CCEA GCSE PHYSICS OUESTIONS

MARK SCHEME

This mark scheme is for use in conjunction with the book *Physics Questions for CCEA GCSE*, ISBN: 978 1 78073 190 2



Colourpoint Educational

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Unit 1:

Motion, Force, Density and Kinetic Theory, Energy, and Atomic and Nuclear Physics



1.1 MOTION

1.1 Motion

- 1. (a) Average speed = distance ÷ time [1] = 44.1 m ÷ 3.0 s [1]
 - = 14.7 m/s [1](b) Average speed = (initial speed + final speed) \div 2 [1] $14.7 = (0 + v) \div 2[1]$ So final speed v = 29.4 m/s [1]
 - (b) rate of change of speed = change of speed ÷ time taken [1] $= (29.4 - 0) \div 3 [1]$ $= 9.8 \text{ m/s}^{2} [1]$
- 2. (a) time = displacement ÷ average velocity [1] = 260 cm ÷ 13 cm/s [1] = 20 s [1]
 - (b) average velocity = (initial velocity + final velocity) \div 2 [1] $13 = (0 + v) \div 2 [1],$ so final velocity = 26 cm/s [1]
 - (c) acceleration = change in velocity ÷ time taken [1] $= (26 - 0) \div 20 [1]$ $= 1.3 \text{ cm/s}^{2} [1]$
- **3.** AB constant speed [1] BC – constant speed [1] CD – at rest [1]
- 4. (a) A [1]
 - **(b)** B [1]
 - (c) 19 m [1]
- 5. (a) acceleration = gradient of graph [1] $= (40 - 20) \div 8 [1]$ $= 2.5 \text{ m/s}^{2} [1]$
 - (b) Distance = area under graph = area of rectangle + area of trapezium [1] $= 120 + \frac{1}{2}(20 + 40) \times 8$ [1 mark for each area] = 360 m [1]
 - (c) Average speed = total distance ÷ total time [1] = 360 m ÷ 14 s [1] = 25.7 m/s (to 1 d.p.) [1]
- **6.** (a) BC (gradient is zero) [1]
 - (b) Rate of change of speed = change in speed ÷ time taken [1] $=(18-8) \div (12-7) [1]$ $= 2 \text{ m/s}^{2} [1]$
 - (c) Distance = average speed × time [1] $= \frac{1}{2}(0+8) \times 5[1]$ = 20 m [1]

7. (a) 28 m/s [1]

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(b) average speed = (u + v) \div 2 [1]
     = (0 + 28) \div 2 [1]
     = 14 \text{ m/s} [1]
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(c) distance = average speed × time [1] $= 14 \times 2.8 [1]$

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= 39.2 m [1]
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- **8.** (a) Father: Speed = distance ÷ time [1] $= 120 \text{ m} \div 15 \text{ s} [1]$ = 8 m/s [1]Son: Speed = $120 \text{ m} \div 30 \text{ s} = 4 \text{ m/s} [1]$
 - (b) Son finished race 10 s after father, while running at 4 m/s [1] Son was $4 \times 10 = 40$ m behind when father finished the race. [1]
- **9.** Time to maximum height = velocity ÷ deceleration [1] $15 \div 10$ [1] [It is a requirement of the spec that you remember that $g = 10 \text{ m/s}^2$] = 1.5 s. [1] Total time of flight = 1.5 + 1.5 = 3 s [1]
- 10. (a) Distance between girls is decreasing at 10 m/s [1] so they meet after 24 seconds. [1]
 - (b) Faster girl has run $6 \times 24 = 144$ m [1], slower girl has run $4 \times 24 = 96$ m [1] So the faster girl has run 144 m - 96 m = 48 m more than the slower girl. [1]

1.2 Force

- 1. F_{engine} Friction = ma [1] F_{engine} - 700 = 2800 × 2 [1; one mark for each side of the equals sign] F_{engine} = 6300 N [1]
- 2. Friction = 40 N [1] 15 - 40 = m × (-0.5) [1; one mark for each side of the equals sign] m = 50 kg [1]
- 3. Mass measures the amount of material in an object; weight measures the force of gravity on it. [1] Mass is a scalar; weight is a vector. [1] [Note that it is not enough to state that weight is a force and that it is a vector. The question requires you to state the *differences*, so you must write about both mass and weight.]
- 4. Newton's First law: A body stays at rest, or if moving it continues to move with uniform velocity [1], unless an unbalanced force makes it behave differently [1]. Newton's Second Law: The acceleration of an object is directly proportional to the force applied to it [1] and inversely proportional to the object's mass [1].
- 5. Since height is constant, weight = lift = 20 000 N [1], so mass of aircraft = 20 000 \div g = 2000 kg [1] Unbalanced force = thrust - drag = 1500 N - 500 N = 1000 N [1] Unbalanced force = ma, so 1000 = 2000 \times a [1], so a = 0.5 m/s² [1]
- 6. (a) Hooke's Law: The extension of a spring is directly proportional to the applied load [1], up to a limit known as the limit of proportionality [1].
 [The first part of Hooke's Law would be regarded as 'threshold', which means it would be essential to get this first mark in order to get access to the second mark.]
 - (b) (i) Additional 4 N stretches spring by 2 cm [1], so 6 N would extend spring by 3 cm [1] Natural length = 18 cm 3 cm = 15 cm [1]
 (ii) k = F ÷ e [1]
 - $(II) = 4 \text{ N} \div 2 \text{ cm} [1]$ = 2 N/cm [1]
 - (c) $e = F \div k = 12 \div 2 = 6$ cm extension [1]
- 7. (a) Area = $0.8 \text{ m} \times 0.8 \text{ m} = 0.64 \text{ m}^2$ [1]

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(b) Weight = pressure × area [1]
= 20 000 × 0.64 = 12 800 N [1]
Mass = weight ÷ g [1]
= 12 800 ÷ 10 [1]
= 1280 kg
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1.2 FORCE

8. (a) The centre of gravity of an object is the point [1] where the entire weight of the object may be thought to act [1].

[The idea that the centre of gravity is a point would be regarded as 'threshold'. This means that it would be essential to get this mark to get access to the second mark.]

(b) When a lever is balanced [1], the sum of the clockwise moments about any point is equal to the sum of the anticlockwise moments [1] about the same point [1].

(c) Moment = $F \times d$ [1] = 6 N × 25 cm [1] = 150 N cm [1] clockwise [1]

- (d) ACWM = CWM [1] so weight × 15 = 150 [1] hence weight = 10 N [1]
- **9.** To use minimum force, apply force as far as possible from the relevant edge. [1] Suppose a force, *F*, is applied 120 cm from 80 cm edge, then:

 $F \times 120 = \text{weight} \times 60 = 50 \text{ N} \times 60 \text{ cm} [1]$

giving *F* = 25 N [1]

(Note that the force is the same regardless of the edge at which it is applied.)

10. Method:

- Suspend the metre ruler at 50 cm using string attached to a retort stand and clamp.
- Adjust the point of suspension if necessary, until metre rule is horizontal.
- Hang, from the metre ruler, unequal slotted masses, m_1 and m_2 on either side of the ruler's point of suspension.
- Adjust the position of the masses until the ruler is horizontal again.
- Calculate the clockwise and anticlockwise moment of the weight of each mass about the point of suspension.
- Repeat for different slotted masses.
- Observe that when the ruler is balanced then ACWM = CWM in every case, verifying the Principle of Moments.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 5 or more points would place you in the 5–6 mark band, 3 or 4 points would place you in the 3–4 mark band and 1 or 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

1.3 Density and Kinetic Theory

1. (a) The density of a material is its mass divided by its volume. [1]

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(b) Volume = mass ÷ density [no marks as it was credited in part (a)]
= 64.8 g ÷ 2.7 g/cm<sup>3</sup> [1]
= 24 cm<sup>3</sup> [1]
Volume = length × breadth × height [1]
2 mast 2 mast 4 = 24 cm<sup>3</sup> [4]
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2 \text{ cm} \times 3 \text{ cm} \times h = 24 \text{ cm}^3 [1]
So h = 24 \div 6 = 4 \text{ cm} [1]
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- $50 \Pi = 24 \div 0 =$
- 2. Method:
 - Find the mass of a clean, dry, empty measuring cylinder using a top-pan balance.
 - Pour the liquid into the measuring cylinder and record its volume.
 - From the combined mass of the measuring cylinder and liquid, subtract the mass of the empty cylinder to find the mass of the liquid.
 - Calculate the density of the liquid by dividing its mass by its volume.
 - Repeat the experiment and average the results for reliability.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 5 or more points would place you in the 5–6 mark band, 3 or 4 points would place you in the 3–4 mark band and 1 or 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

3. Density = mass \div volume [1] = 60 g \div (45 - 15) cm³ [1] = 2 g/cm³ [1]



- (b) As the water cools from 4°C to freezing point its volume expands, bursting the pipe. [1]
- (c) Lagging (insulating) reduces the heat lost by the water in the pipe to the environment [1], so it is unlikely to cool below 4°C [1].

