{2}}\right)^2} = \frac{500 \times 2}{25} = 40\ \Omega$
6	C	$I_{pp} = 2I_p = 2 \times 17 = 34 \text{ A} \qquad \omega = 100\pi = 2\pi f \quad \therefore f = \frac{100\pi}{2\pi} = 50 \text{ Hz}$
7	A	$\frac{V_x^2}{R} = \frac{V_y^2}{\frac{R}{8}} \qquad \frac{V_x^2}{8} = V_y^2 \qquad V_y = \frac{V_x}{\sqrt{8}} = \frac{V_x}{2\sqrt{2}}$

No.	Answers	Further explanations
8	D	The r.m.s. value of an alternating current is the same as the direct current that would consume the same power when flowing through a given resistor.
9	B	$P = V_{rms}I_{rms} = \left(\frac{110}{\sqrt{2}}\right)\left(\frac{5.0}{\sqrt{2}}\right) = 275\ \text{W}$ or $P = \frac{\text{peak power}}{2} = \frac{110 \times 5.0}{2} = 275\ \text{W}$ (280 W to 2 sig. fig.)
10	B	$P = \frac{V^2}{R} = \frac{\left(60\sin\left(50\pi \times 6.0 \times 10^{-3}\right)\right)^2}{20} = 118\ \text{W}$ (120 W to 2 sig. fig.) (switch your calculator to radian measure)
11	A	$P_P = \frac{60^2}{20} = 180\ \text{W}$ $\langle P \rangle = \frac{P_P}{2} = \frac{180}{2} = 90\ \text{W}$ Note: $P_{rms} = \frac{\left(\frac{60}{\sqrt{2}}\right)^2}{20} = 90\ \text{W}$
12	C	

2.2.2 The p-n Junction Diode and Transducers

No.	Answers	Further explanations
1	B	At night the p.d. across R is **approximately** zero. Placing a value of zero in the equation (used below) relating the resistance ratio to the p.d. ratio **must be avoided.** Using the data for the day: $\frac{R}{R_{LDR}} = \frac{12}{4}$ $\frac{R}{100} = \frac{12}{4}$ $\therefore R = \frac{12}{4} \times 100 = 300\ \Omega$
2	D	The p.d. across the LDR is 12 V in the dark when its resistance is infinite. Therefore the supply voltage is 12 V. During the day, the p.d. across the LDR is 2 V and therefore the p.d. across R is 10 V. $V_R = IR$ $10 = 4.0 \times 10^{-3} R$ $R = \frac{10}{4.0 \times 10^{-3}} = 2.5 \times 10^3\ \Omega$

No.	Answers	Further explanations
3	A	At temperature T: $\frac{V_{\text{Therm}}}{V_{\text{Total}}} = \frac{R_{\text{Therm}}}{R_{\text{Total}}}$ $\frac{6.0 - V_X}{12} = \frac{0.10}{0.60}$ $\therefore 6.0 - V_X = \frac{0.10}{0.60} \times 12 = 2.0$ $\therefore V_X = 4.0\ \text{V}$ As the temperature falls, the p.d. across the thermistor increases, therefore the potential at X falls to zero and then becomes negative.
4	B	Dark: $\frac{V_P - 0}{12} = \frac{1.5 \times 10^3}{(1.0 + 1.5) \times 10^3}$ Therefore $V_P = 7.2\ \text{V}$ Bright: $\frac{V_P - 0}{12} = \frac{1.5 \times 10^3}{100 + (1.5 \times 10^3)}$ Therefore $V_P \sim 11\ \text{V}$
5	C	
6	B	The smoothing capacitor must be in parallel with the load.
7	A	To analyse these circuits, start from the positive terminal of the source and see if there is a path to the negative terminal through the system. Circuit 1: When the upper terminal of the source is positive, current will not flow due to the defective diode X. When the lower terminal of the source is positive, the path taken by the current is not through X and the load receives a p.d. across it. Therefore the p.d. across the load occurs only during every half-cycle. Circuit 2: When the upper terminal of the source is positive, there is no path for current through the circuit to reach the negative terminal and therefore there is no conduction during this half of the cycle. When the lower terminal of the source is positive, there is a path for the current to reach the negative terminal through the load and system of diodes. The p.d. across the load therefore occurs only during every half-cycle.
8	D	
9	C	
10	D	
11	C	

