

Principal examiner reports for teachers

Principal examiner reports for teachers summarise what candidates did well and what candidates needed to improve for this examination series only.

This report is to be used in conjunction with the question paper and mark scheme.

For guidance on teaching and learning we provide resources for many of our syllabuses.

Resource	Where to find it
Grade descriptions – Grade descriptions describe the level of performance typically demonstrated by candidates achieving the different grades awarded for a qualification.	School support hub Select: Subject > Resource finder > Syllabus and specimen materials
Schemes of work – Schemes of work are designed to support you in your teaching and lesson planning.	School support hub Select: Subject > Resource finder > Teaching and learning
Lesson planning – Guidance on how to plan a lesson.	Lesson planning
Resource plus – There may be additional resources such as teaching packs containing lesson plans, resources and worksheets and videos for aspects of your syllabus.	School support hub Select: Subject > Resource finder > Teaching and learning
Teaching tools	Teaching Tools
Exemplar candidate responses	School support hub Select: Subject > Resource finder > Teaching and learning
Learner guide – A guide for students to help them understand what the course involves.	School support hub Select: Subject > Resource finder > Teaching and learning
Community forums – Do you have a question or something to share? Our online forums are great way to keep up to date with your subject and the global Cambridge community.	Community forum on the school support hub
Access to scripts for this series.	Access to scripts service
Results analysis is available for some syllabuses.	Results analysis
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PHYSICS

Paper 5054/11 Multiple Choice
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Key messages

Candidates performed well on **Questions 1, 3, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 27, 28, 30, 32, 35, 37, 38 and 39.**

Candidates performed less well on **Questions 2, 8, 9, 12, 18, 24, 25, 26, 29, 31, 33, 34, 36 and 40.**

In calculations, many candidates selected an appropriate approach and used the numerical values given in the text to obtain the correct answer and choose the correct option. Similarly, in the more discursively worded questions, many candidates understood what was being asked and either eliminated options that were incorrect or did not answer the question or selected the correct option. In the more discursively worded questions, many candidates understood what was being asked for an either eliminated options that were incorrect or did not answer the question or were able initially to select the correct option.

In both types of question, responses did not always match what was being asked, particularly where other options contained correct statements that were not relevant to the requirement of the question.

Comments on specific questions

Question 2

- Option **C** was a common incorrect answer.
- All the options show the weight of the sack and the force exerted sideways on the sack in the correct direction. Only option **D** shows the three forces acting in a closed loop where the end of one force meets the beginning of the next force. This is the diagram that shows the forces cancelling to produce a resultant force of zero magnitude on the stationary sack.

Question 8

- Option **C** was a common incorrect answer.
- To cause the acceleration indicated, the resultant force must be directed to the right and have a magnitude of 36 N. This value explains the popularity of choice **C**. The question asks for the magnitude X of the force to the left. This force combines with 54 N force indicated by the text to give a resultant of the appropriate size.

Question 9

- Option **C** was a very common incorrect answer.
- Forces F_1 and F_2 constitute a Newton's third law pair. Force F_2 , therefore, must be a force of the same type as force F_1 that acts on a different object. The force referred to in option **D**, is the opposite of this. This force is a force of a different type that acts on the same object.

Question 12

- Option **D** was a fairly common incorrect answer.
- The quantity force is equal to the rate of change of momentum and so option **A** is correct. Option **D** erroneously suggests that velocity is the rate of change of acceleration whereas acceleration is the rate of change of velocity.

Question 18

- Option **B** was a fairly common incorrect answer.
- The values to be substituted into the equation $c = s \frac{DE}{mDq}$ are either given in the text or can be deduced from the graph. The unit of the x-axis of the graph is the minute whereas the power of the heater is given as 50 W. A watt is a joule/second.

Question 24

- Option **D** was a fairly common incorrect answer.
- Glass is a denser medium than air. The light travelling in the glass strikes the boundary at an angle of incidence that is greater than the critical angle. This is the condition for total internal reflection and so option **B** which shows reflection at a suitable angle of reflection.

Question 25

- Option **C** was a common incorrect answer.
- All three candidates produced a correct suggestion, and so option **A** is correct. Option **C** suggests that the second suggestion is incorrect which is not the case.

Question 26

- Option **A** was a common incorrect answer.
- The tip of the image is located by drawing a vertical line at 6.0° cm to the right of the lens and continuing the ray that passes through the optical centre of the lens until it intersects this vertical line. The second section of the paraxial ray from the object to the tip of the image is straight and passes through the principal axis at a point 1.5 cm to the right of the lens. This gives the focal length of the lens.

Question 29

- Option **A** was a common incorrect answer.
- Most candidates supplied an answer that implied that end P of the block of iron is a south pole. Many candidates realised that the block of aluminium would not be magnetised and chose the correct option.

Question 31

- Option **A** was a common incorrect answer.
- This question relates to the definition of current and knowledge of the fact that units must match such definitions. Since current is defined by the equation:

$$\text{current} = \frac{\text{charge}}{\text{time}} \quad \text{it follows that: the unit of current} = \frac{\text{the unit of charge}}{\text{the unit of time}}.$$

Question 33

- Option **A** was a very common incorrect answer.
- The lamps in the circuit are identical, and the arrangement of the circuit ensures that the reading I_1 is twice the size of reading I_2 . The only option that produces this ratio is option **C**. The choice of option **A** may suggest that it was not realised that the reading I_1 includes both the current in third lamp from the left and the current in the fourth lamp.

Question 34

- Option **C** was a common incorrect answer.
- The question assesses an understanding of the principle of the potential divider. It can also be answered using the equation $V = IR$. A crucial point is the determination of the combined resistance of the two parallel resistors. The choice of option **C** may well have been a consequence of just adding the two resistance values.

Question 36

- Option **A** and option **B** were common incorrect answers.
- The emission of a beta particle (b-particle) causes the number of protons in a nucleus to increase by one and so the nuclide notation for a b-particle is commonly written as ${}^0_{-1}\beta$. The -1 is used to ensure that both the proton (atomic) numbers and the nucleon (mass) numbers in the equation that represents the decay, balance. Misunderstandings about the significance of the -1 and how it is used can lead to results with incorrect nuclide notations.