- 5. (a) (i) Motion of the molecules:
 - In solids the molecules vibrate about fixed positions. [1]
 - In liquids the molecules can move around in any direction and are not in a fixed position, so they can swap places with each other. [1]
 - In gases the molecules move around at high speeds and in all directions. [1]
 - (ii) Forces between the molecules:
 - In solids there are strong forces of attraction between the molecules. [1]
 - In liquids the forces of attraction between the molecules are still quite strong [1], but not as strong as in solids. [1]
 - In gases the forces of attraction between molecules are negligible. [1]
 - (b) In solids the molecules are packed very tightly together, so the density of solids is guite high. [1] In liquids the molecules are close together, but not as close as they are in solids. [1] Liquids therefore have a medium density. [1]

In gases the average separation of the molecules is quite large [1], so gases have a very low density [1].

- 6. (a) Scales covering at least half of paper [1]
 - Axes labels as in table [1]

Points plotted [2]

[4 or 5 points correctly plotted (to within $\frac{1}{2}$ a small square) – 2 marks; 3 points correctly plotted – 1 mark only, < 3 points correct – 0 marks]

Single straight line through (0, 25) and (60, 6) [1]

(b) Gradient = (67 - 25) g ÷ (60 - 0) cm³ [1] $= 42 \text{ g} \div 60 \text{ cm}^{3} [1]$ $= 0.7 \text{ g/cm}^{3} [1]$

The gradient is the density of the liquid (0.7 g/cm^3) . [1]

- (c) The intercept on the vertical axis is 25 g. [1] This is the mass of the cylinder when there is no liquid in it. [1]
- 7. Use the method used in the answer to question 3 to find the density of pure gold, pure silver and the material of the crown. [6]
 - If the crown's density is the same as that of pure gold, then it is genuine. [1]
 - If the crown's density is the between that of pure gold and pure silver, then the goldsmith has been fraudulent. [1]
- 8. Mass of concrete sample = 8000 g = 8 kg [1]Volume of concrete sample = $0.15 \text{ m} \times 0.15 \text{ m} \times 0.15 \text{ m}$ [1] $= 0.003375 \text{ m}^3 = 3.375 \times 10^{-3} \text{ m}^3$ [1] Density = mass \div volume [1] $= 8 \text{ kg} \div 3.375 \times 10^{-3} [1]$ $= 2370 \text{ kg/m}^3$ [1] which is within the limits for the project [1]

- 9. (a) Mass of water = density \times volume = 1.00 g/cm³ \times 1000 cm³ = 1000 g [1]
 - (b) Mass of brine = density \times volume = 1.04 g/cm³ \times 1000 cm³ = 1040 g [1]
 - (c) Mass of salt in brine = mass of brine mass of water = 1040 g 1000 g = 40 g [1]
 - (d) Mass of water = density \times volume = 1.00 g/cm³ \times 500 cm³ = 500 g [1] Mass of brine = density \times volume = 1.08 g/cm³ \times 500 cm³ = 540 g [1] Mass of salt in brine = mass of brine – mass of water = 540 g - 500 g = 40 g [1]
 - (e) The brine measured out contains 40 g of salt [1] (the exact amount required in 1000 cm³ of the new solution). But it contains only 500 cm³ of water (and 1000 cm³ of water are required) so the technician needs to add an additional 500 cm³ of water [1].
- **10. (a)** Volume = mass \div density [1]

 $= 150.0 \text{ g} \div 19.3 \text{ g/cm}^{3}$ [1]

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= 7.77 \text{ cm}^{3} [1]
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- (b) Total volume = volume of gold + volume of copper [1] $= (7.77 + 5.60) = 13.37 \text{ cm}^3 [1]$
- (c) Density = mass ÷ volume [1] $= 200 \text{ g} \div 13.37 \text{ cm}^{3}$ [1] $= 15.0 \text{ g/cm}^{3}$ [1]

1.4A Energy Resources and Efficiency

- 1. Mass [1], pressure [1] and weight [1] are not energy forms. (All the others are forms of energy.)
- 2. (a) Energy cannot be created or destroyed (or the total amount of energy in a closed system is constant). [1] It can only change its form. [1]
 - (b) The total output energy is 1200 J, so the sum of the heat and sound energy is 900 J. [1] So the sound energy is 300 J and the heat energy is 600 J. [1] Total useful energy = kinetic energy + useful heat energy = 300 J + 300 J = 600 J [1]
- 3. **C** Lifting an apple 1 metre off the floor uses approximately 1 joule of energy. [1]
- (a) Renewable energy will never run out. [1] 4. Non-renewable energy cannot be replaced in less than a human lifetime. [1]
 - (b) Renewable: Solar, hydroelectric, tidal, wave, wind, geothermal [3] Non-renewable: coal, oil, gas, turf, lignite, nuclear [3] (A 1/2 mark is awarded for each, rounded down. Note that other correct answers would gain credit. Those given above are the most common.)
 - (c) Advantages: Relatively cheap start-up costs, large reserves of fuel (especially coal) [2] Disadvantages: Non-renewable, very polluting (emit greenhouse gases) [2]
 - (d) Hydroelectricity: destroys habitat. [1] Wind: visually polluting [1]
- 5. (a) Carbon dioxide (from fossil fuels) [1] (b) Oxides of sulfur and nitrogen (from coal and oil) [1]
- **6.** Efficiency = useful output energy ÷ total input energy [1] $= (340) \div (340 + 150 + 10) [1]$ = 0.68 [1]



1 mark for each entry on the diagram [3]

- (b) Efficiency = useful output energy ÷ total input energy [1] $0.3 = 90 \div \text{total input energy} [1]$ Giving: total input energy = 300 MJ [1]
- 8. (a) Nuclear fission [1]
 - (b) Uranium and plutonium [2]
 - (c) Both uranium and plutonium are in finite supply and will eventually run out. [1]

9. Completed table:

Height, <i>h</i> / m	10	7	4	2
Е _р / Ј	140	98	56	28
<i>E</i> _k / J	0	42	84	112

Method 1

Since ball is at rest at 10 m height, its kinetic energy is zero at that height [1]

At 7 m, the height is 70% of the original height, so the potential energy there is 70% of the original 140 J, which is 98 J. [1]

The total energy at the start is 140 J, so E_{k} at 7 m is 140 – 98 = 42 J [1]

When $E_p = 56$ J, the kinetic energy is 140 – 56 = 84 J [1]

When $E_{p} = 56$ J it now has $56 \div 140 = 40\%$ of the original E_{p} .

So the height is 40% of the original height, and 40% of 10 m is 4 m [1]

When E_k is 112 J, then $E_p = 140 - 112 = 28$ J [1]

An E_p of 28 J is exactly half of that in the column to the left, so the height is also half of the 4 m, i.e. the height is 2 m. [1]

Method 2

Since ball is at rest at 10 m height, its kinetic energy is zero at that height [1] At 10 m: $E_p = mgh$, so $140 = m \times 10 \times 10$, giving m = 1.4 kg [1] At 7 m: $E_p = 1.4 \times 10 \times 7 = 98$ J. So $E_k = 140 - 98 = 42$ J [1] When $E_p = 56$ J, $E_k = 140 - 56 = 84$ J, [1] and since $E_p = mgh$, $56 = 1.4 \times 10 \times h$, giving h = 4 m [1] When $E_k = 112$ J, $E_p = 140 - 112 = 28$ J [1] And since $E_p = mgh$, $28 = 1.4 \times 10 \times h$, giving h = 2 m [1]





1 mark for each entry on the diagram [4]

1.4B Work, Power, Kinetic Energy and Gravitational Potential Energy

1. (a) Work = $F \times d[1]$ = 30 N × 2.4 m [1]

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= 72 J [1]
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- (b) We assumed in (a) that the work was done against a frictional force of 30 N [1], so the pushing force and the friction force must be in equilibrium [1].
- 2. (a) Work = F × d [1] = F × 30 m = 60 J [1] so the gravitational force F = 2 N [1]
 - (b) Since F = mg [1] $2 = m \times 10$ [1] so m = 0.2 kg = 200 g [1]
- 3. Work = energy = mgh [1] So 80 000 = 400 × 10 × h [1] giving h = 20 m [1]
- **4.** (a) Useful work = work done raising the load = mgh [1]
 - $= 100 \times 10 \times 0.7$ [1]
 - = 700 J [1]
 - (b) Work on ramp = $F \times d$ [1] = 500 × 2 [1] = 1000 J [1]
 - (c) Work done against friction = total work useful work = 1000 J 700 J = 300 J [1]
 - (d) Work done against friction = friction force × distance [1]
 - 300 J = friction × 2 m [1] giving friction = 150 N [1]

5. Method:

- Measure mass, *m*, of the student in kg on bathroom scales.
- Measure the vertical height, *h*, of a raised platform in metres (for example, 2 breeze blocks on top of each other) with a metre rule.
- Using a stopwatch, time how long, *t*, in seconds, it takes the student to do 50 step-ups.
- Calculate the average power, *P* (in watts) using the equation $P = (F \times h \times 50) \div t$
- Allow the student to rest, then repeat and calculate the average power, for reliability.
- [6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 5 or more points would place you in the 5–6 mark band, 3 or 4 points would place you in the 3–4 mark band and 1 or 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