No.	Answers	Further explanations
12	D	
13	A	Circuit symbol: the arrow in the symbol is the direction of conventional current. From E to C, there is electron-flow in the n-p-n and hole-flow in the p-n-p transistors.
14	C	

2.2.3 Operational Amplifiers

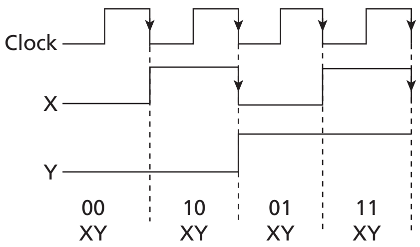
No.	Answers	Further explanations
1	C	
2	B	
3	A	$V = A(V_Y - V_X) = 1.0 \times 10^5 (100 - 40) 10^{-6} = 6\ \text{V}$ $\therefore$ Saturates with $V_o = 5\ \text{V}$
4	B	$\pm V_S = A(V_Y - V_X) \qquad \therefore V_Y - V_X = \dfrac{\pm 5}{1.0 \times 10^5} = \pm 5 \times 10^{-5}\ \text{V} = \pm 50\ \mu\text{V}$
5	A	$V_o = 1.0 \times 10^5 (-80 - -100) 10^{-6} = +2\ \text{V}$
6	A	LED lit when $V_o < 0$ i.e. $V_+ - V_- < 0$ $\quad V_Y - V_X < 0 \quad V_X > V_Y$
7	C	$V_o = A(V_+ - V_-) \qquad \pm 8 = 4 \times 10^5 (0 - V_X)$ $V_X = \dfrac{\pm 8}{4 \times 10^5} = \pm 2 \times 10^{-5}\ \text{V} = \pm 20\ \mu\text{V}$
8	D	V_o is negative when $V_2 > V_1$, i.e. when $V_2 > 1$.
9	C	V_o is negative when $V_2 > V_1$, i.e. when $V_2 > 0$.
10	A	Night: $R_{LDR} > 10\ \text{k}\Omega$ and $V_2 > V_1$. V_o is therefore positive and Y is lit. Day: $R_{LDR} < 10\ \text{k}\Omega$ and $V_2 < V_1$. V_o is therefore negative and X is lit.
11	A	p.d. across $R = 6.0 - 1.2 = 4.8\ \text{V} \qquad R = \dfrac{V}{I} = \dfrac{4.8}{30 \times 10^{-3}} = 160\ \Omega$