Question 40

- Option **A** and option **B** were common incorrect answers.
- The speed of light c in a vacuum has a constant value and hence the equation $c = f\lambda$ ensures that a change in either the wavelength or the frequency of the light leads to the opposite change in the other quantity (the frequency or the wavelength). Here the wavelength of the light from the distant galaxy increases because of the redshift and so the frequency of the light decreases. The selection of option **A** or **B** stems from a misunderstanding of the circumstances when frequency does not change.

PHYSICS

Paper 5054/12 Multiple Choice
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Key messages

Candidates performed well on **Questions 2, 3, 4, 5, 6, 7, 8, 13, 14, 16, 17, 18, 20, 23, 25, 26, 27, 29, 30, 31, 33, 35, 36, 37, 38 and 39.**

Candidates performed less well on **Questions 1, 9, 10, 11, 12, 15, 19, 21, 22, 24, 28, 32, 34 and 40.**

Some questions in an assessment of this type involve calculations. Responses indicated that familiarity with the learning objective being assessed and the relevant equation was not always evident. Incorrect answers can be generated by incorrect rearrangement of equations, incorrect numerical substitutions and an incorrect use of a calculator. The quantity calculated was not always the quantity required by the question. Careful reading of the question was not always evident when determining the quantity required.

In less numerical questions, careful consideration of all options was not always evident. Some contained statements that were correct but did not address the specific requirement of the question, while others appeared plausible but were not correct.

Comments on specific questions

Question 1

- Option **A** was a common incorrect answer.
- The number of periods measured using the method described in option **A** is equal to the number measured using the method in option **D**. The method in option **D** involves switching the digital timer on once and off once. The method in option **A** requires the digital timer to be switched on and off ten times each. Thus, the inaccuracy due to human reaction time delay is less significant for the method described in option **D**.

Question 9

- Option **C** was a common incorrect answer.
- The first deduction to be made is the original location of the centre of gravity. The correct location **Y** was chosen by many candidates. The centre of gravity of the sand is in the middle of the sand layer and lies between points **Y** and **Z**. The water is above this point and this additional weight ensures that the centre of gravity of the bottle is higher than the centre of gravity of the sand. Point **X** is halfway up the bottle and since the weight of the sand is greater than the weight of the air, **X** is too high. When more sand is added to the bottle, it settles above point **Y** and the water layer is moved further up the bottle. Both of these changes raise the centre of gravity.

Question 10

- Options **B** and **C** were common incorrect answers.
- The question assesses knowledge of a unit that is supplied in the syllabus. It may be deduced from the equation: impulse = force $\times$ time. It may also be deduced from impulse = $D(mv)$.

Question 11

- Option **C** was a common incorrect answer.
- The four options each contain a measurable quantity. The quantity work done and the quantity energy are closely related, and energy is often defined as being equal to a quantity of work that may, in some way, be done. Thus, of the four quantities in the options, only energy has the same unit as work done.

and only option **B** may be correct. In fact, the energy transferred mechanically to the trolley is equal to the work done by the force F and so option **B** is not only possible, but it is also correct.

Question 12

- Option **B** was a common incorrect answer.
- As the weight slides down the slope, energy is transferred from its gravitation potential store. In general terms, the energy transferred is equal to mgh but in terms of this question, $mg = W$ and $h = x$. Thus, the energy transferred from the weight is Wx and this is the maximum quantity of work that the weight may do. The diagram shows that the distance y is greater than x and so option **B** is not correct as Wy is greater than Wx .

Question 15

- Option **C** was a common incorrect answer.
- The maximum pressure change in 1.0 minute that is not dangerous for divers can be used to deduce the maximum distance through which the diver may rise in the water in 1.0 minute. The pressure change and distance are related by the equation $\Delta p = \rho g \Delta h$. This in turn gives the maximum safe upward speed of the diver. Option **C** used the correct numerical value but the incorrect unit.

Question 19

- Option **D** was a very common incorrect answer.
- Selection of the correct answer required understanding of the behaviour of a cooling liquid and its effect on temperature. The liquid remains completely liquid as it cools to the melting temperature at time **A**. The temperature does not change as it solidifies between time **A** and time **C**. At time **C** the substance becomes completely solid and then cools as a solid to time **D** where the solid reaches room temperature. At time **D**, the substance has been completely solid for a considerable time.

Question 21

- Option **A** was an incorrect answer selected by some candidates.
- Selection of the correct option required use of the equation $c = f\lambda$. Use of this equation was evident in many responses. The question also assessed an understanding of the fact that equations may only be guaranteed to generate a correct answer when numerical values are expressed in SI base units. With the exception of the kilogram, base units are units without SI multipliers. Expressing the frequency in Hz and the wavelength in m and using the correct equation led to the correct option.

Question 22

- The key, option **A**, was the most commonly selected option but all the other options were selected by some candidates.
- This question assessed some of the factual knowledge given in the syllabus. The answer cannot be deduced without that knowledge.

Question 24

- Option **C** was a common incorrect answer.
- The distance from a mirror, of an image produced in the mirror is equal to the distance from the mirror of the object. Thus, the distance between the image and the object is double the size of the distance between the object and the mirror. When the woman in the question moves 1.0 m (to the right) from the mirror, the object moves 1.0 m to the left. The distance between the image and the object therefore increases by 2.0 m rather than 1.0 m.

Question 28

- Option **B** was a common incorrect answer.
- The distance travelled by the sound is calculated using the speed and the time taken for the sound to travel from the boat to the fish and then back to the boat. This distance is the distance of the double journey and is therefore twice the distance from the boat to the fish. Not dividing by two at some point in the calculation leads to the incorrect option **B**.