6. (a) This means the motor can do 5 J of useful work every second. [1]

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(b) Useful work = mgh [1]
= 12 × 10 × 2.5 [1]
= 300 J [1]
Time = useful work ÷ power [1]
= 300 J ÷ 60 W [1]
= 5 c [1]
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- = 5 s [1]
- 7. (a) 216 000 kg/hour = 216 000 kg in (60 × 60) s [1]
 = 216 000 kg ÷ 3600 s [1]
 = 60 kg/s [1]
 - (b) 12 kW = 12 000 J/s, so every second the power station produces 12 000 J of electrical energy. [1]
 - (c) Assume the kinetic energy of the water is converted to electrical energy. So in 1 second: Kinetic energy = $\frac{1}{2}mv^2 = 12\ 000\ [1]$ So: $\frac{1}{2} \times 60 \times v^2 = 12\ 000$, which gives $v^2 = 400$ and $v = 20\ m/s\ [1]$
 - (d) This is the minimum speed because the calculation takes no account of energy lost as heat and sound. [1]
- 8. Work done is against the motion of the car. k.e. = 78 400 = friction × distance [1] So 78 400 = 5600 × d [1] Giving d = 14 m [1]
- 9. (a) Potential energy = mgh [1] = 1.5 × 10 × 5 [1] = 75 J [1]
 - (b) Total energy lost = 75 + 33 = 108 J [1] So kinetic energy = initial energy – energy lost [1] = 120 - 108 = 12 J [1]
 - (c) Kinetic energy = $\frac{1}{2}mv^2 = 12$ [1] So $\frac{1}{2} \times 1.5 \times v^2 = 12$ [1] which gives $v^2 = 16$ and v = 4 m/s [1]
- **10. (a)** Kinetic energy when ball hits wall = $\frac{1}{2}mv^2$ [1] = $\frac{1}{2} \times 0.150 \times 20^2$ [1] = 30 J [1]
 - (b) Kinetic energy lost = 36% of 30 J [1] = 0.36 × 30 = 10.8 J [1] Kinetic energy left = 30 - 10.8 = 19.2 J [1]
 - (c) Kinetic energy when ball bounces off wall = $19.2 = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.150 \times v^2$ [1] So $v^2 = 19.2 \div 0.075 = 256$ [1] So v = 16 m/s [1]

1.4C Heat Transfer by Conduction, Convection and Radiation

- **1.** (a) Same length and same cross-section area. [2]
 - (b) Heat is conducted from the flame along each rod to the wax. [1] The wax melts and the pin falls off. [1]
 - (c) Copper (first), aluminium, iron, glass (last) [1]
 - (d) The materials in order of conductivity are: copper (highest), aluminium, iron and glass (lowest). [1] In general, metals are much better conductors than non-metals (like glass). [1]
 - (e) (i) Metals have free electrons which can move freely throughout the solid. [1] Free electrons absorb heat from the flame [1], allowing them to move much faster than before. [1] The fast, free electrons then collide with the metal's atoms. [1] Each free electron gives up a little of its kinetic energy in each collision. [1] These collisions cause the atoms to vibrate faster than before. [1]
 - (ii) Non-metals have no free electrons. [1] The glass atoms in the flame absorb heat directly. [1] This causes them to vibrate faster than before. [1] These vibrations are then passed from atom to atom through the solid structure. [1] This process is much slower than electron conduction in metals. [1]

2. (a) Convection [1]

- (b) The liquid atoms absorb heat and move faster. [1] Near the heat source the molecules' average separation increases [1] so the density of the liquid falls. [1] The hotter, less dense liquid rises. [1] Cooler water moves downwards to replace the upward-moving hot water. [1] A convection current is set up in the liquid. [1]
- 3. (a) To be a fair test, both sides of the metal must be at the same temperature. [1] This happens because: If one side is hotter than the other, heat will conduct through the metal from the hot side until both sides are at the same temperature. [1] Copper is an excellent heat conductor. [1]
 - (b) It feels warmer when facing the dull black side than when facing the polished, white side. [1]
 - (c) Matt black surfaces are better emitter than shiny white surfaces. [1]
- **4.** (a) The cork falls first from the dull black surface. [1]
 - (b) Dull black surfaces are better absorbers of heat than shiny white surfaces. [1]
 - (c) Shiny white surfaces are better reflectors of radiation than dull black surfaces. [1]
- **5.** (a) Convection (in air) [1]
 - (b) The smoke is carried by the cool air moving down chimney **B**. [1]
 - (c) Air above the candle flame absorbs heat from the flame. [1] This air expands, becomes less dense than the surrounding air and rises up chimney A. [1] The cool air in the "tunnel" moves to the left to replace the air which has gone up chimney A. [1] This draws cool air down chimney **B**. [1] The movement of the smoke shows the movement of the air in the apparatus. [1]

- "Coldness" does not move. [This is important, but alone it would not gain credit.] The cold metal gate absorbs heat from the person's hand. [1] The movement of heat from the hand causes it to reduce in temperature. [1] So, the hand feels colder. [1]
- 7.

Heat loss through	Method of reducing heat loss	How losses are reduced
Walls	Cavity wall insulation	The cavity between the outside and inside walls is filled with fibre glass wool / mineral wool / urea formaldehyde / polystyrene beads (all are good insulators).
Roof	Loft (or attic) insulation	Mineral wool or fibre glass wool or polystyrene beads are placed between the joists and rafters to reduce heat loss through the roof by conduction and convection .
Windows	Double glazing	The two glass panes trap air (or argon). A trapped gas is a much better insulator than the glass used. So the heat lost by conduction is greatly reduced.

One mark for each method of reducing heat loss. [3] One mark for each word or phrase in the final column. [7]

- 8. (a) Heat cannot travel from the hot liquid to the external environment by conduction or convection through the vacuum. [1]
 - (b) The inner silvered surface reaches almost the same temperature as the liquid as a result of conduction.

But, being silvered, the surface is a poor radiator of heat. [1]

Very little heat which does reach the outer silvered surface is absorbed, because silvered surfaces are poor absorbers. [1]

Most of the heat is reflected back towards the hot liquid. [1]

This means that the hot liquid loses very little heat by radiation. [1]

1.5A Atoms, Nuclei and Isotopes

1. (a) Negative electrons were dotted throughout the atom like currants in a bun (or plums in a pudding). [1]

The positive charge was spread throughout the atom like the dough in the bun. [1]

- (b) (Ernest) Rutherford [1] and (Niels) Bohr [1]
- (c) In the modern theory:

there is a tiny central nucleus which contains almost all of the atom's mass [1] while negatively-charged electrons are located in shells outside the central nucleus. [1] The nucleus contains positively-charged protons and neutral neutrons. [1] Electrons orbit the nucleus in circular paths. [1]

2. Experiment (key points):

- in a highly evacuated chamber
- alpha-particles from a radioactive source are projected normally at a very thin gold foil;
- the objective of a moveable telescope is coated with a phosphor (such as zinc sulfide);
- when alpha-particles strike the phosphor they produce a tiny flash of light (a scintillation)
- which reveals their presence;
- the telescope can move around the gold foil
- so that the physicist can see where the alpha-particles go after striking the foil.

Observations and deductions

- The majority of the alpha-particles passed straight through the gold foil with little or no deflection. This led Rutherford to think that the majority of the atom was simply empty space.
- A small number of alpha-particles were deflected through angles between zero and 90 degrees.
- This led Rutherford to believe there might be a charged particle inside the atom causing either repulsion or attraction of the alpha-particles and hence altering their path (but at this stage he was unsure whether the charge was positive or negative).
- An even small number of alpha-particles were "back-scattered" they never get through to the other side of the foil.
- This led Rutherford to conclude there was a positive charged particle (to cause repulsion of the alpha-particles, that the atom's positively charged particle was very small (to explain why so few alpha-particles were "back-scattered")
- and that this particle in the gold foil was much more massive than the alpha-particle (because it was not knocked out of the gold). Rutherford called this positive particle the nucleus of the atom. [6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 10 or more points would place you in the 5-6 mark band, 6 to 9 points would place you in the 3–4 mark band and 3 to 6 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

- 3. (a) An atom contains the same number of positive protons as it does negative electrons. [1] The magnitude of the charge on the proton is the same as that on the electron. [1]
 - (b)

Particle	Relative mass	Relative charge	Location
neutron	1	0	In the nucleus
electron	¹ / ₁₈₄₀	-1	Orbits the nucleus
proton	1	+1	In the nucleus

Each correct row is awarded 1 mark. [3]

- 4. (a) A is the Mass Number [1], Z is the Atomic Number [1]
 - (b) X is the chemical symbol for the element [1]
 - (c) There are 92 protons [1] and 143 neutrons [1] in the nucleus. There are no electrons in the nucleus [1] (but 92 electrons orbit in shells surrounding the nucleus).
- 5. (a) Isotopes are different forms of the same element having the same number of protons [1] but a different number of neutrons in their nuclei. [1] (Note that in Double Award Science papers the first point is regarded as 'threshold'. This means that candidates would not get access to the second mark if the first point was missing or wrong.)
 - (b) The isotopes are ${}^{12}_{6}A$ and ${}^{13}_{6}B$. [1]