No.	Answers	Further explanations
12	C	$A=-\frac{R_f}{R_i}=-\frac{1.00}{0.20}=-5$
13	B	$V_o=AV_i=-5\times 0.500=-2.5\ \text{V}$
14	B	$I_o=\frac{0-V_o}{R_o}=\frac{0--2.5}{5.0\times 10^3}=0.50\times 10^{-3}\ \text{A}=0.50\ \text{mA}$ $I_f=\frac{V_o}{R_f}=\frac{0--2.5}{1.0\times 10^6}=2.5\times 10^{-6}\ \text{A}=2.5\ \mu\text{A}$
15	C	$V=AV_i=-5\times 2=-10$ This saturates, however, and therefore $V_o=-8$ V.
16	C	Recall that current flows from higher to lower potential. $R_f: \text{P}\rightarrow \text{S}$ $0\ \text{V}\rightarrow -2.5\ \text{V}$ $R_i: V_i\rightarrow \text{P}$ $0.5\ \text{V}\rightarrow 0\ \text{V}$
17	C	This is a summing amplifier where the gains on the inputs are –4 and –2. $-4=-\frac{R_x}{R_y}$ …this ratio could be $\frac{800}{200}$ $-2=-\frac{R_x}{R_z}$ …this ratio could be $\frac{800}{400}$
18	A	$V=-\left((4\times 2)+(2\times 1)\right)=-10\ \text{V}$ This saturates, however, and therefore $V_o=-8\ \text{V}$.
19	B	$V_o=AV_i=-\frac{12}{6}(\pm 4)=\pm 8\ \text{V}$ Since it is an inverting amplifier, the output is inverted. Since the frequency is 500 Hz, the period is 2 ms. $T=\frac{1}{f}=\frac{1}{500}=2\times 10^{-3}\ \text{s}$
20	D	$V=AV_i=-\frac{12}{6}(\pm 8)=\pm 16\ \text{V}$ This saturates at $\pm 10\ \text{V}$. It is an inverting amplifier and therefore the output is inverted.
21	A	$A_1=-\frac{50}{25}=-2$ $A_2=-\frac{60}{20}=-3$ Total gain $=(-2)(-3)=6$ $V_o=AV_i=6\times 0.200=1.2\ \text{V}$

No.	Answers	Further explanations
22	B	Non-inverting amplifier: $A = 1 + \frac{R_f}{R_g} = 1 + \frac{10}{5} = 3 \quad V_o = AV_i = 3 \times (0.800) = 2.4\ \text{V}$
23	C	The negative gradient indicates that the gain is negative. It is therefore an inverting amplifier. $A = -\frac{8\ \text{V}}{0.4\ \text{V}} = -20$
24	B	This is obtained from the *x*-axis at the points where the gradient becomes zero.
25	C	
26	B	
27	A	From the graph, a bandwidth of $0 \rightarrow 10^5$ Hz corresponds to a gain of 10. Since this is an inverting amplifier where $A = -\frac{R_f}{R_i}$, the ratio of R_f to R_i is $\frac{10}{1}$.
28	D	

2.2.4 Logic Gates

No.	Answers	Further explanations
1	A	
2	C	
3	C	
4	B	
5	B	
6	B	
7	D	
8	A	
9	C	Only when both of X and Y are logic 1 is the output Q logic 0. The gate is therefore a NAND gate.

No.	Answers	Further explanations
10	C	**INPUTS:** The half adder has just 2 inputs since it only adds 2 digits of the least significant place value. The full adder has 3 inputs since it adds 2 digits of a given place value plus a digit from a previous 'carry'. **OUTPUTS:** Both the half-adder and the full-adder produce just a 'sum' and a 'carry' and therefore they each have 2 outputs.
11	D	
12	B	
13	B	
14	D	
15	A	Closing both switches sets both input lines to logic 0. The output of the NOR gate is then logic 1 and the LED lights since it is forward biased.
16	C	
17	B	The NOR flip-flop is triggered by a logic 1 on one of its lines. Logic 1 on line X causes Q_1 to be logic 0 and Q_2 to be logic 1. When X and Y return to 0, 0, the outputs Q_1 and Q_2 remain unchanged (are latched). Logic 1 on Y then causes Q_2 to be logic 0 and Q_1 to be logic 1. When X and Y return to 0, 0, the outputs Q_1 and Q_2 remain unchanged (are latched).

