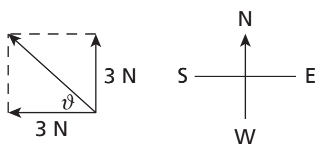
Section A: Mechanics

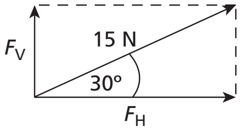
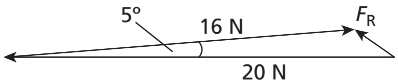
A1 Scientific method and measurement

No.	Answers	Further explanations
1	A	
2	C	$T = \frac{40}{20} = 2.0\ \text{s}$ $\quad f = \frac{1}{T} = \frac{1}{2.0} = 0.50\ \text{Hz}$
3	B	Time for ¾ of an oscillation is 0.15 s. $\therefore \frac{3}{4}T = 0.15\ \text{s}$ $\quad T = \frac{4 \times 0.15\ \text{s}}{3} = 0.20\ \text{s}$ $\quad f = \frac{1}{T} = \frac{1}{0.20\ \text{s}} = 5.0\ \text{Hz}$ or s^{-1}
4	A	
5	B	
6	D	$\text{Slope} = \frac{(12.0 - 4.0)\ \text{A}^{-1}}{(4.0 - 0)\ \text{cm}} = 2.0\ \text{A}^{-1}\text{cm}^{-1}$
7	A	The markings on the scale are separated by intervals of 1 mm. Since this is 0.001 m, the readings should be presented to 3 decimal places of a metre.
8	B	The answer should be represented to 2 significant figures, since the least number of significant figures of the items in the calculation is 2.
9	C	Since the third figure is less than 5, the second figure is not changed. If the third figure were equal to or greater than 5, the second figure would be incremented by 1.
10	C	Area = 200 cm × 80 cm = 2.00 m × 0.80 m = 1.6 m^2
11	C	The number is represented as a power of ten: $M \times 10^p$. The 'mantissa' M is a number in decimal form with only one non-zero digit before the decimal point and p is an integer. The value of p is obtained by the number of decimal places moved in representing the mantissa. A negative value of p indicates that the number being expressed is less than 1.

No.	Answers	Further explanations
12	A	
13	D	
14	C	
15	C	The reading on the main scale at the mark just before the zero mark on the smaller vernier scale is 0.5 cm. The number of the mark on the vernier scale that best aligns with a mark above it on the main scale gives a measure of the hundredths of a cm, which must be added to the reading from the main scale. The number of this mark is 3 and represents $\frac{3}{100}$ cm. Main scale 0.5 cm Vernier scale 0.03 cm Diameter of S 0.53 cm
16	D	The reading on the sleeve at the mark just before the thimble is 6.0 mm. The number of the mark on the thimble that aligns with the centre line on the sleeve gives the reading of the hundredths of a mm, which must be added to the reading from the sleeve. The number of this mark is 12 and represents $\frac{12}{100}$ mm. Sleeve 6.0 mm Thimble 0.12 mm Diameter of R 6.12 mm
17	B	
18	C	An object floats in a fluid if its density (**NOT** its mass or weight) is less than that of the fluid.
19	A	$\rho = \frac{m}{V} = \frac{(200 - 140)\ \text{g}}{(50 - 20)\ \text{cm}^3} = 2.0\ \text{g cm}^{-3}$

A2 Physical quantities, SI units and vectors

No.	Answers	Further explanations
1	C	
2	C	The seven fundamental quantities are: mass, length, time, current, temperature, luminous intensity and quantity of substance.
3	C	Energy is derived from the quantities force and displacement.
4	B	
5	B	Quantities: $F = ma$ Units: $\text{N} = \text{kg ms}^{-2}$
6	C	$\text{Frequency} = \frac{1}{\text{period}} \therefore \text{Unit of frequency} = \frac{1}{\text{s}}$ $\text{Resistance} = \frac{\text{voltage}}{\text{current}} \therefore \text{Unit of resistance} = \frac{\text{V}}{\text{A}}$ $\text{Power} = \frac{\text{energy}}{\text{time}} \therefore \text{Unit of power} = \frac{\text{J}}{\text{s}}$ $\text{Pressure} = \frac{\text{force}}{\text{area}} \therefore \text{Unit of pressure} = \frac{\text{N}}{\text{m}^2}$
7	C	Energy per second = power. The unit of power is the watt (W).
8	A	
9	D	Displacement can be defined as distance **IN A SPECIFIED DIRECTION** from some reference point. Since it has magnitude and direction, it is a vector.
10	B	
11	C	Resultant force directed north = 4 N − 1 N = 3 N Resultant force directed west = 5 N + 1 N − 3 N = 3 N  $\theta = \tan^{-1}\left(\frac{3}{3}\right) = 45°$ The resultant force, and therefore the resultant acceleration, is directed towards the north-west.

No.	Answers	Further explanations
12	C	 Vertically: $F_V = 15\text{ N} \sin 30° = 7.5\text{ N}$ Horizontally: $F_H = 15\text{ N} \cos 30° = 13\text{ N}$
13	B	Magnitude of the resultant force $F_R = \sqrt{16^2 + 12^2}\text{ N} = 20\text{ N}$
14	B	Using the polygon method for adding vectors, the vectors to be added are represented in magnitude and direction by arrows drawn head to tail forming a chain. The resultant vector is then represented in magnitude and direction by the arrow, originating from the beginning of the chain, which closes the polygon.
15	D	The following diagram illustrates the *polygon method* for finding the resultant of two vectors.  Magnitude of resultant force $F_R = \sqrt{16^2 + 20^2 - 2 \times 16 \times 20 \cos 5°} = 4.3\text{ N}$
16	B	Important vectors required by the CSEC® syllabus are: displacement, velocity, acceleration, force and momentum.

A3 Statics

No.	Answers	Further explanations
1	B	Similar electric charge will produce repulsion. Option A: Copper is not a magnetic substance. Option B: Two similarly charged spheres would repel each other. Option C: Gravitational forces would produce **ATTRACTION**, not repulsion. Option D: Nuclear forces would only come into effect at much smaller distances between the nucleons of the two spheres.

No.	Answers	Further explanations
2	C	Option I: Not true. The density of a body is the ratio of its mass to its volume, neither of which depends on the acceleration due to gravity. Option II: True. The force exerted on the spring of a spring balance depends on the force of gravity on the mass causing it. If the acceleration due to gravity is lower, the reading produced by the associated force will also be lower. The lever arm balance also depends on the acceleration due to gravity since forces are necessary to produce the required moments. However, the effect on the clockwise moment is the same as on the anticlockwise moment and therefore the net effect is zero. Option III: True. Since the density of the object is given relative to water, a value of 1 unit is assigned to the density of water. The object is less dense than water since 0.9 is less than 1 and therefore the body floats in water.
3	B	The terms *acceleration due to gravity* and *gravitational field strength* are equivalent. At the surface of the Earth the acceleration due to gravity is $10\ \text{m s}^{-2}$ and the gravitational field strength is $10\ \text{N kg}^{-1}$.
4	C	The weight of a body is the product of its mass and the gravitational field strength at its location. The weight of a body is therefore greater on Jupiter. The mass of a body is the quantity of matter from which it is made and therefore does not change when the body is transferred between the planets.
5	B	The effort required to overcome the load occurs when the clockwise and anticlockwise moments are equal. Since each required moment is the product of the force and the perpendicular distance of its line of action from the pivot, the larger this distance, the smaller is the necessary force. Diagram B is the only one in which the line of action of the effort has a shorter distance to the pivot than does the line of action of the load, and therefore is the only one in which the effort is greater than the load.
6	C	
7	D	

No.	Answers	Further explanations
8	B	The body is in equilibrium and therefore the sum of the clockwise moments about any point is equal to the sum of the anticlockwise moments about that same point. Weight of hanging block $= 0.150\ \text{kg} \times 10\ \text{m s}^{-2} = 1.5\ \text{N}$ Taking moments about the point of support of the rod: $1.5\ \text{N} \times 20\ \text{cm} = W \times 30\ \text{cm}$ $\quad W = \frac{1.5\ \text{N} \times 20\ \text{cm}}{30\ \text{cm}} = 1.0\ \text{N}$ Note that since the rod is uniform its centre of gravity is at its geometric centre, which is 30 cm from the point of support.
9	C	Option I: True. The body is in equilibrium and therefore the sum of the upward forces must be equal to the sum of the downward forces: $R + T = W$. So $W - T = R$. Option III: True. The distances from the centre of the rod to the forces T and R are the same. These forces must therefore also be the same in order to provide the equal but oppositely directed moments about the centre of the rod required for equilibrium. Therefore $R = T$. Option II: Not true. Since $R = T$ and $R + T = W$, therefore $W > T$.
10	A	Option I: True. The body is in equilibrium and therefore the sum of the upward forces must be equal to the sum of the downward forces: $R = P + Q$. Therefore $R - P = Q$. Option II: Not true. Rx and Qy are moments taken about different points and therefore are not necessarily equal. Option III: Not true. Px and Qz are moments taken about different points and therefore are not necessarily equal.
11	C	When a body in **stable equilibrium** is slightly displaced, its centre of gravity rises and a moment is created which restores it to its base. When a body in **unstable equilibrium** is slightly displaced, its centre of gravity falls and a moment is created which topples it. When a body in **neutral equilibrium** is slightly displaced, its centre of gravity remains at the same level and no moment is created.