Question 32

- Options **B** and **C** were common incorrect answers.
- The lamp shines the brightest when the current in it has the greatest value. This is achieved by reducing the resistance of the circuit to the minimum possible value. Closing switch X short-circuits the left-hand resistor so that all the current is in the connecting wires and the switch. The resistance of this part of the circuit decreases to zero which is its minimum possible value. The calculation for the combined resistance of two resistors in parallel shows that the combined resistance of a parallel pair of resistors is less than the resistance of either individual resistor. To reduce the resistance of the circuit to its minimum possible value, the two resistors on the right must both be connected into the circuit in parallel. Thus, both the switches Y and Z must also be closed.

Question 34

- Option **C** was a common incorrect answer.
- To deduce the correct option, it is necessary to recall and use the relative directions of force, magnetic field and current. Some candidates may have known a rule such as the Fleming left-hand rule to assist with this. This process reveals that the current in the wire is directed from X to Y. Candidates who selected option **C** may have used a right-hand rule or had confused which fingers referred to the three quantities. Almost all candidates selected an option in which the direction of the flow of electrons was opposite to the direction of the conventional current.

Question 40

- Options **A** and **D** were common incorrect answers.
- The question assesses three factual aspects of the behaviour of distant galaxies and the electromagnetic radiation they emit. These facts are specified in the syllabus and cannot be deduced solely from the information provided in the question. Statement 2 is incorrect as it is the wavelength rather than the frequency of the observed light that is greater than that of the light when it was emitted. The frequency of the light has decreased when it is observed. Option **A** and option **B** both suggest that statement 2 is correct.

PHYSICS

Paper 5054/21 Theory

Key messages

What candidates did well

- Most candidates demonstrated knowledge of the principles, for example recalling properties of electromagnetic waves and understanding basic ideas about electric circuits and radioactivity.
- Many candidates knew and accurately applied the relevant formulae with clearly presented working steps, for example, when calculating acceleration or kinetic energy.

What candidates needed to improve

- Careful reading of each question before answering was not always evident. In **Question 3(b)**, the volume of air was not always recognised as decreasing by 40 cm^3 rather than becoming 40 cm^3 .
- Attention to command words, logical explanation of responses and consideration of the marks available were not always evident.
- Knowledge of units for physical quantities was not always evident.
- Calculations did not always begin with an algebraic equation rearranged to make the required quantity the subject. Final values were not always shown on the answer line.

Comments on specific questions

Section A

Question 1

(a) (i) Comprehensive responses

- Most candidates recognised that uniform acceleration indicates that there is the same increase in speed or velocity in equal time intervals or the rate of increase in speed is constant.

Limited responses

- Some answers indicated only that the velocity increases without mentioning time.

(ii) Comprehensive responses

- Most candidates quoted the formula for acceleration and obtained the correct answer.

Limited responses

- A few candidates started the calculation using an incorrect formula, for example, acceleration = speed $\times$ time.

(b) Comprehensive responses

- Many answers showed correct lines on the speed-time graph for the constant acceleration and the constant speed parts of the journey.

Limited responses

- Some candidates plotted the final speed at $t = 120 \text{ s}$ as 6 m/s , which is the change in speed, rather than 10 m/s .

(c) Comprehensive responses

- Some candidates answered fully mentioning the respective magnitudes and directions of the forces during the acceleration and the deceleration parts of the journey.

Limited responses

- Many answers did not mention the driving force or a resistive force acting in opposite directions and the resistive force being smaller during acceleration.
- A few answers explained the acceleration part of the journey and only mentioned one force during the deceleration.

Question 2

(a) (i) Comprehensive responses

- Some answers gave a full account of the change in gravitational potential energy as the water falls and the subsequent change to internal or thermal energy as the water reaches point Q.

Limited responses

- A few answers used the idea of a transfer from potential energy to kinetic energy without specifying gravitational potential energy, or referred to 'mechanical energy', which was not always sufficiently precise in this context.
- Sound energy was suggested as the final store of energy in a few answers, rather than thermal energy.

(ii) Comprehensive responses

- Some candidates suggested that the temperature at P is lower and that the average speed of the random movement of the particles is lower at Q.

Limited responses

- Many candidates suggested that the temperature is higher at P.
- A few candidates recognised that the temperature at P is lower and then suggested that the particles were moving faster.

(b) (i) Comprehensive responses

- Most candidates quoted the correct formula for kinetic energy and obtained the correct answer.

Limited responses

- A few candidates used the wrong formula, for example, $KE = mv^2$. The speed term was not always squared in calculations.

(ii) Comprehensive responses

- Most candidates combined the kinetic energy in **Question (b)(i)** with the formula for gravitational potential energy to calculate the maximum height.

Limited responses

- Some candidates used g as 10 rather than 9.8 m/s^2

Question 3

(a) (i) Comprehensive responses

- Most candidates quoted and applied the formula pressure = force / area.

Limited responses

- A few candidates were unable to rearrange the formula to make force the subject or were unable to recall the equation correctly.

(ii) Comprehensive responses

- A few candidates realised that the pressure of the atmosphere outside the syringe is equal to the pressure of the air inside.

Limited responses

- Some answers mentioned friction between the plunger and the syringe even though the question states there is no friction or merely suggested that the force is too small to move the piston.

(iii) Comprehensive responses

- Most candidates used the correct formula for calculating momentum and gave the correct unit.

Limited responses

- A few candidates used incorrect powers of ten in their calculations. Incorrect units for momentum were also seen, for example, kg / m / s rather than kg m / s .

(iv) Comprehensive responses

- Some candidates recognised either that there are many particles or that there are frequent collisions between the particles and the walls of the syringe and thus even a small momentum per collision produces a large pressure.

Limited responses

- Many candidates merely explained how a pressure is exerted rather than trying to explain how the small momentum of one particle can cause a large pressure.

(b) Comprehensive responses

- Many candidates used the relationship $p_1 V_1 = p_2 V_2$ and the final volume V_2 as 50 cm^3 to determine the final pressure.

Limited responses

- Many candidates used the final volume as 40 cm^3 .

Question 4

(a) Comprehensive responses

- Most candidates quoted at least one property, often that all electromagnetic waves have the same speed or are transverse waves.

Limited responses

- Some answers were vague, for example, 'they are all electromagnetic' or 'they are all the same type of wave'.