1.5B Radioactive Decay, **Dangers of Radioactivity and Half-life**

- 1. (a) Radioactivity is the emission of alpha, beta or gamma radiation [1] by an unstable, disintegrating nucleus. [1]
 - (b)

Radiation	Relative mass*	Relative charge*	Nature	Range in air	Stopped by	lonising effect
Alpha	4	+2	Particle, consisting of 2 protons and 2 neutrons	A few cm	Thin paper	Very strong
Beta	¹ / ₁₈₄₀	-1	Particle, a fast electron	Up to a few metres	Few mm aluminium	Weak
Gamma			High energy electromagnetic wave	Unlimited	Thick lead	Very weak

(1 mark for each table entry completed.) [11]

(c) Random means that we cannot predict when a particular nucleus will decay. [1] Spontaneous means that there is no process by which we can speed up or slow down radioactive decay. [1]

2. (a)
$$\frac{235}{92}U \rightarrow \frac{231}{90}Th + \frac{4}{2}\alpha$$
 (Each box is awarded (b) $\frac{14}{6}C \rightarrow \frac{14}{7}N + \frac{0}{-1}\beta$ (Each box is awarded (c) $\frac{228}{88}Ra \rightarrow \frac{228}{88}Ra + \gamma$ (Each box is awarded (c) $\frac{228}{88}Ra \rightarrow \frac{228}{88}Ra + \gamma$

one mark.) [4]

one mark.) [4]

one mark.) [3]

- 3. (a) Background radiation is that which can be detected when all known sources of radioactivity have been removed from the room. [1]
 - (b) Examples of sources: radiation from the Sun, leaks from nuclear power stations, granite rocks on the Earth's surface. [3]
 - (c) The background count is measured first, and then subtracted from the count from the source to obtain the corrected count. [2]

4. Method:

- Determine the background count rate
- with a GM tube and scaler.
- Place the GM tube directly in front of a clamped source of alpha particles,
- with the tube on a wooden cradle and connected to the scaler.
- Slowly move the GM tube away from the alpha source
- until the scaler reading falls to the level of the background count.
- With a ruler, measure the distance between the GM tube and the source.
- This is the range of alpha particles in air.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 6 or more points would place you in the 5–6 mark band, 4 or 5 points would place you in the 3–4 mark band and 2 or 3 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

- 5. Missing words in bold:
 - Alpha radiation is not as dangerous if the radioactive source is outside the body, because it cannot pass through the **skin** and is unlikely to reach **cells** inside the body.
 - Beta and gamma radiation can penetrate the skin and cause damage to cells.
 - Alpha radiation will damage cells if the radioactive source has been breathed in or swallowed.
 - All three forms of radiation can cause **cancer**.

(1 mark for each correct completion) [7]

- 6. Examples of steps:
 - Wearing protective clothing.
 - Keeping the source as far away as possible by using tongs.
 - Being exposed to the source for as short a time as possible.
 - Keeping radioactive materials in lead-lined containers.

[4]

7. (a) The half-life of a radioactive material is the time taken [1]

for its activity to fall to half of its original value. [1]

(Note that in Double Award Science papers the first point is regarded as 'threshold'. This means that candidates would not get access to the second mark if the first point was missing or wrong.)

(b) Activity halves after each half-life.
 So after one half-life the activity will fall to 500 cps. [1]
 (After two half-lives the activity will fall to 250 cps.)
 After three half-lives the activity will fall to 125 cps. [1]

So 21.6 hours is three half-lives. Therefore one half-life is $21.6 \div 3 = 7.2$ hours. [1] See table below.

(Note that the first halving would be given the initial mark. Two further halvings to 125 cps, *but no further*, would gain the second mark.}

Activity / cps	1000	500	250	125
Time in half-lives	0	1	2	3
Time in hours	0	7.2	14.4	21.6

(c) 10 hours as this is the time for the activity to halve. [1]



Scales – covering at least half of paper [1] Axes labels as in table [1] Points plotted [2]

[5 or 6 points correctly plotted (to within $\frac{1}{2}$ a small square) – 2 marks;

3 or 4 points correctly plotted – 1 mark only, < 3 points correct – 0 marks] Curve drawn through all the points [1]

- (b) After 25 minutes the activity is between 400 and 440 cps. Any value in this range would gain credit. [1]
- (c) Approximately 8 minutes [1]
- (d) From the graph, activity drops to half its initial value after 14 minutes [1] (actual value is 13.6 minutes)
- **9.** Activity levels after each half-life: $32 \rightarrow 16 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1$. [1] Since each arrow represents a half-life, the activity will fall to 1 cps after 5 half-lives. [1] So it will take 5×138 days = 690 days. [1]
- 10. 20 hours represents the passage of 4 half-lives. [1] So original activity = $60 \times 2 \times 2 \times 2 \times 2 = 960$ cps [1]

1.5C Uses of Radioactivity, and Fission and Fusion

- 1. (a) Industry: controlling steel thickness in rolling mills / other appropriate response. [1]
 - (b) Medicine: Gamma-ray scanning to detect heart and coronary artery abnormalities / other appropriate response. [1]
 - (c) Agriculture: Gamma ray sterilization of foods to prolong their shelf life / other appropriate response. [1]
- 2. (a) Beta. [1]
 - Alpha radiation would not penetrate the pulp. [1] There would be too little absorption of gamma radiation, [1] (so it would not be sufficiently different when the thickness was too great or too little.)
 - (b) Long half-life. [1] A short half-life emitter would have to be replaced too often. [1]
 - (c) The operator sets the desired thickness and counter detection rate. [1] When the rate is too high, it means that the pulp is too thin (so there has been less absorption) [1] and the control box sends the command to the rollers to squeeze less. [1] When the rate is too low, it means that the pulp is too thick (so there has been more absorption) [1] and the control box sends the command to the rollers to squeeze more. [1]
- **3.** (a) Ionisation is the loss (or gain) of electrons by atoms (or molecules) [1] as a result of a collision with other particles or radiation. [1]
 - (b) Smoke absorbs the alpha particles [1] reducing the number of ions reaching the detector (and causing an alarm to go off). [1]
 - (c) Beta and gamma are much more penetrating than alpha and would be much less absorbed by the smoke. [1]
 - (d) Americium-241 is the better choice. [1] Its long half-life means it will not have to be replaced in the detector. [1]
- 4. (a) Carbon-14 is part of the carbon we ingest as food. [1]
 - (**b**) 56 cpm for 14 grams is 56 ÷ 14 = 4 cpm per gram. [1]
 - (c) Decay from 16 cpm to 8 cpm to 4 cpm takes 2 half-lives. [1] So the body is 2 × 5600 = 11 200 years old. [1]
- **5.** (a) (i) 235 [1]
 - **(ii)** 143 [1]
 - **(iii)** 235 [1]
 - (b) $\frac{239}{94}$ Pu $\rightarrow \frac{235}{92}$ U + $\frac{4}{2}$ α

One mark for each box. [4]

- 6. (a) Fission is the splitting of the nucleus of a heavy element [1] to create two new nuclei [1] and two or three neutrons. [1]
 - In the process vast quantities of energy are produced. [1]
 - (b) Description:
 - The fuel used in a fission reactor is uranium (or an isotope of plutonium or thorium).
 - Fission is initiated by a nucleus of the uranium fuel absorbing a slow moving neutron (causing the uranium of nucleus to split and to create two new nuclei and two or three neutrons).
 - These neutrons go on to cause further fission,
 - thus producing a chain reaction.
 - The fission nuclei carry a lot of kinetic energy.
 - This is captured by water flowing through the reactor
 - and is used to produce the steam needed to drive a turbo-generator which produces electricity.
 - The major hazard of nuclear fission is that the waste products are highly radioactive, with very long half-lives.
 - There is always the danger of a leak of radioactive material into the environment. There is, as yet, no known way to store these waste products until they become safe. (At the moment the radioactive waste is stored deep underground, but it is feared that over tens of thousands of years geological activity could bring it to the surface.)

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 8 or more points would place you in the 5–6 mark band, 5 to 7 points would place you in the 3–4 mark band and 3 or 4 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

- 7. (a) Nuclear fusion is the joining together of two light nuclei [1] to create a new heavier nucleus with the release of energy. [1]
 - (b) Nuclear fusion occurs naturally in the stars, including our Sun. [1]
 - (c) Problem 1: Achieving and maintaining the enormously high temperatures (>10 000 000 °C) needed to get nuclear fusion to occur. [1] Problem 2: Containing reactants for long enough to obtain a sustained reaction. [1]
 - (d) (i) ${}_{1}^{2}H + {}_{1}^{3}H \rightarrow \underline{4} He + {}_{0}^{1}n$

One mark for each box. [2]

- (ii) The particle is a neutron. [1]
- 8. (a) Advantage: Local employment. [1]

Disadvantage: Possibility of leakage of radioactive materials. [1]

- (b) The mining, transport and purification of the uranium ore releases significant amounts of greenhouse gases into the atmosphere. [1]
- (c) Chernobyl: A failure in the cooling system in this Ukrainian reactor [1] caused the top to be blown off the reactor [1] (releasing vast quantities of highly radioactive waste into the environment.) Fukushima: This Japanese nuclear power station was struck by an earthquake [1] and then by a tsunami (in 2011) [1] (The core suffered a 'meltdown' and lots of radioactive material was scattered in the surrounding environment.)