No.	Answers	Further explanations
12	C	Option I: True. The force constant is the gradient of the straight-line section of the graph. $k = \frac{F}{e} = \frac{90\ \text{N}}{15\ \text{cm}} = 6.0\ \text{N cm}^{-1}$ Option II: Not true. For Hooke's law to be conformed to, the load must be proportional to the extension, and therefore the graph must be a straight line. The curve in the graph indicates that the law was not always obeyed. Option III: True. The *x*-coordinate of 10 cm corresponds to the *y*-coordinate of 60 N. Option IV: Not true. The proportional limit has been surpassed where the graph ceases to be a straight line.
13	D	Stability is increased by lowering the height of the centre of gravity and/or by increasing the width of the base of the object. Option D is the only one in which both of these changes are made and is therefore the only option which **DEFINITELY** increases the stability of the object.
14	B	When the load was increased by 40 N the length of the spring stretched from 15 cm to 25 cm. The extension corresponding to this increase in load is therefore 10 cm. $k = \frac{F}{e} = \frac{40\ \text{N}}{10\ \text{cm}} = 4.0\ \text{N cm}^{-1}$
15	B	Since the force constant of the spring is 4.0 N cm^{-1}, the first 20 N stretched it by 5.0 cm. $F = ke \quad \therefore e = \frac{F}{k} = \frac{20\ \text{N}}{4.0\ \text{N cm}^{-1}} = 5.0\ \text{cm}$ The length when the load is completely removed is therefore 15 cm – 5.0 cm = 10 cm.

A4 Kinematics

No.	Answers	Further explanations
1	C	$a = \frac{v_2 - v_1}{t} = \frac{(19.0 - 4.0)\ \text{m s}^{-1}}{(5.0)\ \text{s}} = 3.0\ \ \text{m s}^{-2}$
2	A	This problem involves velocities in two opposite directions. Taking the direction of v_2 as positive and the direction of v_1 as negative: $a = \frac{v_2 - v_1}{t} = \frac{(24 - -24)\ \text{m s}^{-1}}{0.12\ \text{s}} = 400\ \text{m s}^{-2}$
3	A	$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{36\ \text{km}}{2.0\ \text{h}} = \frac{36\ 000\ \text{m}}{2.0 \times 3600\ \text{s}} = 5.0\ \text{m s}^{-1}$
4	C	$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{(8.0 + 8.0)\ \text{m}}{(2.0 + 12.0 + 6.0)\ \text{s}} = \frac{16\ \text{m}}{20\ \text{s}} = 0.80\ \text{m s}^{-1}$
5	D	$\text{average velocity} = \frac{\text{displacement}}{\text{time}} = \frac{(8.0 - 8.0)\ \text{m}}{(2.0 + 12.0 + 6.0)\ \text{s}} = \frac{0\ \text{m}}{20\ \text{s}} = 0\ \text{m s}^{-1}$
6	A	$v = \frac{\Delta s}{\Delta t} = \frac{(120 - 30)\ \text{m}}{(3.0 - 0)\ \text{s}} = 30\ \text{m s}^{-1}$
7	D	Velocity is represented by the gradient of the displacement–time graph.
8	C	Taking upwards as positive displacement, an object shot into the air starts with an initial positive velocity. This will uniformly decrease with time due to the opposing gravitational force. At the highest point the velocity will have decreased to zero. It will then increase uniformly but in the opposite direction (downwards, i.e. negative) until it returns to its starting point. Since the acceleration due to gravity is always constant and directed downwards, the gradient of the graph is always constant and negative.
9	D	Distance D travelled is represented by the area between the graph line and the time axis. $D = \frac{20\ \text{m s}^{-1} \times\ 4\ \text{s}}{2} = 40\ \text{m}$
10	B	The object changes direction when its velocity switches from positive to negative at $t = 4$ s.
11	A	Acceleration is obtained from the gradient of the velocity–time graph. $a = \frac{\Delta v}{\Delta t} = \frac{(48 - 24)\ \text{m s}^{-1}}{(20.0 - 12.0)\ \text{s}} = 3.0\ \text{m s}^{-2}$

No.	Answers	Further explanations
12	C	Distance D travelled is represented by the area between the graph line and the time axis. $D = \left(\dfrac{24\ \text{m s}^{-1} \times 8.0\ \text{s}}{2}\right) + \left(24\ \text{m s}^{-1} \times 8.0\ \text{s}\right) = 290\ \text{m} \quad (2\ \text{s.f.})$
13	D	The only force on the object is the constant force of gravity. Since the resultant force is the product of the object's mass and acceleration, the acceleration is therefore always constant.
14	B	As the object falls its acceleration is the constant acceleration due to gravity. This is represented by the constant gradient of the velocity–time graph Q.
15	C	As the object falls its velocity increases. This is represented by the increasing gradient of the displacement–time graph R.
16	B	Since the gradient of the displacement–time graph is initially zero and then constant, the velocity of the object is initially zero and then constant.

A5 Dynamics

No.	Answers	Further explanations
1	C	Aristotle believed that the force on a body was proportional to its velocity. He argued that the more horses pulling a carriage, the faster it will go. He failed to consider all the forces acting on the body and did not consider, for example, friction. Newton later showed that the resultant force on a body is **PROPORTIONAL TO ITS ACCELERATION** ($F_R = ma$) and not to its velocity.
2	D	The resultant force on a body must be zero if it is not accelerating. $F_R = ma$ (i.e. if it is at rest or is moving at constant velocity).
3	A	$F_R = ma \quad \therefore a = \dfrac{F_R}{m} = \dfrac{(40 - 8)\ \text{N}}{0.500\ \text{kg}} = 64\ \text{m s}^{-2}$
4	C	X: Law 3. If body A exerts a force on body B, then body B exerts an equal but oppositely directed force on body A. Y: Law 2. The resultant force on a body causes it to accelerate. Z: Law 1. Every body continues in its state of rest or uniform motion in a straight line unless compelled to act otherwise by a resultant force.

No.	Answers	Further explanations
5	A	Taking velocity to the right as positive: $F_R = \frac{m(v_2 - v_1)}{t}$ $\therefore$ Time of impact $t = \frac{m(v_2 - v_1)}{F_R} = \frac{0.400\ \text{kg}(10 - -20)\ \text{m s}^{-1}}{600\ \text{N}} = 0.020\ \text{s}$
6	C	Option I: True. A has a greater resistive force on it, due mainly to greater air resistance at its greater velocity. Options II, III: The resultant force on both cars is zero since they both travel at constant velocity.
7	D	Option I: True. Note that a closed system is one in which external forces can have no effect. Option II: Not true. It is the **TOTAL** momentum immediately before a collision which is equal to the **TOTAL** momentum immediately after the collision. Option III: True. Since momentum is a vector quantity, two bodies having momentum equal in magnitude but opposite in direction will have a total momentum that cancels to zero.
8	C	Only one of the masses is moving before the collision and only one is moving after the collision. The total momentum immediately before the collision must be equal to the total momentum immediately after the collision. Since the masses are the same, the velocities of the moving masses must therefore also be the same.
9	A	Taking velocity to the right as positive: Initial momentum $= (2.0\ \text{kg} \times 5.0\ \text{m s}^{-1}) + (3.0\ \text{kg} \times -10\ \text{m s}^{-1})$ $= -20\ \text{kg m s}^{-1}$ The negative sign indicates that the momentum is directed to the left.
10	C	Taking the initial velocity of the mass *m* as positive: Total momentum before the collision $= (m \times v) + \left(\frac{m}{2} \times -2v\right) = 0$ By the law of conservation of linear momentum, the total momentum after the collision is therefore also zero.