(b) Comprehensive responses

- Many candidates suggested correctly that either the teeth absorb X-rays or that the tissue around the teeth partially transmits the X-rays.

Limited responses

- Many candidates suggested incorrectly that X-rays are reflected by the teeth, whereas the question makes clear that the detector is placed behind the teeth and any reflection would not reach the detector.

(c) (i) Comprehensive responses

- Many candidates correctly suggested that the motion of particles is a longitudinal motion and that this motion is an oscillation, backwards and forwards in the direction of the energy transfer.

Limited responses

- Some candidates, whilst recognising the longitudinal nature of ultrasound, needed to describe an actual oscillation rather than just a 'movement'.
- Some other candidates described an oscillation but not the direction of this oscillation.

(ii) Comprehensive responses

- Most candidates used the relationship between speed, distance and time correctly and also that the distance travelled by the wave is twice the distance from the scanner to the bone.

Limited responses

- A few candidates did not halve the distance travelled by the wave.

(iii) Comprehensive responses

- Many candidates recognised that the wavelength decreases as the wave slows down on emerging into air with some candidates explaining this in terms of the frequency remaining unchanged and using the formula $v = f\lambda$.

Limited responses

- Many candidates suggested that the wavelength increases or did not attempt to explain how the change in speed affects the wavelength.

Question 5

(a) (i) Comprehensive responses

- Many candidates realised that movement of the bar creates the wave, usually by moving up and down.

Limited responses

- Some answers did not mention the wooden bar which, ideally, should move up and down to create the waveform shown.

(ii) Comprehensive responses

- Many answers described the placing of two obstacles in the tank with a small gap between them, sometimes linked to the wavelength of the wave.

Limited responses

- Some candidates stated that 'barriers' or 'obstacles' can be placed in the tank, without there being any gap in the barriers or without stating that the wave can diffract at the edges of the barrier.

(iii) Comprehensive responses

- Most candidates suggested counting the number of crests or wavelengths created in a measured time and dividing by the time.

Limited responses

- Some answers suggested the measurement of various times, such as the time to hit the end of the tank or the measurement of the number of cycles seen on the screen.

(b) (i) Comprehensive responses

- Most candidates marked and labelled the amplitude correctly.

Limited responses

- Some answers marked the crest as the amplitude and not the distance from the top of the wave to the mean position.

(ii) Comprehensive responses

- Many answers calculated the time for one wave as 0.50 s and then halved this as the final answer.

Limited responses

- Many answers only found the time for one oscillation which is the time for a particle to move from the top of the wave to the bottom and then back to the top.

(iii) Comprehensive responses

- Many answers suggested that the particle initially increases in speed as it falls. A few of these answers then suggested the speed is a maximum in the middle of the oscillation or that it has zero speed at the bottom of the wave.

Limited responses

- A few candidates suggested that the speed is constant, which is true of the wave itself but not of a particle oscillating in the wave.
- Some candidates suggested that the particle speeds up as it travels down and slows down as it travels up without recognising that it has no speed at the bottom of the wave.

Question 6

(a) (i) Comprehensive responses

- Most answers involved a correct calculation using power, current and voltage to obtain the current in one lamp and then the value doubling the value obtained to obtain the current in the battery.

Limited responses

- Some candidates produced answers where the current in each lamp was twice the current in the battery.

(ii) Comprehensive responses

- Most answers correctly used the formula relating resistance, current and voltage.

Limited responses

- Some candidates incorrectly used the current in each lamp, rather than the current in the battery to find the total resistance of the circuit.

(iii) Comprehensive responses

- Most answers recognised that the resistance of the lamp increases and many answers explained that this was because of the increase in temperature of the lamp as it is first switched on.

Limited responses

- Some candidates attempted to answer in terms of the arrangement of lamps in parallel and did not realise that the resistance varies.

(b) Comprehensive responses

- Some candidates recognised that the density of the gas means that the metal atoms and explained this fully in terms of the reduced density of the hot gas near the lamp causing the metal atoms to rise.

Limited responses

- Some candidates suggested that the density of the metal atoms is lower than the density of the air.

Question 7

(a) Comprehensive responses

- Many candidates described operation of the relay, starting with a current in the coil, then the magnetisation of the iron core and armature and finally their attraction.

Limited responses

- Some candidates did not mention the current in the coil or stated that the current actually flows in the iron core rather than in the coil.

(b) Comprehensive responses

- Most candidates recognised that the core no longer acts as a magnet and some candidates then explained the contacts moving apart, either because the springy metal pushes the contacts apart or that gravity acts on the pivoted iron armature.

Limited responses

- Some candidates, whilst recognising that the attraction stops, did not explain that the iron is no longer magnetised or did not give a reason why the contacts should actually move apart.

(c) Comprehensive responses

- Many candidates suggested that steel would be permanently magnetised and some candidates then explained that this means that the contacts never come apart or the switch in the relay remains closed.

Limited responses

- Some candidates incorrectly suggested that steel is a poor conductor or that steel becomes a very strong magnet.

(d) Comprehensive responses

- Some candidates recognised that the bathroom contains water and that there is the possibility of an electric shock. Using the relay, the switch used by the person is only attached to a low voltage or low current and is safer.

Limited responses

- Some answers suggested that the purpose of the relay is to regulate the flow of current or to act as a fuse rather than to switch the heater on or off using a lower voltage or current.

Question 8

(a) (i) Comprehensive responses

- Most candidates gave a harmful effect of ionising radiation, usually cancer.

Limited responses

- A few answers were not specific, for example, 'ionising radiation is poisonous'.

(ii) Comprehensive responses

- Many candidates recognised that the atom loses an electron to become a positive ion, usually by 'knocking off an electron' but only a few candidates explained the attraction that occurs between the alpha particle and the electrons in the atom.

Limited responses

- Some candidates suggested that electrons move from the alpha particle to the atom or merely stated that an alpha particle contains two neutrons and two protons.

(iii) Comprehensive responses

- Many candidates suggested ways to reduce the risk of working with radioactive sources, usually using lead shielding, tongs to handle the sources or reducing the exposure time.