- 9. (a) Seawater for deuterium [1] and lithium (in the Earth's crust) for tritium. [1]
 - (b) 4 000 000 (four million times more energy) [1]
 - (c) Unlike fission, fusion produces no long half-life radioactive waste products. [1] Unlike fossil fuels, fusion produces no greenhouse gases such as carbon dioxide. [1]
- 10. (a) International Thermonuclear Experimental Reactor [1]
 - (b) ITER (which also means "the way" in Latin) is an energy project involving 35 nations in the construction of a fusion reactor (in southern France). [1] It is thought that no single country could afford this project and it is unlikely that many countries would have the technical expertise to do the work alone. That is why international cooperation is required. [1]

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Unit 2:

Waves, Light, Electricity, Magnetism, Electromagnetism and Space Physics



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24

2.1A Waves

- **1.** In longitudinal waves the particles vibrate [1] parallel to the direction in which the wave is moving. [1] In transverse waves, the particles vibrate [1] perpendicular to the direction in which the wave is moving. [1]
- 2. (a) Transverse: water waves, electromagnetic waves (such as light) (or other valid example). [1] (b) Longitudinal waves: sound, ultrasound [1] (Note that it is best not to refer to slinky springs which can produce *both* types of wave.)
- 3. (a) Frequency is the number of compressions passing a fixed point every second. [1] (b) Wavelength is the distance between the centres of two consecutive compressions. [1]
 - (c) Amplitude is the maximum distance any particle in the wave moves [1] from the centre of its motion. [1]
- **4.** (a) Amplitude = 2.5 cm [1]
 - (b) Frequency = 1 ÷ time between peaks [1] $= 1 \div 8 s = 0.125 Hz [1]$
 - (c) Wavelength = distance between peaks. In this case, however, the horizontal axis is time, not distance [1] (so it is not possible to find the wavelength from the graph).
- 5. Sound can cause paper pieces to jump; or an opera singer's sound can break a wine glass; or other valid example. [1]
- 6. (a) Amplitude = $30 \text{ cm} \div 2 = 15 \text{ cm} [1]$
 - (b) First to sixth peak = 6 1 = 5 waves. [1] Wavelength = $45 \div 5 = 9 \text{ cm} [1]$
 - (c) Frequency = speed ÷ wavelength [1] $= 36 \text{ cm/s} \div 9 \text{ cm} [1]$ = 4 Hz [1]
 - (d) 4 Hz means 4 waves pass every second, [1] so $4 \times 60 = 240$ waves pass every minute. [1]

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Wavelength	Frequency	Speed
2 m	5 Hz	10 m/s
12 cm	500 Hz	60 m/s
18 mm	150 Hz	2.7 m/s
1.6 mm	5 kHz	8 m/s
5×10 ⁻⁷ m	6×10 ¹⁴ Hz	3×10 ⁸ m/s

(1 mark for each table entry completed.) [4]

2.1A WAVES

- **8.** Time between compressions = $4.5 \text{ s} \div 9 \text{ waves} = 0.5 \text{ s}$ Frequency = number of waves passing in 1 second = $1 \div 0.5 = 2$ Hz [1] (first mistake: third student took *f* to be 0.45 Hz). Wavelength = distance between compressions = $90 \text{ cm} \div 9 \text{ waves} = 10 \text{ cm} [1]$ (second mistake: third student took wavelength to be 9 cm)
- 9. (a) An analogy is a comparison. [1]
 - (b) Glass is analogous to the shallow water; air is analogous to the deep water. [1]
 - (c) Their wavelength increases. [1]
 - (d) Their wavelength increases. [1]
- **10. (a)** 20 Hz 20 000 Hz [2]
 - (b) Ultrasound [1]
 - (c) (i) Medicine: scanning for heart or coronary artery abnormalities. [1]
 - (ii) Industry: scanning to find defects in metals (for example, railway tracks). [1]

2.1B Reflection, Refraction, Echoes, Sonar and Radar

- 1. (a) Arrow as shown in the diagram. [1]
 - (b) Reflected wavefronts as shown in the diagram: parallel to each other [1], equally spaced [1] and with the same wavelength as the incident waves [1].



- 2. (a) Arrow as shown in the diagram. [1]
 - (b) Refracted wavefronts similar to that shown in the diagram: parallel to each other [1], equally spaced [1] and with a smaller wavelength than the incident waves [1].



- Frequency in deep water = speed ÷ wavelength [1] = 4.5 cm/s ÷ 1.8 cm [1] = 2.5 Hz [1] Frequency in shallow water is also 2.5 Hz [1]
- 4. (a) An echo is a reflection of sound. [1]
 - (b) (i) The first sound came directly from Pádraig. [1] The second sound is the echo of this first sound from the wall. [1]
 - (ii) The additional path taken by the second sound is (2×170) m = 340 m [1] The time to travel this additional path is 1.0 s, so the speed of sound is 340 m \div 1 s = 340 m/s [1]

- 5. (a) Distance to fish and back to trawler = speed × time [1] = $1500 \text{ m/s} \times 0.3 \text{ s}$ [1] = 450 m [1] Distance between fish and trawler = $\frac{1}{2} \times 450 = 225 \text{ m}$ [1]
 - (b) The second echo is from the sea bed. [1]
- 6. (a) RADAR (radio detection and ranging) is an electromagnetic wave in the microwave part of the spectrum. [1]
 SONAR (sound navigation and ranging) is an ultrasound wave (although some sonars are in the audible range). [1]
 - (b) Radar is very much faster than sonar. All aircraft are fast, and some are so fast that a sonar wave would never reach them. [1]
 In addition, by the time a sonar wave travelled the distance from the emitting device, the aircraft would no longer be there. [1]
 - (c) Distance to aircraft and back to station = speed × time [1] = 3×10^8 m/s × 1.5×10^{-3} s [1] = 4.5×10^5 m [1] Distance between aircraft and station = $\frac{1}{2} \times 4.5 \times 10^5$ m = 2.25×10^5 m = 225 km [1]
- 7. (a) $3 \text{ squares} = 3 \times 50 \text{ microseconds} = 150 \text{ microseconds} [1]$
 - (b) Distance from A to B and back to A = speed × time [1] = $1500 \text{ m/s} \times 150 \times 10^{-6} \text{ s}$ [1] = 0.225 m = 225 mm [1] Distance between A and B = $\frac{1}{2} \times 225 \text{ mm} = 112.5 \text{ mm}$ [1] (which is just over 110 mm as required).
 - (c) Some of the ultrasound energy is absorbed in the baby's tissues. [1]
- 8. (a) Wavelength = 12 cm ÷ 6 wavelengths [1]
 = 2 cm [1]

```
(b) 5 waves pass in 20 s [1]
so f = 5 \div 20 = 0.25 Hz [1]
Speed = frequency × wavelength [1]
= 0.25 Hz × 2 cm [1]
= 0.5 cm/s [1]
```

9. Distance to crack and back to detector = speed × time [1] = $6000 \text{ m/s} \times 20 \times 10^{-6} \text{ s}$ [1] = 0.12 m [1] Distance between crack and detector = $\frac{1}{2} \times 0.12 \text{ m} = 0.06 \text{ m} = 6 \text{ cm}$ [1]

```
10. Speed of first wave = frequency × wavelength [1]
= 1.5 \times 10^{6} Hz × 1000 \times 10^{-6} m [1]
= 1500 m/s [1]
Speed of second wave = 1500 m/s [1]
Wavelength of second wave = speed ÷ frequency [1]
= 1500 m/s ÷ 2 \times 10^{6} Hz [1]
= 7.5 \times 10^{-4} m = 750 micrometres [1]
```

2.1C Electromagnetic Waves

- 1. They can all travel in a vacuum OR they all travel at the speed of light in air/vacuum. [1]
- 2. radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays ([1] for correct names, [1] for correct order) [2]
- 3. Speed = frequency × wavelength = 200 000 × 1500 = 3×10⁸ m/s [1] Time = distance ÷ speed [1] = 900 000 m ÷ 3×10⁸ m/s [1] = 0.003 s = 3 ms [1]
- 4. Reduce exposure time in the sun [1] and apply frequent sun-blocks. [1]
- **5.** Infrared light can cause skin burns. [1]

6.

Name of wave	Typical wavelength / m
Infrared	1×10 ⁻⁵
Radio waves	1000
Gamma rays	1×10 ⁻¹¹
Visible light	5×10 ⁻⁷

(1 mark for each table entry completed) [4]

Note: This question requires candidates to first identify the missing regions. Then, candidates should arrange the figures in the table in order of increasing values. Finally, place the regions side-by side with the increasing wavelengths and write the names in the table.