A6 Energy

No.	Answers	Further explanations
1	B	Chemical potential energy stored in the diesel releases thermal energy as it is burnt. The thermal energy is used to boil water and produce steam which then creates a pressure to turn a turbine, giving it kinetic energy. This produces a relative motion between a coil and magnetic field in a generator, which causes a transfer of kinetic energy to electrical energy.
2	D	Gravitational potential energy of the water transfers to kinetic energy as it falls and turns a turbine. The kinetic energy of the turbine produces a relative motion between the coil and magnetic field in a generator, which causes a transfer of kinetic energy to electrical energy.
3	B	Crude oil is a non-renewable source of energy because it cannot be readily replaced.
4	C	$W = Fs = 800\ \text{N} \times 5.0\ \text{m} = 4000\ \text{J}$
5	C	Since the acceleration is zero, the resultant force is zero and the 800 N applied by Kimran is used only to overcome friction. The 4000 J of work done by Kimran is all used to overcome friction.
6	A	$P = \frac{W}{t} = \frac{4000\ \text{J}}{20\ \text{s}} = 200\ \text{W}$
7	C	A stretched elastic band stores elastic potential energy. Bread stores chemical potential energy. A mango hanging from a tree stores gravitational potential energy.
8	D	As the coconut falls its gravitational potential energy converts to kinetic energy. $\Delta E_{\text{p}} = mg\Delta h = 32\ \text{N} \times 20\ \text{m} = 640\ \text{J}$
9	A	$E_{\text{KA}} = \frac{1}{2}mv^2 \qquad E_{\text{KB}} = \frac{1}{2}m(2v)^2 = 4 \times \frac{1}{2}mv^2$ $\therefore E_{\text{KB}} = 4 \times 200\ \text{J} = 800\ \text{J}$
10	B	$mgh = \frac{1}{2}mv^2 \qquad gh = \frac{1}{2}v^2$ $h = \frac{v^2}{2g} = \frac{(20\ \text{m s}^{-1})^2}{2 \times 10\ \text{m s}^{-2}} = 20\ \text{m}$

No.	Answers	Further explanations
11	A	$\text{efficiency} = \frac{\text{useful work output}}{\text{work input}} = \frac{1200\ \text{N} \times 5.0\ \text{m}}{8000\ \text{J}} = 0.75 \text{ or } 75\%$
12	A	$\frac{1}{2}mv^2 = mgh \quad \frac{1}{2}v^2 = gh$ $v = \sqrt{2gh} = \sqrt{2 \times 10\ \text{m s}^{-2} \times 4.0\ \text{m}} = 8.9\ \text{m s}^{-1}$
13	B	$\Delta E_P = mg\Delta h \qquad \Delta E_P = 2.0\ \text{kg} \times 10\ \text{m s}^{-2} \times 4.0\ \text{m} = 80\ \text{J}$
14	C	

A7 Hydrostatics

No.	Answers	Further explanations
1	A	$P = \frac{F}{A}$ To create maximum pressure the block must rest on the smallest area. $P = \frac{1200\ \text{N}}{(0.60 \times 0.20)\,\text{m}^2} = 10\ 000\ \text{Pa}$
2	B	$P = P_{\text{Atm}} + P_W = P_{\text{Atm}} + (h\rho g)_W$ $P = 1.0 \times 10^5\,\text{Pa} + (20\ \text{m} \times 1000\ \text{kg m}^{-3} \times 10\ \text{m s}^{-2}) = 3.0 \times 10^5\ \text{Pa}$
3	C	$P = \frac{F}{A}$ Therefore by increasing the area of contact the pressure is reduced.
4	D	$P = h\rho g$ where h is the depth of water and ρ is its density.
5	C	The **PRESSURE** produced by the force at X is transmitted to Y. For the pressure to be the same, the force at Y must be greater than that at X since Y has a greater area. $P_X = P_Y \quad \therefore \frac{f_X}{a_X} = \frac{F_Y}{A_Y}$

No.	Answers	Further explanations
6	C	P_X is zero since above X is a vacuum. P_Y = 15 cm Hg since 15 cm of mercury is above it, causing the pressure at Y. P_Z = 75 cm Hg since 75 cm of mercury is above it, causing the pressure at Z.
7	A	$P = P_{Atm} + P_L = P_{Atm} + (h\rho g)_L$ $P = 1.0 \times 10^5 \text{ Pa} + (0.20 \text{ m} \times 5.0 \times 10^3 \text{ kg m}^{-3} \times 10 \text{ m s}^{-2}) = 1.1 \times 10^5 \text{ Pa}$
8	B	In accordance with the principle of Archimedes, an upthrust will act on the small mass, equal to the weight of the water it displaces.
9	D	Upthrust is always equal to the weight of the fluid displaced; if the body floats, then it is also equal to the weight of the body itself. If the acceleration of a body is zero, then the resultant force on the body is also zero (Since $F_R = ma$).
10	C	Since the body accelerates upwards, the resultant force must be directed upwards and therefore the upthrust (= weight of air displaced) must be greater than the weight of the balloon and its contents.
11	A	The object floats and therefore: Weight of object = weight of liquid displaced ∴ mass of object = mass of liquid displaced $200 \text{ g} = \rho_L V_L$ (since mass = density × volume) $200 \text{ g} = 1.60 \text{ g cm}^{-3} \times V_L$ $V_L = \dfrac{200 \text{ g}}{1.60 \text{ g cm}^{-3}} = 125 \text{ cm}^3$

Section B: Thermal Physics and Kinetic Theory

B1 Nature of heat, macroscopic properties and phenomena

No.	Answers	Further explanations
1	A	The caloric theory was **REPLACED BY** the kinetic theory. Count Rumford's 'cannon boring' experiment provided evidence **AGAINST** the caloric theory.
2	B	

No.	Answers	Further explanations
3	B	Option B: The body temperature of a human is about 37 °C and fluctuates just a few degrees below and above this. A suitable range of the thermometer is therefore from about 34 °C to 43 °C. Option A, C & D: When a liquid-in-glass mercury thermometer is removed from a patient, the mercury in its stem rapidly contracts. Since mercury has very strong cohesive forces between its particles, it snaps at the narrow constriction in its bore, leaving the section of mercury above the constriction to be read. Alcohol is not capable of snapping at the constriction and would all return to the bulb on removal from the patient.
4	B	Option II: Not true. A small red hot steel pin is at a higher temperature than a bucket of warm water but contains less thermal energy since it has a much lower heat capacity. Option I: True. Although the small pin has less thermal energy than the bucket of warm water, heat will flow from the pin to the water since the pin is at a higher temperature than the water. Option III: True. Heat is thermal energy which flows from places of higher temperature to places of lower temperature.
5	B	
6	D	The body temperature of a healthy human is about 37 °C and only fluctuates by a few degrees.
7	C	Option I: True. Thinner walls provide less material for the thermal energy to conduct through and therefore the transfer process is quicker. Option II: Not true. Mercury is a metal and is a much better conductor than is alcohol. It therefore responds faster to temperature change than alcohol. Option III: True. A larger bulb and longer stem implies that a greater volume of liquid can be contained and a correspondingly greater change in volume of liquid will be obtained on heating. The readings on the scale will therefore be further separated and can be read with greater precision. Option IV: True. A thinner bore results in a longer stem for a given volume and therefore the readings will be further separated and can be read with greater precision.