Limited responses

- Some answers were too vague or ineffective, such as wear 'protective gear' or 'safety goggles'.

(b) (i) Comprehensive responses

- Most answers gave the correct nuclide formula for an alpha particle.

Limited responses

- A few candidates gave the proton number instead of the mass number and vice versa.

(ii) Comprehensive responses

- Many candidates recognised that the proton number increases by 1 and the number of neutrons decreases by 1 or that the mass number remains the same.

Limited responses

- Many candidates did not describe the effect on the composition of the atom or just stated that since a beta particle is an electron the nucleus of the atom is unchanged when a beta particle is emitted. They did not appear to realise that beta radiation comes from the nucleus.

(c) Comprehensive responses

- Some candidates recognised that alpha particles will not reach the detector in any of the arrangements, beta particles only reach the detector in arrangements 1 and 2 and gamma radiation reached the detector in all three arrangements.

Limited responses

- Many candidates ticked the correct boxes for gamma radiation.
- Some candidates ticked arrangement 1 for alpha radiation, implying that alpha particles can travel through 20 cm of air.

Question 9

(a) (i) Comprehensive responses

- Many candidates suggested that Mars and Venus have different orbital times or orbital speeds and then extended their explanation to draw Venus and Earth at two different times, indicating the different distances between the planets or explained this in words.

Limited responses

- Some candidates merely drew the planets at one time, which was not helpful.
- The different orbital times were sometimes incorrectly linked to the different masses of the planets rather than to their distances from the Sun.

(ii) Comprehensive responses

- Most answers were correct.

Limited responses

- Some answers repeated the factor of 10^7 which is shown on the answer line or gave the answer as $0.4 (\times 10^7 \text{ km})$.

(b) Comprehensive responses

- Many answers recognised that the candidate is not correct and gave data from two of the planets that do not obey the suggested relationship.

Limited responses

- Some candidates did not use data from **Table 9.1** and gave a theoretical argument, often flawed, such as 'the larger the mass the less the speed'.
- A few candidates compared orbital speed with mass.

(c) Comprehensive responses

- Most candidates calculated the density correctly.

Limited responses

- A few candidates used the wrong data from the table.

(d) Comprehensive responses

- Most candidates gave the correct formula.

Limited responses

- Some candidates gave the orbital speed as R / T rather than $2 \pi R / T$.

PHYSICS

Paper 5054/22 Theory

Key messages

What candidates did well

- Most candidates had a sound general knowledge of the principles, for example they were able to recall a form of Newton's First Law and the principle of moments, sometimes giving the conditions accurately by stating that the principle applies at equilibrium. Renewable energy sources were generally well recalled and ray diagrams for a simple lens were drawn well.
- Many candidates knew and accurately applied relevant formulae giving clearly presented working steps, for example when calculating acceleration or finding the area under a speed–time graph.
- Most candidates demonstrated a sound understanding of speed–time graphs, correctly identifying steady speed as a horizontal line and uniform acceleration as a straight line with positive slope.
- Many candidates correctly applied the formula for power in terms of energy and time, converting time to seconds, and interpreting the prefix mega as $\times 10^6$.
- Efficiency was often correctly expressed as output $\div$ input, in terms of either power or energy, with many candidates computing values accurately to 2 significant figures.

What candidates needed to improve

- It is important to read each question carefully before answering for example being sure to use the correct data in **Question 1** or ensuring to calculate the power input rather than the energy input in **Question 3**.
- Candidates should pay particular attention to the command word used in a question, explain their responses logically, and choose the length of their answer based on available marks, considering multiple ideas if more than one mark is given.
- Even though most units are given for the answer in a calculation, units for quantities should be known.
- Calculations should, ideally, start with an algebraic equation which may be rearranged so that the required quantity is the subject of the equation. The final value should be shown on the answer line.
- When a question asks 'Show, by calculation, ...', working steps must be included.
- Newton's First law should not be confused with the Third law and should involve a statement such as constant velocity unless a resultant or unbalanced force acts rather than a statement such as 'unless an external force acts'.
- Candidates should realise the difference between the definition of moment and the principle of moments and should know the condition under which the principle applies.
- Candidates should know the meaning of each term in the formula $\Delta E = mc\Delta\theta$.
- Candidates can give their calculated answers to any number of significant figures, equal to or greater than given in the question, usually two figures. There is no need to round answers to 2 sig. figures in this paper but, if doing so, candidates should do so correctly.
- Candidates should be able to convert times in hours or minutes into seconds and know the meaning of prefixes such as mega and kilo.
- Candidates need to be able to draw a normal to an inclined surface.

Comments on specific questions

Question 1

(a) Comprehensive responses

- Most candidates showed an understanding that, on a speed-time graph, steady speed is represented by a horizontal line while uniform acceleration is represented by a straight line with a positive slope.

Limited responses

- Some candidates included an accelerating section at the start of the constant speed line for the athlete or, for the cyclist, drew a curved line.
- Using incorrect values for the final speed limited the performance of a few candidates.

(b) Comprehensive responses

- Most candidates correctly wrote down and used the formula for acceleration.

Limited responses

- Some candidates omitted the unit for acceleration or gave the unit as m/s or m/s^{-2} .
- Although values of the speed at two different times are given in the question, some candidates used incorrect values of speed or time from the graph in their calculation.

(c) Comprehensive responses

- Most candidates were able to calculate the distance travelled by the athlete at constant speed.
- Many candidates were able to calculate the distance of the cyclist as the area under the graph.

Limited responses

- Some candidates calculated the total distance travelled in a time of 6.0 s, rather than in 5.0 s.
- In a significant number of answers, the distance travelled by the accelerating cyclist was calculated as final speed $\times$ time.

(d) Comprehensive responses

- Many candidates correctly stated that Newton's First law relates to objects at rest or in motion at constant velocity and that the motion changes if an unbalanced or resultant force acts on the object. They then applied this to the athlete.