Module 3: Atomic and Nuclear Physics

2.3.1 Particulate Nature of Electromagnetic Radiation

No.	Answers	Further explanations
1	C	For a given frequency of light above the threshold frequency, a given intensity will cause emission of a particular number of electrons per second. This determines the current. Increasing the voltage does not change the amount of electrons produced per second and therefore the current remains constant. An increasing reverse potential produces a force in opposition to the motion of the electrons allowing fewer of them to be ejected from the metal. A particular value of this reverse potential stops all electron emission.
2	B	Increasing the number of incident photons proportionately increases the chances of photoelectric emission.
3	C	The threshold frequency is the frequency above which photoelectric emission occurs. At this frequency the kinetic energy of the photo-electrons is zero. $hf = W_o + E_K \qquad W_o = hf = 6.63 \times 10^{-34} \times 4.0 \times 10^{14} = 2.7 \times 10^{-19}$ J
4	A	$hf = W_o + E_K \qquad hf = hf_o + E_K$ $E_K = hf - hf_o = 6.63 \times 10^{-34}\left(6.0 \times 10^{14} - 4.0 \times 10^{14}\right) = 1.3 \times 10^{-19}$ J
5	B	$\lambda_o = \frac{c}{f_o} = \frac{3.00 \times 10^8}{4.0 \times 10^{14}} = 7.5 \times 10^{-7}$ m
6	C	$hf = W_o + E_K \qquad E_K = hf - W_o$ This is a graph $y = mx + c$, where the gradient m, is h.
7	D	$hf = W_o + eV_s \qquad V_s = \frac{hf - W_o}{e} = \frac{hf - hf_o}{e}$ $= \frac{6.63 \times 10^{-34}\left(9.0 \times 10^{14} - 4.0 \times 10^{14}\right)}{1.60 \times 10^{-19}} = 2.1$ V
8	C	

No.	Answers	Further explanations
9	A	To convert joules to electron volts, divide by the electronic charge. $\frac{6.4\times10^{-20}\ \text{J}}{1.60\times10^{-19}\ \text{C}} = 0.40\ \text{eV}$
10	B	The threshold frequency for photoelectric emission from a metal is a property of the metal and has nothing to do with the incident radiation. $hf_o = W_o \quad f_o = \frac{W_o}{h} = \frac{4.0\times1.60\times10^{-19}}{6.63\times10^{-34}} = 9.65\times10^{14}\ \text{Hz}$ (Note: W_o converted from eV to J.)
11	C	$h\frac{c}{\lambda} = W_o + E_K \qquad E_K = h\frac{c}{\lambda} - W_o$ $E_K = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{300\times10^{-9}} - 2.0\times1.60\times10^{-19} = 3.43\times10^{-19}\ \text{J}$
12	A	
13	C	The work function of a metal is a property of the metal and not of the incident radiation.
14	C	**Option C:** Increasing the intensity of the incident radiation does not alter the energy of the individual photons. Since each electron emission can only be produced by a single photon, the kinetic energy and hence the speed of the emissions is therefore unaffected.
15	B	$hf = W_o + E_K \qquad hf = W_o + eV_s$ $W_o = hf - eV_s = (6.63\times10^{-34}\times8.0\times10^{14}) - (1.60\times10^{-19}\times1) = 3.7\times10^{-19}\ \text{J}$
16	C	Note: X has a higher frequency and higher energy, since it has a greater stopping potential. Photons of Y and Z have the same wavelength, frequency and energy, since they have the same stopping potential. The electrons produced by Y and Z are ejected with the same speed, since Y and Z have the same energy. Y produces a greater current because it consists of a greater number of photons per second.
17	A	$eV = h\frac{c}{\lambda} \qquad V = \frac{hc}{\lambda e} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{500\times10^{-9}\times1.60\times10^{-19}} = 2.49\ \text{V}$