No.	Answers	Further explanations
8	C	Option I: True. Mercury freezes at –39 °C and boils at 357 °C. Since it must function as a liquid in the thermometer, it therefore has a limited range. The thermoelectric thermometer utilises metals which have high melting points and can therefore be used to measure very low and very high temperatures. Option II: Not true. Thermoelectric thermometers respond rapidly due to the high conductivity of the metals from which they are made. Liquid-in-glass thermometers respond slowly since glass is a poor conductor. Option III: True.
9	D	
10	A	Option III: Untrue. Liquids flow because the forces between their particles are weak and do not produce rigid bonds that can restrict motion.
11	C	Option I: Untrue. Brownian motion is **NOT** the motion of the atoms or molecules of a liquid or gas. Option III: True. It is the motion of small particles suspended in the liquid or gas and is due to their bombardment by the atoms or molecules of the liquid or gas. Option II: True. It increases with temperature since the greater kinetic energy of the molecules of the liquid or gas will result in greater forces of collision on bombardment with the suspended particles and therefore more kinetic energy will be transferred to them.
12	A	
13	B	A temperature of θ°C is related to a temperature of T K by $T = 273 + \theta$
14	A	Pressure law: $p \propto T$ (volume is constant and T is thermodynamic or kelvin temperature) $\therefore p = k_1T$ The p–T graph is a straight line through the origin with slope k_1.

No.	Answers	Further explanations
15	D	Charles' law: $V \propto T$ (pressure is constant and T is thermodynamic or kelvin temperature) $\therefore V = k_2 T$ Since 0 K = –273 °C, the line will intercept the θ axis at –273 °C. This produces a positive intercept on the *V*-axis.
16	B	Boyle's law: $p \propto \left(\frac{1}{V}\right)$ (temperature is constant)
17	C	$\frac{p_b V_b}{T_b} = \frac{p_t V_t}{T_t}$ where 'b' denotes 'bottom' and 't' denotes 'top'. T is constant so $p_b V_b = p_t V_t \qquad pV_b = p_t(4V_b) \qquad p_t = \frac{p}{4}$
18	B	Since the gas is freely expandable its pressure is the constant pressure of the surrounding atmosphere. $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$ p is constant so $\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \frac{V}{(127 + 273)\text{ K}} = \frac{2V}{T_2} \qquad \frac{1}{400\text{ K}} = \frac{2}{T_2}$ $T_2 = 2 \times 400\text{ K} = 800\text{ K}$ $800\text{ K} = (800 - 273)°\text{C} = 527°\text{C}$
19	B	Option II: Untrue. The volume of a gas is directly proportional to its kelvin (thermodynamic) temperature, **NOT** to its Celsius temperature.
20	C	

No.	Answers	Further explanations
21	B	Option A: Not true. The temperature of the gas does not rise because the process is performed slowly and the vessel is a good conductor. Any tendency for the temperature to change is prevented by conduction through the walls of the vessel. Option C: Not true. The speed of the molecules does not change because the temperature does not change. Option D: Not true. The volume does not change because the vessel is strong and rigid. Option B: True. Since the number of molecules in the vessel is increasing, the number of them striking the walls during any given period must also increase.
22	D	Pressure law: The pressure of a **FIXED MASS** of gas at **CONSTANT VOLUME** is directly proportional to its thermodynamic temperature.
23	A	Option A: True. The volume of the gas visibly increases. The bead of alcohol was steady before heating and after heating. Since the pressure above the bead of alcohol is the constant atmospheric pressure, the pressure of the trapped gas below the bead must also be constant for the bead to remain at rest. Options B, C: Not true. The pressure is constant. Option D: Not true. Air was not added during the process and therefore the mass of air cannot increase.

B2 Thermal measurements

No.	Answers	Further explanations
1	C	See answer 2 below
2	C	The heat capacity C of a body is the heat needed to raise the temperature of the body (**NOT** 1 kg of it) by 1 K. Heat capacity $C = mc = \frac{E_H}{\Delta T}$ $\therefore$ SI unit of heat capacity is $\frac{J}{K}$

No.	Answers	Further explanations
3	A	$\Delta T_A = \frac{E_H}{m \times c}$ $\Delta T_B = \frac{E_H}{m \times 2c}$ $\Delta T_C = \frac{E_H}{2m \times c}$ $\Delta T_D = \frac{E_H}{2m \times 2c}$ The greatest temperature rise occurs in option A since it has the smallest denominator.
4	C	$E_H = mc\Delta T$ $\therefore$ SI unit of specific heat capacity c is $\frac{\text{J}}{\text{kg K}}$
5	B	$P = \frac{mc\Delta T}{t}$ $c = \frac{Pt}{m\Delta T}$ $c = \frac{500\ \text{W} \times (4.0 \times 60\ \text{s})}{2.0\ \text{kg} \times 20\ \text{K}} = 3000\ \text{J kg}^{-1}\text{K}^{-1}$
6	A	
7	A	$E_H = ml$ $l = \frac{E_H}{m}$ $\therefore$ SI unit of l is $\frac{\text{J}}{\text{kg}}$
8	C	Option I: Not true. The specific latent heat of fusion of a substance is the heat needed to change **UNIT MASS** of the substance from solid to liquid without a change of temperature. Option II: Not true. The latent heat of vaporisation of a body is the heat needed to change the body (**NOT** unit mass of it) from liquid to gas without a change of temperature. Option III: True. When latent heat is released from the molecules of a gas, the molecules lose potential energy and can no longer overcome the attractive forces of surrounding molecules. This causes them to pack closer together and to exist in the liquid state. Similarly when latent heat is released by the molecules of a liquid, those molecules lose potential energy and can no longer overcome the strong attractive forces of the neighbouring molecules. This results in the formation of the rigid bonds of a solid.
9	A	The horizontal lines of the graph indicate the temperatures at which the body changes state. The body is therefore in the gaseous state above the higher horizontal line and in the liquid state directly below this line.
10	B	The higher horizontal line of the graph indicates that the boiling point is 70 °C (and the lower horizontal line indicates that the melting point is 30 °C).

No.	Answers	Further explanations
11	B	The kinetic energy of the particles of a substance is a measure of its temperature. In stage X the temperature is constant and therefore the kinetic energy of the particles of the substance must also be constant.
12	B	$P = \frac{ml}{t} \quad \therefore l = \frac{Pt}{m}$
13	C	$E_H = (1.0\ \text{kg} \times 4200\ \text{J kg}^{-1}\text{K}^{-1} \times 90\ \text{K}) + (1.0\ \text{kg} \times 2.3 \times 10^6\ \text{J kg}^{-1})$ $= 2.7 \times 10^6\ \text{J}$
14	B	Increased surface area provides a larger region for the molecules to escape to the air. At a higher temperature the molecules have more kinetic energy and can more readily escape the attractive forces of the neighbouring molecules. Wind removes the evaporated molecules, preventing them from bouncing back to the liquid. Increased humidity will increase the chances of evaporated molecules colliding with molecules above the liquid and thereby bouncing back into the liquid. It therefore reduces the rate of evaporation.
15	C	Option III: Not true. An external heat source is necessary for boiling but not for evaporation.
16	B	Option III: Untrue. The refrigerant in a freezing compartment of a fridge **EVAPORATES** and thereby cools the food within it as it absorbs latent heat of vaporisation.

B3 Transfer of thermal energy

No.	Answers	Further explanations
1	C	Options A, B and D describe heating due to radiation, convection and radiation respectively. Conduction is the transfer of thermal energy from particle to particle. It occurs mainly in solids and to a greater extent in metals than in non-metals. The hot electric iron and the shirt are both solids in contact with each other and therefore energy is transferred between them mainly by conduction.
2	C	The hot water is less dense than the cooler water below it and therefore convection currents will not flow downwards to melt the ice. The ice can only receive heat from the hot water by conduction. Since the water boils at the top before the ice melts, water must be a poor thermal conductor.