Limited responses

- Some candidates gave a statement of Newton's First law where an object has constant speed or is at rest 'unless an external force acts', rather than 'unless a resultant force acts'. There are several external forces acting on the athlete, his weight and the contact force with the road. The use of 'external' limited some answers.

Question 2

(a) Comprehensive responses

- Most candidates clearly stated the principle of moments and the condition under which this principle applies.

Limited responses

- Many candidates did not include the equilibrium condition. A small number of answers omitted the word 'moment' in their statement or applied the principle to a closed system rather than to a system in equilibrium.

(b) Comprehensive responses

- Most candidates recognised that moment = force $\times$ distance, with some answers correctly using the weight of the plank and the correct distance (0.40 m).

Limited responses

- A significant number of candidates used the weight of the stone rather than the plank to calculate the moment.

(c) Comprehensive responses

- Most candidates correctly multiplied the mass of the candidate by 9.8 to find the weight and used a moment equation. Some candidates were able to use the moment of all three of the weights of the stone, the plank and the candidate in an equation of the form $F_1d_1 = F_2d_2 + F_3d_3$ to find the distance.

Limited responses

- Some candidates combined the weights and the distances for the clockwise moments rather than treating them separately or omitted one of the forces from the calculation.

Question 3

(a) (i) Comprehensive responses

- Most candidates correctly stated at least two of the many factors that determine the size of the pressure.

Limited responses

- Some candidates gave only one factor, or listed incorrect factors such as the thickness of the dam or the temperature of the water.

(ii) Comprehensive responses

- Most candidates correctly stated upwards and downwards as the directions of the forces.

Limited responses

- Some candidates gave only one correct direction or gave incorrect directions such as 'left' or 'right'.

(b) Comprehensive responses

- Most candidates correctly named one other renewable energy source, such as geothermal, tidal, solar, wind, biomass, or wave energy.

Limited responses

- Some candidates gave non-renewable sources such as nuclear, coal, oil, or natural gas. A few gave vague answers such as 'sunlight' or 'windmills' without specifying solar energy or wind energy.

(c) (i) Comprehensive responses

- Many candidates used the correct relationship between energy, power and time using the time in seconds and the power as $2.5 \times 10^6 \text{ W}$. They showed clear algebraic or numerical working.

Limited responses

- Some candidates used the wrong time, for example 30 minutes or 0.50 hours without converting the time to seconds or used 2.5 MW incorrectly as $2.5 \times 10^3 \text{ W}$.

(ii) Comprehensive responses

- Most candidates recalled the equation for efficiency either in terms of energy or power.

Limited responses

- Some candidates calculated, and gave as their final answer, the energy input rather than the power input or incorrectly suggested that efficiency = input / output.

Question 4

(a) Comprehensive responses

- Most candidates were able to state what is meant by specific heat capacity.

Limited responses

- While giving the meaning of specific heat capacity, some candidates only referred to the amount of energy needed for unit rise in temperature or the amount of energy to raise the temperature of unit mass rather than mentioning both mass and temperature rise.

(b) Comprehensive responses

- Most candidates quoted the formula that involves specific heat capacity correctly and used the correct temperature change.

Limited responses

- Some candidates interpreted T in a formula involving specific heat capacity as time instead of temperature change, whereas others confused energy and temperature change in the formula.

(c) (i) Comprehensive responses

- Many candidates demonstrated a good understanding of the thermal implications of the vacuum between the walls in this question. They often explained that the absence of particles meant there is no conduction or convection and that only radiation can transfer thermal energy.

Limited responses

- Many answers referred to the presence of trapped air or trapped energy in a vacuum.

(ii) Comprehensive responses

- Many candidates identified shiny or smooth and white for the surface as being a poor absorber and poor emitter of thermal or infra-red radiation.

Limited responses

- Candidates were asked to suggest and explain a colour and a texture for the surface of the walls. A few answers only gave the colour and many answers concentrated on the absorbing properties of the surface. The inside surface needs to emit least radiation with the mug at common room temperatures.

(d) Comprehensive responses

- Most candidates named and described convection in air, or evaporation from the surface of the water, as the reason for the water cooling faster when the lid is removed.

Limited responses

- Some candidates referred to convection within the liquid rather than in the air.
- In explaining convection, candidates needed to refer to the decrease in density as air is warmed, leading to a convection current, and in evaporation that the higher energy particles of water escape the surface.

Question 5

(a) (i) Comprehensive responses

- Most candidates were able to draw the normal at approximately the correct angle.

Limited responses

- Some candidates did not make clear which line was the normal, a line which should be at right angles to the surface of the prism at P.

(ii) Comprehensive responses

- Most candidates were able to correctly draw the horizontal ray through and emerging from the central glass block with many candidates also being able to complete the ray diagram to show how the rays of light travel through and out of both prisms correctly.

Limited responses

- Some diagrams incorrectly showed dispersion of a ray with only one colour.
- Some diagrams only showed the correct refraction as light enters the prisms.

(iii) Comprehensive responses

- Many answers showed the prisms in the correct orientation and most answers showed the rays diverging.

Limited responses

- Candidates needed to make sure that the rays were diverging as the arrangement should demonstrate the action of a diverging lens.

(b) Comprehensive responses

- Most candidates completed the ray diagram with the two rays given, and showed the image extending from the intersection of the two rays to the principal axis.

Limited responses

- Some candidates located the image by drawing a ray through the optical centre of the lens without continuing the path of the lower ray of light or, after passing through the lens, without this ray being reasonably parallel to the principal axis.

(c) Comprehensive responses

- Most candidates correctly described the variation of wavelength and frequency from one side of the spectrum to the other.

Limited responses

- Candidates should avoid contradictory statements, for example, 'wavelength decreases from left to right with gamma having the largest wavelength'.
- Some candidates only gave one property or explained incorrectly that speed varies across the spectrum.

Question 6

(a) Comprehensive responses

- Most candidates were able to state how the definitions of e.m.f. and p.d. differ from each other, usually in terms of the energy transfers involved or where the transfers occur in the circuit.

Limited responses

- Some candidates gave only a definition of p.d. or of e.m.f. without making clear the difference between the two.
- Some candidates suggested that e.m.f. is a force.