No.	Answers	Further explanations
18	D	Power of 1 photon $= \frac{E_1}{t} = \frac{hc}{\lambda t}$ Power of N photons, $P = \frac{Nhc}{\lambda t}$ $\frac{N}{t} = \frac{P\lambda}{hc} = \frac{0.12 \times 600 \times 10^{-9}}{6.63 \times 10^{-34} \times 3.00 \times 10^{8}} = 3.6 \times 10^{17}\ \text{s}^{-1}$
19	B	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.00 \times 10^{8}} = 7.3 \times 10^{-12}\ \text{m}$
20	C	Decreasing the accelerating p.d., decreases the kinetic energy of the electrons and hence **increases** their *de Broglie wavelength*. Larger wavelength results in **greater** diffraction causing the rings to be **further apart**.
21	B	$hf = W_o + eV_s \qquad \therefore V_s = \frac{hf}{e} - \frac{W_o}{e}$ This is a straight line graph of gradient $\frac{h}{e}$ and intercept $\frac{-W_o}{e}$.
22	B	$\lambda = \frac{h}{mv} \qquad v = \frac{h}{m\lambda} \qquad \therefore v \propto \frac{1}{\lambda}$ since h and m are constant.
23	A	$I = I_o e^{-\mu x} \qquad \frac{1}{4} = 1e^{-0.15\mu} \qquad \ln 0.25 = -0.15\mu \qquad \mu = \frac{\ln 0.25}{-0.15} = 9.2\ \text{m}^{-1}$
24	D	$I = I_o e^{-\mu x} \qquad 100 = 400e^{-50x} \qquad \frac{1}{4} = e^{-50x}$ $\ln 0.25 = -50x \qquad x = \frac{\ln 0.25}{-50} = 0.028\ \text{m}$
25	C	$E = \frac{1}{2}mv^2 \qquad v = \sqrt{\frac{2E}{m}} \qquad \lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2E}{m}}} = \frac{h}{\sqrt{2Em}}$
26	D	$E = hf = 6.63 \times 10^{-34} \times 3.08 \times 10^{15} = 2.04 \times 10^{-18}\ \text{J}$ $= \frac{2.04 \times 10^{-18}}{1.60 \times 10^{-19}}\ \text{eV} = 12.8\ \text{eV}$ Energy released for transition from E_4 to $E_1 = -0.85\ \text{eV} - -13.6\ \text{eV} = 12.8\ \text{eV}$
27	C	$-1.5\ \text{eV} - -13.6\ \text{eV} = 12.1\ \text{eV}$ So the accelerating p.d. is 12.1 V.

No.	Answers	Further explanations
28	B	$13.6\times1.6\times10^{-19} = 2.2\times10^{-18}$ J
29	C	$E_3 - E_1 = \frac{hc}{\lambda}$ Therefore $h = (E_3 - E_1)\frac{\lambda}{c}$
30	D	$E = h\frac{c}{\lambda}$ $E \propto \frac{1}{\lambda}$ $E = hf$ Therefore $E \propto f$
31	B	λ_0 is the minimum wavelength causing X-ray production. This represents the photon of maximum energy which is produced when the total kinetic energy of a bombarding electron converts to electromagnetic energy.
32	A	Note: The minimum wavelength (maximum energy) of the X-ray photon occurs when the total electrical energy of an electron (eV) produces it. $eV = h\frac{c}{\lambda_0}$ $\lambda_0 = \frac{hc}{eV} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{1.60\times10^{-19}\times120\times10^{3}} = 1.0\times10^{-11}$ m
33	C	The kinetic energy is obtained from the electrical energy. $\frac{1}{2}mv^2 = eV$ $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.60\times10^{-19}\times120\times10^{3}}{9.11\times10^{-31}}} = 2.1\times10^{8}$ m s^{-1}
34	C	

2.3.2 Atomic Structure and Binding Energy

No.	Answers	Further explanations
1	D	
2	D	The atomic number Z (92) is the number of protons. The mass number A (235) is the number of nucleons. The number of neutrons N is 143 since $A = Z + N$. For a neutral atom, the number of protons is equal to the number of electrons and therefore the number of electrons is 92.
3	C	
4	B	$\frac{V}{d}q = mg$ $V = \frac{mgd}{q} = \frac{\left(\rho\frac{4}{3}\pi r^3\right)gd}{q}$