No.	Answers	Further explanations
3	A	The convection current rises only directly above the heating source because this region of the liquid is hottest and least dense.
4	C	Option I: Not true. Metals are better conductors than non-metals because they contain **FREE** electrons.
5	B	Option III: Not true. Hot bodies emit radiation of **SHORTER** wavelengths than do cooler bodies.
6	D	**Conduction** and **convection** cannot occur through the vacuum. The silvered inner-facing walls of the vacuum reduce the **radiation** transferring since silvered surfaces are poor absorbers and emitters of radiation. The poor conducting cover and case reduce the **conduction**.
7	B	The black cans will absorb the thermal radiation more readily than the silver cans. Both of the black cans have the same surface area to absorb the radiation, but since can B contains less water to be heated, its temperature rises faster.
8	D	Black surfaces are better absorbers *and* emitters than white surfaces at the same temperature. Option I: True. In the freezer you are a net **EMITTER** of thermal radiation since you are warmer than the surroundings. White is a poor emitter and therefore you would not easily lose heat. Option II: True. The fridge is a net **ABSORBER** of thermal radiation since its contents are cooler than the surroundings. A white fridge is a poor absorber and therefore its contents will be kept cooler. Option III: True. The oven is a net **EMITTER** of radiation since its contents are warmer than the surroundings. If its outer walls are white it would be a poor emitter and therefore retain its heat better.
9	B	Option A: True. Black surfaces are better absorbers than white surfaces at the same temperature. Option B: Not true. Shiny light surfaces are poorer emitters than black surfaces at the same temperature. Option C: True. Radiation is the only process of thermal transfer which can propagate through a vacuum. Option D: True. Rough surfaces are better absorbers and emitters than smooth surfaces at the same temperature.
10	C	

No.	Answers	Further explanations
11	C	Option III: Not true. By keeping the walls and roof sealed, convection of the hot air to the surroundings is prevented, allowing the greenhouse to **MAINTAIN ITS WARMTH**.
12	B	
13	C	Option C: Not true. The heater panel is placed **BELOW** the storage tank to allow the flow of water by a natural convection current to the tank above it.

Section C: Waves and Optics

C1 Wave motion

No.	Answers	Further explanations
1	D	The increased speed of the motor causes the frequency f of the vibration to increase. The speed v of the water wave is constant because it depends on the depth of the water. Since $v = \lambda f$ the wavelength λ must therefore decrease.
2	C	Only **ELECTROMAGNETIC** waves travel at 3.0×10^{8} m s^{-1} in a vacuum.
3	B	
4	B	The distance from a compression to the nearest rarefaction is equal to **HALF** of a wavelength.
5	C	$T = 200 \text{ ms} = 0.200 \text{ s} \qquad \therefore f = \frac{1}{T} = \frac{1}{0.200 \text{ s}} = 5.0 \text{ Hz}$
6	A	$v = \lambda f \qquad \therefore \lambda = \frac{v}{f} = \frac{40 \text{ m s}^{-1}}{5.0 \text{ Hz}} = 8.0 \text{ m}$
7	B	The amplitude is the maximum displacement of the vibration from its mean position: 10 mm.
8	C	$v = \lambda f \qquad \therefore f = \frac{v}{\lambda} = \frac{32 \text{ m s}^{-1}}{0.80 \text{ m}} = 40 \text{ Hz}$
9	D	Note that the dots E and G are both on the left-most line of successive compressions.

No.	Answers	Further explanations
10	C	Particles are in phase in a transverse or longitudinal progressive wave when they have the same displacement and are moving in the same direction.
11	A	

C2 Sound waves and electromagnetic waves

No.	Answers	Further explanations
1	D	The speed (through air) of sound waves of frequencies within the audible range can be taken as constant.
2	C	
3	A	
4	A	
5	D	If x = depth of water, the distance to the seabed and back to surface = $2x$ $\therefore v = \frac{2x}{t}$ $x = \frac{vt}{2} = \frac{1500 \text{ m s}^{-1} \times 1.2 \text{ s}}{2} = 900 \text{ m}$
6	A	$v = \frac{D}{t} \quad \therefore D = vt = 333 \text{ m s}^{-1} \times 6.0 \text{ s} = 2000 \text{ m}$ or 2.0 km (to 2 sig. fig.)
7	B	The volume and pitch of a sound wave are respectively dependent on its amplitude and frequency.
8	B	The energy of the wave spreads into the surroundings and only a portion of it returns to Jennifer. The decrease in energy results in a decrease in the strength or amplitude of the vibrations. The 'loudness' or volume observed diminishes because the amplitude of oscillation of the eardrum decreases.
9	B	Visible light waves have frequencies of the order 10^{14} Hz but the maximum frequency in the audible range of sound waves is only 2×10^{4} Hz (i.e. 20 kHz).
10	A	The speed of sound waves (through air) of frequencies within the audible range can be taken as constant.

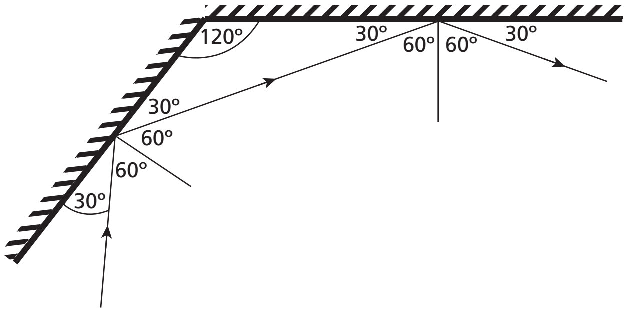
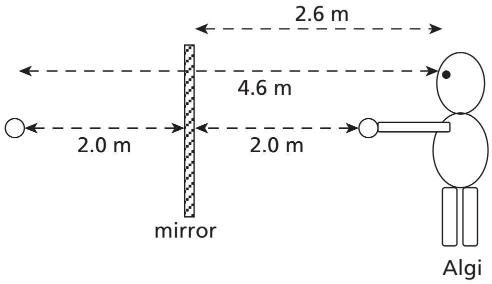
No.	Answers	Further explanations
11	C	Thermal radiation is electromagnetic radiation emitted by all bodies above zero kelvin. It is due to the thermal motion of the charged particles from which the body is made.
12	C	See table for Q13 below.
13	B	**Type of em wave** / **Wavelength**: radio — from 1 mm to several km (includes microwaves with wavelengths between 1 mm and 1 m) infrared — from 10^{-7} m to 1 mm visible light — from violet 4×10^{-7} m to red 7×10^{-7} m ultraviolet — From 10^{-8} m to 10^{-7} m X-ray — From 10^{-12} m to 10^{-8} m gamma — Less than 10^{-11} m 1 nm = 10^{-9} m
14	B	
15	A	$v = \lambda f$ Since the speed of all electromagnetic waves is the same in air: $\lambda_1 f_1 = \lambda_2 f_2 \qquad \therefore f_2 = \frac{\lambda_1 f_1}{\lambda_2} = \frac{400\text{ m} \times 7.5 \times 10^5\text{ Hz}}{500\text{ m}} = 6.0 \times 10^5\text{ Hz}$
16	D	
17	B	The type of electromagnetic wave produced within the atomic nucleus of a radioactive element is **GAMMA**. X-rays are produced as high speed electrons bombard a metal target.

Type of em wave	Wavelength
radio	from 1 mm to several km (includes microwaves with wavelengths between 1 mm and 1 m)
infrared	from 10^{-7} m to 1 mm
visible light	from violet 4×10^{-7} m to red 7×10^{-7} m
ultraviolet	From 10^{-8} m to 10^{-7} m
X-ray	From 10^{-12} m to 10^{-8} m
gamma	Less than 10^{-11} m
1 nm = 10^{-9} m	

C3 Light waves: wave–particle duality, shadows and reflection

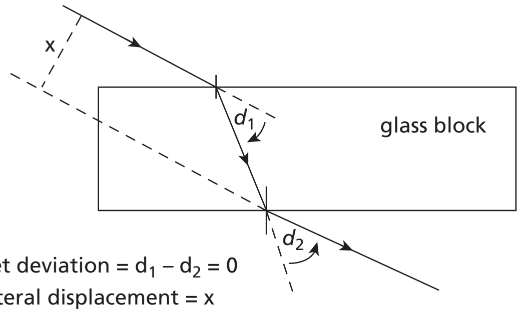
No.	Answers	Further explanations
1	A	
2	C	