(b)(i) Comprehensive responses

- Most candidates were able to state the relationship between resistance, current and voltage.

Limited responses

- None seen.

(ii) Comprehensive responses

- Most candidates correctly identified that the current was the same in the two components.

Limited responses

- Some candidates focused on the fact that the resistance of the LDR changes with light intensity and assumed that the current in this component would change whereas, wrongly, that the current in the fixed resistor would be constant.

(c)(i) Comprehensive responses

- Most candidates correctly calculated the p.d. across the fixed resistor by subtracting the two values given in the question.

Limited responses

- None seen.

(ii) Comprehensive responses

- Many candidates were able to calculate the resistance of the LDR by first calculating a current, with a few answers using a potential divider method.

Limited responses

- Candidates sometimes incorrectly used the e.m.f., rather than the p.d. across the fixed resistor with the resistance of the fixed resistor to calculate the current.

(d) Comprehensive responses

- Some candidates were able to complete all of the boxes correctly.

Limited responses

- Many candidates were able to recognise some of the correct relationships, often that the resistance of the LDR decreases and the current increases or that if the p.d. across the resistor changes in one way then the p.d. across the LDR changes in the opposite way.

Question 7

(a) (i) Comprehensive responses

- Many candidates were able to illustrate the magnetic field around the solenoid, showing the direction of the magnetic field.
- Some candidates drew the magnetic field accurately within the solenoid.

Limited responses

- Some answers were limited as the pattern drawn did not cover the area within the solenoid.
- Arrows showing the direction of the magnetic field were not always consistent, particularly being consistent within and outside the solenoid on a field line that passes in a loop through the solenoid.

(ii) Comprehensive responses

- Most candidates stated correctly that the field lines were closer together.

Limited responses

- Some candidates incorrectly suggested that the field reverses.
- Whilst it is not wrong to suggest that the magnetic field would cover a larger area, some candidates stated, in doing so, that the lines would be further apart.

(b) (i) Comprehensive responses

- Many candidates explained fully how the induction of a current is produced.

Limited responses

- Some candidates needed to use correct terminology, describing the magnetic field as being 'cut' by the coil or 'changes' within the coil and that the voltage produced is 'induced'.
- There was confusion in some answers with the suggestion that the field of the coil cuts the solenoid, cuts the current or that two magnetic fields interact to produce the current.

(ii) Comprehensive responses

- Most candidates correctly suggested that more turns are needed on the coil. A few suggested using an iron core or increasing the voltage of the power supply.

Limited responses

- Some candidates just suggested using a stronger magnetic field without indicating how this is achieved.
- A few answers suggested using an alternating current.

(iii) Comprehensive responses

- Many candidates mentioned Lenz's law as the origin of the repulsion; this was backed up in a few answers with a description of like poles appearing on one end of the solenoid and on the adjacent side of the coil

Limited responses

- Whilst some candidates mentioned that like poles repel, the position of these poles was not clear and in some answers the two poles on the coil itself appeared to repel each other.
- There was confusion in some answers with repulsion of like charges.

Question 8

(a) Comprehensive responses

- Many candidates mentioned that beta particles are more ionising but less penetrating than gamma radiation.

Limited responses

- Some candidates referred to the properties of beta particles without making a comparison with gamma rays, merely suggesting that beta particles have 'medium ionising properties' or are 'able to pass through various materials'.

(b) (i) Comprehensive responses

- Most candidates correctly stated that the detector would be a Geiger–Müller tube.

Limited responses

- Spelling mistakes were common but often could be interpreted correctly.
- The spark counter was sometimes given as an answer but this was not the detector shown in the question.

(ii) Comprehensive responses

- Most candidates correctly commented on the random emission of radiation.

Limited responses

- There were many responses implying that candidates do not understand the difference between random and spontaneous.
- Some candidates suggested that the readings were different merely as there was a change in background radiation levels.

(iii) Comprehensive responses

- Most candidates were able to calculate the correct average background count and show their working.

Limited responses

- A few candidates incorrectly added the background counts or gave the total of the three readings as the average.

(iv) Comprehensive responses

- Some candidates gave the correct answer (50), showing halving of the count after background is removed and then the final addition of the background count.

Limited responses

- Many answers showed the halving of a count, usually 90 to 45, but sometimes halving of 80 to 40 without the addition of the background to give the measured value.

(c) Comprehensive responses

- Some candidates recognised that the shorter half-life leads to the isotope decaying faster or being in the body for a shorter time.

Limited responses

- Many candidates simply repeated the information in the question and did not mention why iodine was the better isotope to use.

(d) Comprehensive responses

- A few candidates stated that a neutron in the nucleus of iodine changes into a proton or that the number of protons increases by 1 and the number of neutrons decreases by 1.

Limited responses

- Many candidates mentioned only that the number of neutrons and protons change.
- A few candidates gave a definition of isotopes.

Question 9

(a) Comprehensive responses

- Some candidates were able to draw the orbit of Halley's comet passing through X and Y and to the left of the Sun between the orbits of Mercury and Venus.

Limited responses

- Most candidates drew an incorrect orbit, sometimes merely a circular orbit concentric with the planetary orbits or an orbit that has the closest distance of approach to the right of the Sun.

(b) Comprehensive responses

- Many candidates used detailed vocabulary, with correct references to terms such as 'Mercury has a shorter orbital path', 'a greater orbital speed' or 'a larger gravitational field strength caused by the Sun'.

Limited responses

- Some candidates, in trying to explain that Mercury takes a shorter time, only suggested that this was because this planet is closer to the Sun and did not extend their argument to compare the circumference of the orbits or compare the speeds of the planets.

(c) (i) Comprehensive responses

- Many candidates correctly stated 'fusion' or 'nuclear fusion'.

Limited responses

- Some candidates referred to 'fission' or 'fussion'.

(ii) Comprehensive responses

- Many candidates were able to state that the outward force, caused by nuclear fusion or radiation pressure, is balanced with, or equal to, the inward force of the Sun's gravity.