- 7. (a) Gamma rays are much more ionizing than ultraviolet light. [1]
 - (b) Gamma rays can penetrate much deeper into the human body than ultraviolet light. [1]

2.2A Reflection and Refraction of Light

1. The angle of incidence is equal to the angle of reflection. [1]



(1 mark for each of normal, incident ray, reflected ray, angle of incidence and angle of reflection) [5]

- Virtual [1]
 Erect [1]
 Same size as the object [1]
 Laterally inverted [1]
 Same distance behind the mirror as the object is in front of the mirror [1]
- 4. (a) Angle of reflection at $M_1 =$ angle of incidence at $M_1 = 40^{\circ}$ [1] Angle between M_1 and reflected ray is 50° [1] Angle between ray incident on M_2 and mirror is (90° – 50°) = 40° [1] So angle of incidence at $M_2 = 50^{\circ}$ [1] Thus angle of reflection at $M_2 = 50^{\circ}$ [1]
 - (b) The rays are parallel to each other (this effect is used in bicycle reflectors) [1]



The angles marled x are all equal to each other (alternate, vertically opposite, law of reflection). [1] So: $2x = 60^{\circ}$ giving $x = 30^{\circ}$. [1]

6. (a) Refraction is the bending of light as it passes from one material into another. [1]



(1 mark for refraction on correct side of normal, 1 mark for r > i) [2]



 wavelength decreases [1] frequency is unchanged [1] speed decreases [1]

(b)

8. (a) See diagram below. (1 mark for reflected ray inside glass, 1 for refracted ray) [2]
(b) See diagram below. (1 mark for total internal reflection inside glass, 1 for no refracted ray) [2]



Ray diagram **A**

Ray diagram ${\boldsymbol{\mathsf{B}}}$

9. Method:

- Place a semi-circular glass block on a sheet of white paper and draw around its outline with a pencil.
- Direct a ray of light from a ray box at the middle of the block's straight edge, as in diagram A.
- Observe both the refracted and the faint internally reflected ray.
- Slowly move the ray box so as to increase the angle of incidence at the straight edge until the emergent ray is seen along the straight edge of the block.
- Mark two small pencil crosses on the ray incident on the curved surface of the block.
- Remove the glass block.
- With a ruler, draw a line joining the cross marks and extend the line to the straight edge outline.
- With a protractor, draw the normal at the point of emergence (denoted by a dotted line in the diagrams).
- With a protractor, measure the angle of incidence at this point of emergence. This is the critical angle and is identified in diagram B.
- Diagram C shows what is observed if the student moves the ray box a little too far, so as to exceed the critical angle.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 7 or more points would place you in the 5–6 mark band, 4 to 6 points would place you in the 3–4 mark band and at least 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)



(1 mark per diagram) [3]

10. (a) Points:

- Optical fibres are lengths of solid glass core with an outer plastic sheath.
- The material surrounding the glass core is less optically-dense than the core.
- Provided the fibre is not bent too tightly, light will strike the core-cladding boundary at an angle greater than the critical angle
- and be totally internally reflected at the surface of the glass core.
- Repeated internal reflections allow the light to pass through the fibre with minimum loss of energy.
- (1 mark for each of the bullet points) [5]
- (b) Medical use: endoscopes (in keyhole surgery) (or other valid example) [1] Non-medical use: Data communications (for example, broadband) (or other valid example) [1]

2.2B Dispersion and Lenses

- 1. (a) Each colour is refracted by a slightly different amount. [1]
 - (b) Red, Orange, Yellow, Green, Blue, Indigo, Violet [1]
 - (c) A (visible) spectrum [1]
 - (d) Violet [1]
 - (e) Violet slows down the most when it enters the glass. [1]
 - (f) Red [1]
 - (g) Wavelength decreases, frequency remains the same. [2]
- 2. (a) Lens B is concave [1]
 - (b) A is convex [1]
- **3.** (a) The focal length is the distance between the principal focus [1] and the optical centre of a lens. [1]



4. The ray diagram should look like that shown below.



[5]

5. The ray diagram should look like that shown below. [6] Image properties: real [1]; inverted (upside down) [1]; 12 cm from the optical centre of the lens [1]; 10 cm high. [1]



6.

Desition of			Proper	ties of the Ima	ties of the Image		
object	Location of image	Erect or Inverted	Nature	Enlarged or Diminished	Application		
Between lens and F	Same side as object, further from lens	Erect	Virtual	Enlarged	Magnifying glass		
At F	At infinity			Enlarged	Searchlight		
Between F and 2F	Beyond 2F	Inverted	Real	Enlarged	Cinema projector		
At 2F	At 2F	Inverted	Real	Same size	Telescope – erecting lens		
Just beyond 2F	Between F and 2F	Inverted	Real	Diminished	Camera		
At infinity	At F	Inverted	Real	Diminished	Camera		

(1/2 mark for each table entry completed; round down to nearest mark) [8]

2.2B DISPERSION AND LENSES

7. (a) (i) [1] and (ii) [1]





(b) Short sight is a disease of the eye in which the eyeball is too long (or the lens is too thick). [1] It is corrected using a concave lens in front of eye. [1]

(This makes the incoming rays of light diverge, as shown in the diagram, so that they meet on the retina after passing through the eye.)



Diagram: (1 mark for lens correctly marked; 1 for two rays correctly marked; 1 for rays converging at the retina) [3]

- 8. Method:
 - This experiment requires a metre ruler, a convex lens in a suitable holder and a white screen.
 - Tape the ruler to the bench and place the white screen at the zero centimetre mark.
 - Place the lens, in its holder, beside close the screen.
 - Slowly move the lens away from the screen until the image of an object several metres away is as sharp as possible.
 - Measure the distance from the centre of the lens to the screen, using the metre ruler.
 - This distance is the focal length of the lens.

[6]

- 9. Completed sentences:
 - A (converging / diverging / parallel) lens is used to produce an image of an object on a (film / screen / lens). [2]
 - The image is (real / virtual / neither real nor virtual). [1]
 - The image is (larger than / smaller than / the same size as) the object. [1]
 - Compared to the object, the image is (nearer to / further from / the same distance from) the lens. [1]
 - Compared to the object, we (know / can't tell) that the image is (erect / inverted). [2]

10. Diagram [4]



2.3A Electricity – Simple Circuits and Ohm's Law

- 1. (a) ammeter [1]
 - (b) voltmeter [1]
 - (c) lamp [1]
 - (d) resistor [1]
 - (e) rheostat [1]
 - (f) fuse [1]
 - (g) cell [1]
 - (h) battery [1]
 - (i) switch [1]
- **2.** (a) 3 V [1]
 - (**b)** 3 V [1]
 - (c) 1.5 V [1]
 - (**d**) 6 V [1]
 - (e) 4.5 V [1]
 - (**f**) 0 V [1]
- 3. (a) Conductors have free electrons, insulators do not. [1]
 (b) ([1] for each arrow) [2]



4. Q = lt [1]= 2.5 A × (5 × 60) seconds [1] = 750 C [1]

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5. (a) The current flowing in a metallic conductor is directly proportional to the voltage across its ends [1]

provided the temperature of the conductor remains constant [1].

- (b) Method:
 - (1) Connect, in series with each other, a variable resistor initially set to maximum resistance, an ammeter, a power supply unit (PSU) and a 50 cm length of resistance wire.
 - (2) Connect a voltmeter in parallel with the resistance wire.
 - (3) Switch on the PSU. Slowly decrease the resistance of the variable resistor until a current is observed on the ammeter and a voltage on the voltmeter.
 - (4) Record the readings of current and voltage in a prepared table.
 - (5) Switch off the PSU to allow the wire to cool to room temperature.
 - (6) Repeat steps (3) to (5) for currents up to about 1.0 A.
 - (7) Plot the graph of voltage against current and with a ruler draw the straight line of best fit.
 - (8) It will be a straight line through the (0, 0) origin, confirming that the voltage across the wire is directly proportional to the current flowing through it.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 7 or more points would place you in the 5-6 mark band, 4 to 6 points would place you in the 3–4 mark band and at least 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

6. (a) $R = V \div I[1]$

= 0.6 V ÷ 0.20 A [1] $= 3.0 \Omega [1]$ **(b)** $V = 0.25 \text{ A} \times 3.0 \Omega$ [1] = 0.75 V [1]

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(Curve [1], of increasing gradient [1], through the (0, 0) origin [1]) [3]



(Curve [1] crossing the vertical axis [1]) [2]

8. (a) $V = I \times R[1]$

- $= 0.3 \times 4 [1]$
- = 1.2 V [1]
- (b) 3 Ω: 0.2 A [1]
 - 6 Ω: 0.1 A [1]
- (c) $3 \Omega: V = I \times R = 0.2 \times 3 = 0.6 \text{ V} [1]$ 6 Ω: $V = I \times R = 0.1 \times 6 = 0.6$ V [1]
- (d) 1.8 V (the voltage across the 4 Ω resistor + the voltage across the 3 Ω and 6 Ω resistors). [1]

9.