No.	Answers	Further explanations
5	C	$\frac{V}{d}q = mg \qquad V = \frac{mgd}{q}$ $\therefore V \propto \frac{1}{q}$ since mgd is constant. $\frac{V_2}{V} = \frac{q}{q_2} \quad \therefore V_2 = \frac{q}{4q}(V) = \frac{V}{4}$
6	B	$\frac{V}{d}q = mg \qquad V = \frac{mgd}{q}$ $\therefore V \propto \frac{m}{q}$ since gd is constant. $\frac{V_2}{V} = \frac{qm_2}{mq_2} = \frac{q(2m)}{m(2q)} = 1 \qquad \therefore V_2 = V$
7	C	
8	C	
9	A	Note that 2.5 is a common factor for each of the charges and that the smallest difference between the magnitudes of the charges is 2.5.
10	A	
11	B	Binding energy $E_b = 4 \times 7.05\text{ MeV} = 28.2\text{ MeV}$ $1\text{ u} \equiv 931\text{ MeV} \qquad \therefore E_b \equiv \frac{28.2\text{ MeV}}{931\text{ MeV u}^{-1}} = 0.0303\text{ u}$ $1\text{ u} = 1.66 \times 10^{-27}\text{ kg} \qquad \therefore E_b \equiv 0.0303\text{ u} \times 1.66 \times 10^{-27}\text{ kg u}^{-1} = 5.0 \times 10^{-29}\text{ kg}$
12	C	$E = mc^2 = (4.0319\text{ u} - 4.0015\text{ u})1.66 \times 10^{-27}\text{ kg u}^{-1}\left(3.00 \times 10^8\text{ m s}^{-1}\right)^2$ $= 4.54 \times 10^{-12}\text{ J}$
13	B	$1\text{ u} \equiv 931\text{ MeV} \qquad \therefore 6.41\text{ MeV} \equiv \frac{6.41\text{ MeV}}{931\text{ MeV u}^{-1}} = 6.89 \times 10^{-3}\text{ u}$
14	C	$1\text{ u} \equiv 1.66 \times 10^{-27}\left(3.00 \times 10^8\right)^2 = 1.49 \times 10^{-10}\text{ J}$
15	C	$\Delta m = 228.02873\text{ u} - 224.02020\text{ u} - 4.00260\text{ u} = 5.93 \times 10^{-3}\text{ u}$ $5.93 \times 10^{-3}\text{ u} \times 1.66 \times 10^{-27}\text{ kg u}^{-1} = 9.84 \times 10^{-30}\text{ kg}$

No.	Answers	Further explanations
16	B	
17	D	The values of w and x for the neutron should be known ($w = 1$ and $x = 0$). The values of y and z can then be found by balancing the superscripts and subscripts in the equation.

2.3.3 Radioactivity

No.	Answers	Further explanations
1	C	$1 \rightarrow \frac{1}{2} \rightarrow \frac{1}{4} \rightarrow \frac{1}{8}$ in 3 half-lives 24 days = $3t_{\frac{1}{2}}$ $t_{\frac{1}{2}} = \frac{24 \text{ days}}{3} = 8$ days
2	B	The decay constant λ is not affected by mass. $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{0.693}{5700 \text{ y}} = 1.2 \times 10^{-4} \text{ y}^{-1}$
3	D	$N = N_0 e^{-\lambda t}$ $0.75 \times 10^6 = (3.0 \times 10^6) e^{-(1.0 \times 10^{-2})t}$ $\ln \frac{0.75 \times 10^6}{3.0 \times 10^6} = -(1.0 \times 10^{-2}) t$ $t = \frac{\ln 0.25}{-1.0 \times 10^{-2}} = 140$ years
4	A	30 hours is 5 half lives. $100\% \rightarrow 50\% \rightarrow 25\% \rightarrow 12.5\% \rightarrow 6.25\% \rightarrow 3.125\%$
5	D	The background count rate must be subtracted from the detected count rate to obtain the count rate of the carbon. The masses of the live plant and of the old specimen used in the calculation must be the same. Count rate of 1.0 g of live plant = $(25 - 5)$ min^{-1} = **20 min^{-1}** Count rate of 10 g of specimen = $(17.5 - 5)$ min^{-1} $\therefore$ Count rate of 1 g of specimen = $\frac{(17.5 - 5) \text{ min}^{-1}}{10}$ = **1.25 min^{-1}** **20 min^{-1}** $\rightarrow$ 10 min^{-1} $\rightarrow$ 5 min^{-1} $\rightarrow$ 2.5 min^{-1} $\rightarrow$ **1.25 min^{-1}** $\therefore$ 4 half-lives $\therefore$ $4 \times 5700 = 22\,800$ years (23 000 years to 2 sif. fig.)
6	B	${}^{216}_{84}\text{Po} \rightarrow 2\left({}^{4}_{2}\alpha\right) + 2\left({}^{0}_{-1}\beta\right) + {}^{208}_{82}\text{Pb}$