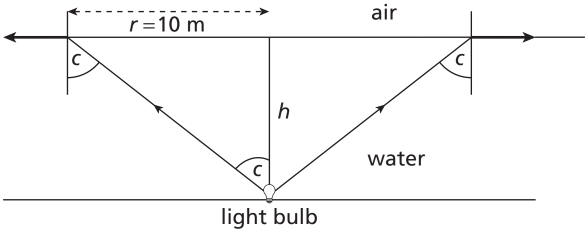
No.	Answers	Further explanations
3	C	The wavelength of blue light is smaller than that of red light and therefore blue light diffracts less than does red light.
4	B	
5	D	Wavelengths of about 1 km are large enough to undergo noticeable diffraction over the hill and to reach the observer at Y.
6	B	Young's experiment provides evidence for the **WAVE NATURE** of light, since the bright and dark fringes produced can be explained in terms of the interference of light waves.
7	B	When the vibrations reaching a point are out of phase by $\frac{1}{2}$ wavelength they cancel each other, producing a dark fringe.
8	B	The fringe separation x depends on the wavelength λ, the distance between the slits and the screen D, and the distance d between the slits according to the equation: $x = \frac{\lambda D}{d}$. From the equation it can be seen that if the distance between the slits decreases the fringe separation will increase.
9	C	
10	A	P: crest on trough → destructive Q: crest on crest → constructive R: trough on trough → constructive
11	C	P: 2 mm – 2 mm = 0 mm Q: 2 mm + 2 mm = 4 mm R: – 2 mm – 2 mm = –4 mm
12	D	Rainbows are produced by the refraction and dispersion of light, which are phenomena demonstrating the change in direction of light waves.
13	D	The position of the image depends only on the perpendicular distance of the object in front of the mirror. Even if Amoka and her friend leave the room the image will be in the same position.
14	C	The image in a plane mirror is **VIRTUAL** since light is not where the image appears to be.

No.	Answers	Further explanations
15	B	$x = 60°$ 
16	B	
17	D	
18	B	During an eclipse of the Moon, the Moon enters the umbra of the Earth produced as a result of the **EARTH BLOCKING LIGHT** from the Sun.
19	C	Option IV: Not true. Since light from a given point on the object now has several different straight paths into the camera, the image of that point will now be spread over a region on the film. This produces a blurred or **LESS FOCUSED** image.

C4 Light waves: refraction, critical angle and total internal reflection

No.	Answers	Further explanations
1	A	
2	C	Virtual images may be produced without a mirror. Examples are: • the crooked image of a straight straw in a glass of water • the image formed by a concave lens • the image formed by a convex lens when the object is placed closer to the lens than its principal focus.
3	C	
4	C	

No.	Answers	Further explanations
5	D	 net deviation = $d_1 - d_2 = 0$ lateral displacement = x
6	B	
7	C	
8	D	
9	A	$\frac{\eta_s}{\eta_d} = \frac{v_d}{v_s} = \frac{2.4\ \text{m s}^{-1}}{2.0\ \text{m s}^{-1}} = 1.2$
10	B	$\frac{\eta_x}{\eta_a} = \frac{\sin\theta_a}{\sin\theta_x} = \frac{\sin 50}{\sin 30} = 1.5$
11	D	$\frac{v_x}{v_a} = \frac{\sin\theta_x}{\sin\theta_a}$ $\therefore v_x = \frac{\sin 30°}{\sin 50°} \times 3.0 \times 10^8\ \text{m s}^{-1} = 2.0 \times 10^8\ \text{m s}^{-1}$
12	D	$\frac{\lambda_x}{\lambda_a} = \frac{\sin\theta_x}{\sin\theta_a}$ $\therefore \lambda_x = \frac{\sin\theta_x}{\sin\theta_a} \times \lambda_a = \frac{\sin 30°}{\sin 50°} \times 6.0 \times 10^{-7}\ \text{m} = 3.9 \times 10^{-7}\ \text{m}$
13	B	Sound travels **FASTER** in glass than in water since the particles are closer together in glass and can relay the vibrations more rapidly.
14	C	For light entering a second medium perpendicular to its surface there is no deviation. For light entering a second medium at any other angle • if the second medium is denser, it deviates towards the normal • if the second medium is less dense, it deviates away from the normal.
15	B	Note that dispersion occurs as the light **ENTERS** the glass.

No.	Answers	Further explanations
16	B	
17	C	$\sin c = \frac{1}{1.3} \quad \therefore c = \sin^{-1}\left(\frac{1}{1.3}\right) = 50°$
18	B	c is always the angle between the ray and the normal in the medium of greater refractive index when the refracted ray is along the interface of the media.
19	B	
20	A	 $\tan c = \frac{10}{h} \quad \tan 49° = \frac{10\ \text{m}}{h} \quad \therefore h = \frac{10\ \text{m}}{\tan 49°} = 8.7\ \text{m}$
21	D	Due to the refractive index of the material of the cable, light travels through it at a lower speed than it does through air (i.e. less than $3.0 \times 10^8\ \text{m s}^{-1}$).

C5 Lenses

No.	Answers	Further explanations
1	C	Option II: Not true. Only rays **PARALLEL** to the principal axis will pass through the principal focus.
2	D	
3	C	
4	B	
5	D	
6	C	
7	B	

No.	Answers	Further explanations
8	C	
9	D	Parallel rays which pass through a convex lens will always focus on the focal plane at a point where the ray through the optical centre (which is not deviated) intercepts it.
10	A	$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \quad \therefore \frac{1}{v}=\frac{1}{f}-\frac{1}{u}$ $\frac{1}{v}=\frac{1}{20.0\text{ cm}}-\frac{1}{50.0\text{ cm}}=\frac{1}{33.3\text{ cm}} \qquad v = 33\text{ cm } (2\text{ s.f.})$
11	A	$\text{magnification} = \frac{v}{u}=\frac{33.3\text{ cm}}{50.0\text{ cm}}=0.67$
12	C	$\text{magnification} = \frac{I}{O} \qquad 0.67=\frac{I}{2.0\text{ cm}}$ $\therefore I = 0.67 \times 2.0\text{ cm} = 1.3\text{ cm } (2\text{ s.f.})$
13	D	$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \quad \therefore \frac{1}{8.0\text{ cm}}+\frac{1}{v}=-\frac{1}{12.0\text{ cm}}$ $\frac{1}{v}=-\frac{1}{12.0\text{ cm}}-\frac{1}{8.0\text{ cm}}=-\frac{5}{24.0\text{ cm}}$ $v=-\frac{24.0\text{ cm}}{5}=-4.8\text{ cm}$ Note that for **CONCAVE** lenses the focal length *f* in the formula is **NEGATIVE**. The **negative** value of *v* indicates that the image is **virtual**.
14	D	Ray C will pass through F since it is originally parallel to the principal axis. Rays A and B will therefore intercept the principal axis at points closer to the lens than F and ray D will intercept the principal axis at a point further from the lens than F.

Section D: Electricity and Magnetism

D1 Electrostatics

No.	Answers	Further explanations
1	C	
2	B	

No.	Answers	Further explanations
3	C	X tends to repel Z along the line through B, and Y tends to attract Z along the line through D. The resultant force on Z is therefore along the line through C, midway between D and B.
4	D	The field in the central region between the plates of diagram D is uniform. If electric field lines were drawn in this region they would be parallel and evenly spaced.
5	C	Option I: Not true. The free charges in metals are the negatively charged electrons; the protons are fixed in position in the nuclei of the atoms. Option II: True. Oppositely charged bodies attract each other. Option III: True.
6	C	Electric field lines are directed towards negative charge.
7	C	Similar charges repel. In this case, the charges are both negative.
8	D	
9	C	The charge on the drop must be opposite in sign to the charge on X and similar in sign to the charge on Y so that it will be attracted **UPWARD** by X and repelled **UPWARD** by Y. These upward forces will balance the downward force of gravity on the drop.