Switch		Resistance between	
S1	S2	points A and B / Ω	
Open	Open	10	
Open	Closed	5.5	
Closed	Open	6	
Closed	Closed	5	

(1 mark for each table entry completed) [4]

Explanation:

- When both switches are open, the 6 Ω and 4 Ω resistors are in series, giving 10 Ω .
- When only S1 is open, the 6 Ω and 2 Ω are in parallel (giving 1.5 Ω). This 1.5 Ω is in series with the 4 Ω, giving 5.5 Ω.
- When only S2 is closed, the 6 Ω and 3 Ω are in parallel (giving 2 Ω). This 2 Ω is in series with the 4 Ω , giving 6 Ω.
- When both switches are closed, the 3 Ω , 6 Ω and 2 Ω are all in parallel (giving 1 Ω). This 1 Ω is in series with the 4 Ω , giving 5 Ω .

- **10. (a)** The ratio *V* ÷ *I* is constant. [1]
 - **(b)** $R = V \div I[1]$
 - $= 8 \Omega$ (for all values in the table) [1]
- **11. (a)** Connect two of the 2 Ω resistors in parallel to produce a 1 Ω resistor. [1]
 - (b) To the combination described in (a) connect a single resistor in series. [1]
 - (c) Connect two of the 2 Ω resistors in series with each other. [1]

- **1.** (a) Any TWO (1 mark each) from: cross section area, material wire is made from, temperature [3]
 - **(b)** A [1]
 - (c) The resistance of a metal wire is directly proportional to its length. [1]
- **2.** (a) 1.8Ω of wire has length 90 cm, so by proportion: 1 Ω of wire has length 90 \div 1.8 = 50 cm [1] 2Ω has length $2 \times 50 = 100$ cm [1]
 - (b) 50 cm of wire has resistance of 1 Ω , so by proportion: 10 cm of wire has resistance 0.2 Ω [1] 40 cm of wire has resistance $4 \times 0.2 = 0.8 \Omega$ [1]
- **3.** (a) Length, material, temperature [3]
 - (b) The resistance is decreasing as the cross-section area increases. [1]
 - (c) Resistance (vertical axis) against 1/Area [1]
 - (d) k = RA[1]
 - $= 48 \times 0.5$ [1]
 - = 24 [1]
 - Ω mm² [1]
 - (e) $R = k \div A = 24 \div 2.4 = 10 \Omega$ [1]
- **4.** (a) Halving the length halves the resistance to 2.4 Ω . [1] Doubling the area halves the resistance to 1.2Ω . [1] Joining 4.8 Ω and 1.2 Ω in series gives a total resistance of 4.8 + 1.2 = 6.0 Ω . [1]
 - (b) Joining 4.8 Ω and 1.2 Ω in parallel gives a total resistance of $(4.8 \times 1.2) \div (4.8 + 1.2)$ [1] $= 0.96 \Omega [1]$
- **5.** (a) Independent: cross-section area [1] Dependent: resistance [1] Controlled: length, material, temperature [3]
 - (b) Continuous: resistance, cross-section area, length, temperature [4] Categoric: material [1]
 - (c) Method:
 - Measure out and cut 50 cm lengths of wire, all of the same material, but with different crosssection areas. [1]
 - Using an ohmmeter across each wire, measure the resistance of each specimen and record the results in a table. [1]
 - Repeat the measurements. [1]
 - Calculate the average resistance for each cross-section area. [1]
 - For each wire calculate the product resistance × area [1]
 - RA will be a constant, demonstrating that resistance is inversely proportional to cross-section area. [1]
 - (d) Plot the graph of resistance (vertical axis) against the reciprocal of the cross-section area (1/ cross-section area). [1]

The graph is a straight line through the origin, confirming that $R \propto 1/A$ (or resistance is inversely proportional to area). [1]

6. As the temperature increases the lattice ions vibrate with greater frequency, greater amplitude and greater average speed. [3]

This causes the drifting free electrons to collide with the lattice ions with greater frequency. [1] At a given voltage, increased collision frequency reduces the rate of flow of charge [1] and hence increases the electrical resistance [1].

7. (a) Radius = half the diameter = $\frac{1}{2} \times 0.30 = 0.15$ mm [1] Area = πr^2 [1] $= \pi \times 0.152$ [1] $= 0.070 686 \text{ mm}^2$ [1] (b) Since resistance is inversely proportional to area of cross section, From the hint: $(R \times A)$ for first reel = $(R \times A)$ for second reel [1] $2.50 \times 0.070\ 686 = 10.00 \times A_{\text{second}}\ \text{reel}\ [1]$ Area of cross section of second reel = $(2.50 \times 0.070686) \div 10.00[1]$ $= 0.0176715 \text{ mm}^2$ [1] $0.0176715 = \pi r^2$ Therefore: $r^2 = 0.0176715 \div \pi = 0.005625$ [1] $r = \sqrt{(0.005625)} = 0.075 \text{ m}$ [1] Diameter = $2 \times \text{radius} = 2 \times 0.075 \text{ mm} = 0.15 \text{ mm}$ (as required) [1]

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2.3C Electrical Energy and Power, and Electricity in the Home

1. (a) Heat [1] **(b)** $I = P \div V[1]$ Current in conventional bulb = $150 \div 230$ [1] = 0.652 A [1] Current in LED = 35 ÷ 230 = 0.152 A [1] Additional current on conventional bulb = 0.652 - 0.152 = 0.5 A (to 1 dp) [1] (c) Additional power of conventional bulb = 150 - 35 = 115 W [1] Additional energy used = power \times time [1] $= 115 \times (60 \times 60 \times 2000)$ [1] $= 828 \times 10^6 \text{ J} = 828 \text{ MJ} [1]$ 2. (a) A kilowatt-hour is the amount of electrical energy [1] used by a device rated at 1000 J/s in one hour. [1] **(b)** 2750 W = 2.750 kW [1]Energy used in kWh = number of kilowatts \times number of hours [1] $= 2.750 \times (24 \div 60) [1]$ = 1.1 kW h [1]Cost = number of kW h \times cost of 1 kWh [1] $= 1.1 \times 17p[1]$ = 18.7 pence (to 1 dp). [1] 3. (a) Total time spent daily in shower = (7 + 9 + 8 + 6) = 30 minutes = 0.5 hours [1] Total time in shower over 1 week = $0.5 \times 7 = 3.5$ hours [1] Number of kW h = number of kilowatts × number of hours [1] $= 3.0 \times 3.5$ [1] = 10.5 kWh [1] Cost = number of kW h \times cost of 1 kWh [1] $= 10.5 \times 17p[1]$ = 178.5 pence (to 1 dp). [1] (b) Daily use = number of kilowatts \times number of hours = $3 \times 0.5 = 1.5$ kWh [1] Energy used = power × time = $1500 \times (60 \times 60) = 5.4 \times 10^6$ J = 5.4 MJ [1] So Patrick is correct since use > 5 million joules **4.** (a) T1 = neutral, T2 = earth, T3 = live [3] (b) C1 is blue, C2 is brown [2] (c) P1 is the cord grip, P2 is the fuse [2] (d) If the current in the circuit exceeds the maximum safe current [1] the fuse will melt [1] disconnecting the apparatus from the electrical supply. [1] This is done to protect the device from overheating and possibly going on fire. [1] (e) The lack of an earth wire suggests the device might be double-insulated. [1] This is done when the outer casing is made of a material which is not an electrical conductor, [1] so there is no point to which the earth wire could be sensibly attached. [1]

2.3C ELECTRICAL ENERGY AND POWER, AND ELECTRICITY IN THE HOME





(c)

Upper switch connected to	Lamp on / off
С	On
D	Off
С	Off
D	On
	Upper switch connected to C D C D

(1 mark for each table entry completed) [4]

- (d) To control a light from either end of a long corridor. [1]
- 6. (a) Only appliances with a conducting (metal) casing can be earthed. [1] Some appliances have a casing which is made of a plastic insulator. [1]
 - (b) (Appliances which have a casing which is made of a plastic insulator) are double insulated for safety [1].
- 7. (a) If the current in the device exceeds the maximum safe value [1] then the wire in the fuse will melt [1] disconnecting the appliance from the electrical supply [1] and protecting it from electrical damage or fire [1].

(b) Content:

- If a live wire accidentally makes contact with the metal casing
- there is the danger that a person touching the casing will receive a fatal electric shock.
- In an earthed device, the current would flow through the live wire, the casing
- and the earth wire to earth.
- The resistance of the earth wire is very low,
- resulting in such a large current in the live wire
- that the fuse will melt and disconnect the electrical supply.
- The casing is then no longer live, so the user is protected.
- In addition, current no longer flows, so the appliance cannot suffer further damage.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 7 or more points would place you in the 5–6 mark band, 4 to 6 points would place you in the 3–4 mark band and at least 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

- **8.** (a) (i) Kettle: $I = P \div V = 2900 \div 230 = 12.6 \text{ A}$ [1] So select the 13 A fuse. [1]
 - (ii) Xbox One: $I = P \div V = 112 \div 230 = 0.49 \text{ A}$ [1] So select the 1 A fuse. [1]
 - (b) (i) If the fuse rating is much less than the normal current in the device it will melt immediately the device is switched on. [1] The user will continually be changing blown fuses. [1]
 - (ii) If the fuse rating is much more than the normal current in the device and the current exceeds the maximum safe value, it will not melt before considerable damage is done. [1]

2.4 Magnetism and Electromagnetism

1. Field lines as shown, all arrows consistent with polarity. [2]



2. (a) [1] (b) [2] (c) [1] (d) [2]



- (e) More turns on the coil; larger current in the coil; iron rod inside the coil. [3]
- (f) An electromagnet can be switched on or off by switching the current on or off. [1] A bar magnet is a 'permanent' magnet. [1]

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3. Method:

- Arrange a solenoid above a newton balance on which an iron plate has been placed, as shown below.
- Record the weight of the plate.
- Switch on the current to the solenoid and record the new balance reading and the solenoid current.
- The difference in balance readings gives the upward force on the plate and hence it is a measure of the strength of the electromagnet.
- Repeat for different currents.
- A graph of upward force on plate against current is a straight line through the origin, demonstrating direct proportionality.