No.	Answers	Further explanations
7	B	$Th \rightarrow 2\left({}^{4}_{2}\alpha\right) + 2\left({}^{0}_{-1}\beta\right) + {}^{224}_{88}Ra$ Working backwards in the equation yields ${}^{232}_{90}Th$ $\therefore$ 90 protons.
8	A	Since only α affects the nucleon number, work first with α and then adjust with β for the lower subscript. ${}^{220}_{86}Rn \rightarrow {}^{12}_{4}X + {}^{208}_{82}Pb$ $3\left({}^{4}_{2}\alpha\right) + 2\left({}^{0}_{-1}\beta\right) = {}^{12}_{4}X$
9	B	
10	C	**Source:** Gamma rays are absorbed less by body tissue than are alpha or beta emissions. **Half life:** The half life of 6 hours is not too short or too long. It gives the source enough time to reach the target site through the blood stream and is diminished to about 3% of its strength in just 24 hours thereby reducing the risk of contamination.
11	B	$C_D - C_B = \frac{k}{x^2}$ $\therefore C_D = k\frac{1}{x^2} + C_B$ This is a straight-line graph of gradient k and y-intercept C_B. (C_B = background count rate)
12	D	
13	C	Use Fleming's left-hand rule. Note that β deflects more than α due to its much smaller mass. Also note that the direction of beta flow is opposite to the flow of conventional current.
14	D	Bromine is added to REDUCE the discharge period.

List of Physical Constants Used in this Book

Physical constant		Value
Universal gravitational constant	G	6.67×10^{-11} N m^2 kg^{-2}
Acceleration due to gravity (at the surface of the Earth)	g	9.81 m s^{-2}
Radius of the Earth	R_E	6380 km
Mass of the Earth	M_E	5.98×10^{24} kg
Mass of the Moon	M_M	7.35×10^{22} kg
Pressure of 1 atmosphere		1.00×10^{5} N m^{-2}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
Coulomb constant	$\frac{1}{4\pi\varepsilon_0}$	9.00×10^{9} N m^2 C^{-2}
Mass of electron	m_e	9.11×10^{-31} kg
Charge of electron	e	1.60×10^{-19} C
Density of water	ρ_W	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	c_W	4200 J kg^{-1} K^{-1}
Specific latent heat of fusion of ice	l_f	3.34×10^{5} J kg^{-1}
Specific latent heat of vaporisation of water	l_v	2.26×10^{6} J kg^{-1}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
Speed of light in free space	c	3.00×10^{8} m s^{-1}
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Permittivity of free space	ε_0	8.85×10^{-12} F m^{-1}
Planck constant	h	6.63×10^{-34} J s
Unified atomic mass unit	u	1.66×10^{-27} kg (931 MeV)
Molar gas constant	R	8.31 J K^{-1} mol^{-1}
Stefan–Boltzmann constant	σ	5.67×10^{-8} W m^{-2} K^{-4}