D2 Current electricity

No.	Answers	Further explanations
1	D	
2	A	Conductors have more **FREE** electrons per unit volume than do insulators.
3	A	Option II: Not true. The SI unit of current is the **AMPERE**, A. Option III: Not true. **CURRENT** is the rate of flow of **ELECTRIC CHARGE**.
4	A	$I = \frac{Q}{t} = \frac{15 \times 10^{-6}\ \text{C}}{3.0\ \text{s}} = 5.0 \times 10^{-6}\,\text{A}$ or $5.0\ \mu\text{A}$
5	D	

No.	Answers	Further explanations
6	B	The period T is 50 ms since the horizontal axis of the graph shows this to be the time for one complete waveform. frequency $f = \frac{1}{T} = \frac{1}{0.050\ \text{s}} = 20\ \text{Hz}$
7	B	The line of the graph must repeatedly pass between the **POSITIVE AND NEGATIVE** voltages for it to be an alternating voltage.
8	A	Options B: Not true. $P = \frac{V^2}{R}$ Option C: Not true. $P = VI$ Option D: Not true. $Q = It$
9	C	$E = QV = 40 \times 10^{-6}\,\text{C} \times 12\ \text{V} = 4.8 \times 10^{-4}\ \text{J}$
10	D	$P = VI \qquad V = \frac{P}{I} = \frac{500\ \text{W}}{2.0\ \text{A}} = 250\ \text{V}$
11	C	$P = I^2R \qquad R = \frac{P}{I^2} = \frac{500\ \text{W}}{2.0^2\ \text{A}^2} = 125\ \Omega$
12	D	$P = \frac{E}{t} \qquad E = Pt = 500\ \text{W} \times 4.0\ \text{s} = 2000\ \text{J}$
13	D	initial power $P = \frac{V^2}{R}$ final power $P_2 = \frac{(2V)^2}{R} = \frac{4V^2}{R} \qquad \therefore P_2 = 4P$

D3 Circuits and components

No.	Answers	Further explanations
1	D	Option II: Not true. Manganese(IV) oxide is placed around the carbon rod to prevent **HYDROGEN** from collecting around it and raising the internal resistance of the cell.

No.	Answers	Further explanations
2	A	Option B: Not true. Y is a semiconductor diode connected so that current flowing through the battery has a direction **OPPOSITE** to what it would have when the cell is discharging. Option C: Not true. Y rectifies **ac to dc**. Option D: Not true. Z is a **VARIABLE RESISTOR** used to adjust the current to a suitable value.
3	C	The internal resistance of a lead–acid cell is about 0.01 Ω, but that of a zinc-carbon cell is about 0.5 Ω.
4	D	$E = VIt = 12\ \text{V} \times 80\ \text{A} \times 3600\ \text{s} = 3.5 \times 10^6\ \text{J} = 3.5\ \text{MJ}$
5	C	Component P: Filament lamp. The resistance increases as the voltage across the lamp increases. Component Q: Semiconductor diode. Conduction only occurs when the voltage across the diode is in one direction; a minimum voltage is required for conduction in that direction. Component R: Metallic resistor. Unlike P and Q, this is the only one that obeys Ohm's law, since the current is always directly proportional to the voltage.
6	B	$V = IR \qquad \therefore R = \frac{V}{I} = \frac{3.0\ \text{V}}{12\ \text{A}} = 0.25\ \Omega$
7	C	If a material obeys Ohm's law, the **CURRENT** through it is directly proportional to the potential difference between its ends.
8	D	
9	C	Option III: Not true. **Ammeters** are placed in series with the component through which they measure current. Ideally they should have **NO RESISTANCE** so that they do not alter the current they are to be measuring. **Voltmeters** are placed in parallel with the component across which they measure potential difference. Ideally they should have **INFINITE RESISTANCE** so that they do not take current from the component and thereby alter the potential difference they should be measuring.
10	B	For the lower branch: $V = IR = 2.0\ \text{A} \times (1.0 + 2.0)\ \Omega = 6.0\ \text{V}$ Since the potential difference across parallel branches in a circuit is the same, the potential difference across the upper branch is also 6.0 V.

No.	Answers	Further explanations
11	A	$V = IR \quad \therefore I = \frac{V}{R} = \frac{6.0\ \text{V}}{2.0\ \Omega} = 3.0\ \text{A}$
12	C	$R = \frac{2.0\ \Omega \times 3.0\ \Omega}{2.0\ \Omega + 3.0\ \Omega} = 1.2\ \Omega$
13	C	The combined pd across resistors in parallel is equal to the pd across each of the branches (i.e. 3.0 V). The emf is equal to the total pd across all the resistors in the circuit.
14	B	Option I: Not true. $I_x = \frac{3.0\ \text{V}}{6.0\ \Omega} = 0.50\ \text{A}$; $I_y = \frac{3.0\ \text{V}}{2.0\ \Omega} = 1.50\ \text{A}$ The currents in X and Y are therefore different. Option II: True. Option III: Not true. The current from the battery is 0.50 A + 1.5 A = 2.0 A
15	A	When the switch is closed, current has to flow through X, causing it to glow. It bypasses Y by flowing through the conducting wire connected across it, and therefore bulb Y does not glow. This bypass is known as a 'short circuit'.
16	A	The lower branch has a total resistance of 4 Ω whereas the upper branch contains a single 2 Ω resistor. Since the upper branch contains less resistance it will take the most current.
17	B	Current through components connected in series is always the same.
18	D	In circuit D the ammeter is not measuring the current through the resistor X since it is not connected in series with it. Also, the voltmeter is not measuring the potential difference across the resistor X since it is not connected in parallel with it. These readings cannot therefore be used to find the resistance of X.
19	B	$R = \frac{V}{I} = \frac{3.0\ \text{V}}{2.0\ \text{A}} = 1.5\ \Omega$
20	C	The positive pole of each measuring instrument must be connected **TO FACE THE POSITIVE POLE OF THE BATTERY** along the line of the circuit.
21	D	

No.	Answers	Further explanations
22	C	Option I: Not true. Excessive current may be flowing due to either an internal short circuit in the appliance or due to a power surge external to the appliance. During an internal short circuit, current flows in the live and earth wires, but during the power surge external to the appliance, current continues to flow in the live and neutral wires (since nothing is wrong with the appliance itself). In both cases current flows in the **LIVE** wire, and therefore by placing the fuse there, the excessive current is always detected. Option II: Not true. By connecting the appliance **IN SERIES** with the fuse or circuit breaker, any excessive current which flows through the appliance will also flow through the fuse or circuit breaker and will therefore be detected.
23	D	The total current entering the branches under normal operational conditions is 7.5 A. The fuse should be rated at a value a little above this, so a 9 A fuse is suitable.
24	A	$25\ \text{kWh} = 25\,000\ \text{Wh} = 25\,000 \times 3600\ \text{W s} = 9.0 \times 10^{7}\ \text{J}$ or 90 MJ

D4 Electronics

No.	Answers	Further explanations
1	B	Circuit P: The diode is forward biased and therefore allows the flow of the constant direct current from the cell. Circuit Q: The diode is reverse biased, preventing the flow of the direct current from the cell. Circuit R: The diode connection switches between forward and reverse bias every half cycle of the sinusoidal ac source. The varying current in the circuit only flows for the half of each cycle when the diode is forward biased and it is therefore in one direction only.
2	C	Option I: Not true. The rectified current is a varying current but is **NOT** an alternating current since it does not repeatedly flow in opposite directions.
3	C	
4	A	

No.	Answers	Further explanations
5	A	If any of the inputs to the OR gate is 1, then the output is 1; otherwise the output is 0. The inputs are A = 1, B = 0, and therefore the output is D = 1. The NOT gate switches the input. Since D = 1, E = 0. If both inputs to the AND gate are 1, then the output is 1; otherwise, the output is 0. Since the inputs are C = 1, E = 0, the output is F = 0.
6	D	If any of the inputs to the NOR gate is 1, then the output is 0; otherwise, the output is 1. The inputs are A = 1, B = 1, and therefore the output is C = 0. If both inputs to the AND gate are 1, then the output is 1; otherwise the output is 0. Since the inputs are A = 1, B = 1, the output is D = 1. If any of the inputs to the NOR gate is 1, then the output is 0; otherwise the output is 1. The inputs are C = 0, D = 1, and therefore the output is E = 0.

D5 Magnetism

No.	Answers	Further explanations
1	C	Option C: When a magnetic pole is brought near to a location on an unmagnetised magnetic material, a magnetic pole of **opposite** polarity is induced at the location. The two facing opposite poles then attract.
2	A	Magnetic fields are directed out of N poles and into S poles. The magnetic field of the magnet is therefore directed to the right and through the iron bar. The atomic magnetic dipoles within the iron bar will align with the magnetic field so that their fields also point in the same direction, i.e. to the right.
3	A	The magnetism of the Earth is such that it has its S pole near to the geographic North pole and a N pole near to the geographic South pole. The N pole of a magnetised needle therefore points to the geographic North pole where the Earth has a magnetic S pole.
4	C	
5	B	The paths of the iron filings are connecting opposite poles and therefore by knowing any one pole, the other connected poles can be determined.