[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 5 or more points would place you in the 5–6 mark band, 3 or 4 points would place you in the 3–4 mark band and at least 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

4. (a) (i) [1] and (ii) [1]



- (b) (i) The wire makes a complete vertical oscillation every 2 seconds. [1]
 - (ii) The wire makes 500 vibrations per second, [1] but this is so rapid that no vibrations are observed. [1]
- (c) The electric motor. [1]

- 5. (a) Needle moves momentarily to the left [1] and then returns to zero. [1]
 - (b) Needle does not move it continues to point to zero. [1]
 - (c) Needle moves momentarily to the right [1] and then returns to zero. [1]
- 6. (a) DC is a current which flows in one direction only. [1] AC is a current which reverses its direction [1] periodically. [1]
 - (b) A is AC. [1] B and C are both DC. [2]
 - (c) AC mains supply. DC battery. [2]
- 7. (a) (i) There is momentary flick of the needle [1] which then returns to zero. [1]
 - (ii) The needle continues pointing to zero. [1]
 - (iii) There is a momentary flick of the needle in the opposite direction to (i). [1] The needle then returns to zero. [1]
 - (b) Soft iron [1]
 - (c) Explanation:
 - Closing the switch causes a rapid increase in current in coil B.
 - This causes a rapid increase in the magnetic field in B.
 - The coils are linked magnetically by the iron core.
 - There is therefore a rapid increase in the magnetic field in coil A.
 - This changing magnetic field in coil A causes an induced potential difference across the terminals of coil A.
 - Since coil A is part of a closed circuit, an induced current flows in coil A.
 - The current causes the needle to kick.
 - When the current in coil B reaches a steady value, there is no longer a current in coil A, so the needle returns to zero.

[6]

(Note that this would almost certainly be a 'Quality of Written Communication' question. Each bullet point above should be regarded as an indicative point. 6 or more points would place you in the 5–6 mark band, 4 or 5 points would place you in the 3–4 mark band and at least 2 points would place you in the 1–2 mark band. Whether you were placed at the top or bottom of the mark band would depend on the quality of your written communication.)

- 8. (a) A is a step-up transformer [1] B is a step-down transformer [1]
 - (b) By increasing the voltage at the power station end [1] the current in the transmission lines is reduced to a minimum. [1] The reduced current means less energy is lost as heat in the transmission lines. [1]
 - (c) The National Grid. [1]
- 9. (a) A transformer consists of a (laminated) soft iron core on which two coils are wound. [1] One is the primary coil (to which the input AC voltage is applied). [1] The other coil is the secondary coil (from which the output voltage is taken) [1]. The secondary coil in a step up transformer has more turns than the primary coil. [1]

(b) (i)
$$\frac{N_{s}}{N_{p}} = \frac{V_{s}}{V_{p}}$$
 [1]
so $\frac{N_{s}}{560} = \frac{6}{240}$ [2]

which gives N_{c} as 14 turns [1]

- (ii) $V_{p} I_{p} = V_{s} I_{s} [1]$ 240 × $I_{p} = 60 \times 0.4 [2]$ giving $I_{p} = 0.01 \text{ A} [1]$
- **10.** The transformer decreases voltage at A to ¼ of the original value to give the new voltage at B. [1] So, in reverse:

The transformer increases voltage at B by 4 times its original value to give new voltage at A. [1] The transformer increases voltage at B from 24 V to give $4 \times 24 = 96$ V at A. [1]

2.5A The Earth and Solar System, Stars and the Big Bang Model

- 1. (a) Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune (1 mark for the correct names, 1 mark for the correct order) [2]
 - (**b**) (**i**) Mars [1]
 - (ii) Jupiter [1]
 - (c) Asteroids and comets [2]
 - (d) Moons [1]
- 2. (a) Artificial satellites are put into space by humans; natural satellites are not. [2]
 - (b) Observation of the Earth, weather monitoring, astronomy, communications (or other valid examples). [4]
- 3. (a) A stellar nebula is a collection of hydrogen gas and dust from which stars are formed. [1]
 (b) Gravitation pulls the nebula into a spinning disc. [1] The core at the centre becomes very hot and dense [2] and the pressure becomes very high. [1] The core becomes so hot that it can be observed from afar – it is now a protostar. [1] After millions of years the core temperature becomes so high that hydrogen fusion starts. [1] (At this stage the protostar has become a star.)
 - (c) planets [1]
- 4. (a) Spectroscopic studies of light from stars, including our Sun. [1](b) The fusion of hydrogen into helium. [1]
- 5. Naturally occurring elements, apart from hydrogen, are formed by nuclear fusion in stars. [1] So all the elements in our bodies (except hydrogen) were formed within stars. [1]



(1 mark for each entry completed) [4]



(1 mark for each entry completed) [4]

- (b) At stage A: There is an explosion in which the outer layers of the star are ejected [1] this is called a supernova. [1] The star will shine for a relatively short time [1] with the brightness of 10 billion suns. [1]
- (c) 'Black hole' is a suitable name because gravity there is so great that no light can escape from this star. [1]
- (a) Main sequence [1] 8.
 - (b) The outward force of thermal expansion (sometimes called 'radiation pressure') is balanced by the inward force of gravity. [1]
- 9. (a) Big Bang Theory [1] (b) 14 billion years ago [1]
- 10. Description:
 - the universe began at a singularity, as an explosion, known as the Big Bang; [1]
 - there then followed rapid expansion and cooling; [1]
 - this led to the eventual formation of neutrons and protons; [1]
 - further expansion and cooling allowed nuclei to form; [1]
 - eventually, after further expansion and cooling, the temperature had dropped sufficiently for electrons to combine with neutrons and protons to form atoms of hydrogen. [1]

2.5B Red Shift, CMBR, Space Travel and Life on Other Planets

- 1. (a) The light from distant galaxies is shifted towards the longer wavelength (red) part of the spectrum. [1]
 - (b) Red shift tells us that distant galaxies are getting further and further away from us because space is expanding. [1]
 - (c) The light from Andromeda is blue-shifted. Andromeda is an unusual galaxy because it is getting closer and closer to our own galaxy, the Milky Way. [1]
- 2. (a) Cosmic Microwave Background Radiation [1]
 - (b) CMBR is the remnant or after-glow of the Big Bang. [1]
 - (c) CMBR can only be explained by the Big Bang Theory. [1]
- 3. (a) Exoplanets are planets discovered beyond our Solar System. [1]
 - (b) (i) Two reasons: Stars are much bigger than exoplanets. [1] Stars emit their own light, exoplanets can only reflect starlight. [1]
 - (ii) As the planet orbits its star, it sometimes comes between us and the star. [1] When this occurs there is a sudden, slight reduction in the amount of light reaching us from the star. [1] As the planet moves further, the amount of light observed from the star returns to its normal value. [1]
- 4. (a) The composition of planetary atmospheres is determined by the spectroscopic examination of the light passing through their atmospheres. [1]
 - (b) The presence of oxygen would indicate the possibility of life on the planet. [1]
- 5. The journey would take so long that many generations would pass before anyone would arrive. [1] The distance is so great that the spacecraft would be unable to carry enough fuel, oxygen or food. [1] There are ethical issues relating to what some would call "suicide missions". [1]
- 6. (a) A light year is the distance that light can travel in one year. [1] (b) The distance between Earth and the stars is so great that a very large unit is required. [1]
- 7. (a) The 'habitable zone' of a star is that region within which life (as we know it) could exist. [1] The planet must not get too far away from the star so that there would be insufficient light and heat to support life. [1] Nor can the planet get too close to the star so that life could not survive the intense radiation and heat. [1]

(Between these extremes is the habitable zone.)

(b) distance = speed \times time [1] So 1 light year = $3 \times 10^8 \times 3.2 \times 10^7 = 9.6 \times 10^{15} \text{ m}$ [1] So 4.2 light years = $4.2 \times 9.6 \times 10^{15} = 4.032 \times 10^{16} \text{ m}$ [1] Convert to kilometres: $4.032 \times 10^{16} \text{ m} = (4.032 \times 10^{16} \div 1000) \text{ km} \approx 4.0 \times 10^{13} \text{ km} [1]$