No.	Answers	Further explanations
6	D	Magnetic field lines are directed from N pole to S pole outside the magnet.
7	A	The magnet magnetises the iron bar by aligning the magnetic atomic dipoles of the iron bar with its magnetic field. Therefore a S pole is created at the end of the bar facing the N pole of the magnet and a N pole is created at the end of the bar facing the S pole of the magnet. Field lines directed out of the N pole of the magnet therefore converge towards the facing pole of the iron bar and spread from the other end of the bar towards the opposite pole of the magnet.

D6 Electromagnetism

No.	Answers	Further explanations
1	C	Use of the right-hand grip rule (with the fingers in the direction of the current) reveals that the right end of the coil is a magnetic N pole and the left end of the coil is a magnetic S pole. Field lines directed from the magnetic N pole of the coil curve until they enter its magnetic S pole.
2	A	Use of the right-hand grip rule (with the thumb in the direction of the current) reveals the correct field pattern.
3	D	Use of the right-hand grip rule on option D (with the fingers in the direction of the current) reveals that the right end of the coil is a magnetic N pole and therefore the field lines are directed out of this end of the coil.
4	C	Option II: Not true. The magnet of a plotting compass must be a permanent magnet.
5	C	Electromagnets are only magnetised when current flows in their coils. If a steel core is used the magnetism will be sustained even when the current no longer flows.
6	A	**F**irst → **F**ield se**C**ond → **C**urrent **T**humb → **T**hrust (Force)
7	C	By use of Fleming's left-hand rule.
8	A	$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \therefore V_s = \frac{N_s}{N_p} \times V_p = \frac{200}{4000} \times 120\text{ V} = 6.0\text{ V}$

No.	Answers	Further explanations
9	B	By use of Fleming's left-hand rule. Note that the direction of electron flow is opposite to the flow of conventional current. When using the rule here the finger representing current must therefore be directed to the left.
10	C	
11	C	
12	C	An induced emf is only created when there is **RELATIVE MOTION** between a conductor and a magnetic field. In option C the magnet is at rest in the coil and therefore no current is induced. Note that in option D the region around the coil carrying the alternating current will have an associated varying magnetic field which can induce an alternating current in any nearby conductor.
13	A	Option III: Not true. If there is no relative motion between the conductor and the magnetic field there can be no induced current.
14	D	
15	B	When a magnetic pole is pushed into or pulled out of the end of a coil, it induces a pole on the coil which opposes the motion. In option B, as the S pole of the magnet enters the coil, it induces a magnetic S pole there in order to oppose entry of the magnet. The other end of the coil therefore becomes a magnetic N pole. Use of the right-hand grip rule on the coil (with the thumb in the direction of the field) then reveals that the current flows as shown in the diagram.
16	C	When the angle between the motion of the coil and the magnetic field is 90°, the rate of cutting of the field lines is at a maximum and therefore the emf induced is at a maximum.

No.	Answers	Further explanations
17	D	Option I: Not true. A transformer has ac at its input and its output terminals. Option II: Not true. When a transformer increases current, it decreases voltage. The term 'step-up', as used with transformers, refers to its effect on voltage. This transformer increases current and therefore steps down voltage. It is a **STEP-DOWN** transformer. Option III: True. The ac input to the primary coil of a transformer creates a magnetic field which rapidly reverses direction. This magnetic field enters and withdraws from the output coil inducing an ac in it of the same frequency.
18	C	Option A: True. Induced eddy currents within the core reduce the efficiency of the transformer. By having a core made from laminations which are insulated from each other, these currents are minimised. Option B: True. The two coils are not connected and therefore current cannot flow from one to the next. Option C: Not true. For an ideal transformer $\frac{N_s}{N_p} = \frac{I_p}{I_s}$. It follows that if the number of turns on the secondary coil is twice that on the primary coil then the current in the secondary coil is **HALF** that in the primary coil. Option D: True. For an ideal transformer $\frac{V_s}{V_p} = \frac{I_p}{I_s}$ It follows that if the voltage across the secondary coil is twice that across the primary coil then the current in the secondary coil is only half that in the primary coil.
19	A	$\frac{I_p}{I_s} = \frac{V_s}{V_p} \qquad \therefore I_p = \frac{V_s \times I_s}{V_p} = \frac{6.0\ \text{V} \times 5.0\ \text{A}}{120\ \text{V}} = 0.25\ \text{A}$
20	D	Power $P = VI$ and so if the transmission voltage is increased by a transformer of given power output, the transmission current must **DECREASE**.

Section E: The Physics of the Atom

E1 Models and structure of the atom

No.	Answers	Further explanations
1	B	
2	C	
3	C	Option I: Not true. Alpha particles were shot through gold foil in an evacuated chamber and it was noticed that **MOST PASSED THROUGH WITHOUT DEVIATION** but **A FEW WERE STRONGLY DEFLECTED**.
4	D	Option I: Not true. The nucleon number (mass number) is 62. Option II: Not true. The atomic number (proton number) is 28 and the mass number is 62. Option III: True. Option IV: True. For a neutral atom, the number of protons must be equal to the number of electrons.
5	B	Option I: Not true. Isotopes have **THE SAME ATOMIC NUMBER** (proton number) but different mass numbers. Option III: Not true. The lower number (subscript) is the atomic number and must be the same.

E2 Radioactivity and nuclear energy

No.	Answers	Further explanations
1	B	
2	C	The beta particle has a mass relative to the proton of about $\frac{1}{1840}$.
3	B	

No.	Answers	Further explanations
4	C	By use of Fleming's left-hand rule. Note that beta flow is opposite in direction to conventional current flow. α particles deviate less than β particles. Although they have twice the charge, they have a much greater mass, and therefore require a greater force to deviate them by any given amount. γ waves are not deviated since they have no charge.
5	D	Since opposite charges attract each other the negative β particles deviate towards the positively charged plate and the positive α particles deviate towards the negatively charged plate. γ waves are uncharged and therefore do not deviate.
6	B	Cloud tracks are produced as condensation occurs on the ionised air molecules. Tracks produced by α particles are thick and straight since these particles ionise the air strongly on collision and are not easily deflected due to their high speed and relatively large mass. Tracks produced by β particles are thin and randomly directed since these particles only weakly ionise the air on collision and are easily deflected due to their relatively small mass. Tracks produced by γ waves are sparse and scattered since these waves are very weakly ionising as they transfer their electromagnetic energy.
7	D	The α particle is represented by ${}^{4}_{2}\alpha$. The sums of values of the superscripts on each side of the equation are the same. The sums of values of the subscripts on each side of the equation are the same.
8	A	The β particle is represented by ${}^{0}_{-1}\beta$. The sums of values of the superscripts on each side of the equation are the same. The sums of values of the subscripts on each side of the equation are the same.
9	B	

No.	Answers	Further explanations
10	D	
11	B	The graph indicates that during a period of 4 days the count rate falls to half of the value it had at the start of the 4 days. The half-life is therefore 4 days.
12	C	$100\% \rightarrow 50\% \rightarrow 25\% \rightarrow 12.5\%$ 24 days contains 3 half-lives. $\therefore$ Each half life is $\frac{24 \text{ days}}{3} = 8 \text{ days}$
13	A	Half-life = 5700 years. $\therefore$ 17 100 years represents a period of 3 half-lives $\left(\frac{17\ 100 \text{ y}}{5700 \text{ y}} = 3\right)$. $8 \times 10^{12} \rightarrow 4 \times 10^{12} \rightarrow 2 \times 10^{12} \rightarrow 1 \times 10^{12}$ Therefore 1×10^{12} particles remain.
14	C	$\Delta E = \Delta mc^2 \quad \Delta m = \frac{\Delta E}{c^2} = \frac{3.6 \times 10^{23} \text{ J}}{(3.0 \times 10^8 \text{ m s}^{-1})^2} = 4.0 \times 10^6 \text{ kg}$