Limited responses

- Some candidates recognised that the inward force of gravity was involved but did not complete the argument by describing the cause of the outward force or that the two forces were balanced.

(iii) Comprehensive responses

- Many candidates showed a good knowledge of the life cycle of a star and were able to refer to the various stages from the depletion of hydrogen to the formation of a Red Giant and a planetary nebula or white dwarf.

Limited responses

- Some candidates did not make clear that the Sun will become a Red Giant rather than a Red Supergiant and sometimes stated that the Sun will become a supernova.

PHYSICS

Paper 5054/32 Practical Test

Key messages

Make and record observations, measurements and estimates

What candidates did well

- Many candidates recorded measurements to an appropriate degree of precision.
- Many candidates were able to use the apparatus provided carefully to take the required measurements.

What candidates needed to improve

- Some candidates did not repeat measurements when results were unexpected or did not follow the trend shown by the data.
- Some candidates used incorrect or non-standard units for quantities.

Interpret and evaluate experimental observations and data

What candidates did well

- Many candidates were able to process results using stated equations.
- Many candidates were able to plot points accurately on graphs using regular scales with data covering at least half of the grid.

What candidates needed to improve

- Some candidates recorded calculated values that were inconsistent with the data obtained.
- Some lines of best fit did not show an even distribution of data points above and below the line.
- Some candidates did not correctly determine 90 per cent and 110 per cent limits or calculate percentage differences between values.
- Some candidates did not use their data effectively to support conclusions.

Evaluate methods and suggest possible improvements

What candidates did well

- Candidates were able to identify control variables.
- Many candidates were able to describe common techniques to ensure accurate results.

What candidates needed to improve

- Some suggested improvements were not sufficiently specific to the method or apparatus being used.

Plan experiments and investigations

What candidates did well

- Many candidates were able to identify all of the apparatus needed to conduct a specific experiment.
- Many candidates were able to identify the dependent and independent variables and how they should be measured.
- Many candidates were able to write well structured plans.

What candidates needed to improve

- Some candidates omitted measured quantities or units from their results tables.
- Some candidates did not explain clearly how results would be processed to reach a conclusion.

Comments on specific questions

Question 1

(a) (i) Comprehensive responses

- Most candidates recorded an appropriate value for t within the required range.

Limited responses

- Some candidates recorded values for t which were outside the acceptable range or stated t to the nearest second. Values of time were expected to be recorded to at least the nearest tenth of a second.

(ii) Comprehensive responses

- Most candidates divided t by 20 and rounded their answer correctly.

Limited responses

- Some candidates divided t by an amount other than 20, often 10, resulting in an incorrect value for T .
- A few candidates did not round values correctly. Some candidates did not apply rounding conventions correctly.

(b) Comprehensive responses

- Most candidates obtained suitable values using a second length of thread.

Limited responses

- Some candidates did not adjust the length of the pendulum accurately resulting in inaccurate values for time t .

(c) Comprehensive responses

- Few candidates were able to use their data to find ratios or the expected value of T when l is doubled to show that the period is not proportional to the length.

Limited responses

- Most candidates quoted values and then stated that T did not double and did not find ratios for length and period or the expected value for T and compare this with their actual value to show that the period and length are not proportional.

(d) (i) Comprehensive responses

- Some candidates were able to substitute into the equation and evaluate correctly, stating the answer to two significant figures.

Limited responses

- Candidates did not square T or made other arithmetic errors in the evaluation.
- Candidates did not state the answer to the two significant figures required.

(ii) Comprehensive responses

- Candidates were able to repeat the calculation using a second set of data collected.

Limited responses

- Candidates made an error in evaluating a second value for the acceleration due to gravity. Common errors were not squaring T or substituting incorrect data.

(e) Comprehensive responses

- Candidates performed a suitable calculation such as finding 90 per cent and 110 per cent of one value to determine a range within which the other value should sit or finding the percentage difference between the values.
- Candidates gave a statement which matched their calculation.

Limited responses

- Some candidates used a mean value when calculating the percentage difference.
- Some candidates calculated 90 per cent or 110 per cent of both values but did not determine the range of one value.

- Some candidates did not show that the second value was within the range of the first.

(f) Comprehensive responses

- Many candidates described a suitable technique to obtain accurate results.
- Candidates made detailed reference to the apparatus and measurements taken in their descriptions.

Limited responses

- Candidates gave incomplete descriptions of a technique. Some responses referred to 'eye level' without identifying what should be viewed at eye level.

Question 2

(a) (i) Comprehensive responses

- Candidates recorded the temperature of the hot water to the nearest 0.5 °C.

Limited responses

- Some candidates stated the temperature to the nearest degree giving an integer value.
- A few candidates stated the temperature to a precision that is not possible to obtain using standard thermometers such as 75.3 °C.

(ii) Comprehensive responses

- Most candidates recorded a lower temperature at 240 seconds.

Limited responses

- Some candidates did not read the table headings correctly and recorded their value in the column for beaker Q.

(b) (i) Comprehensive responses

- Most candidates recorded data for the second beaker of water.

Limited responses

- Some candidates recorded values in incorrect columns in the table.
- Some candidates did not obtain readings with a lower drop in temperature using the lid.

(ii) Comprehensive responses

- Most candidates stated correct units for time and temperature as s and °C.

Limited responses

- A few candidates used incorrect expressions for units. Common incorrect answers were secs and C°.

(c) Comprehensive responses

- Most candidates found the difference between their values for temperature.

Limited responses

- Some candidates made an arithmetic error or found the difference between temperatures in different beakers at the same time.

(d) Comprehensive responses

- Some candidates gave a correct comparison of rates by referring to the decrease in temperature in the same interval of time or by calculating the rate in °C/s.

Limited responses

- Most candidates made a correct comparison of the decrease in temperature but did not refer to the decrease being in the same period of time.
- A few candidates attempted to explain why the temperature decreased. The question required comparison of the data rather than explanations of causes.

(e) Comprehensive responses

- Most candidates were able to state a valid factor which would affect the rate of cooling and so should be controlled.

Limited responses

- A few candidates gave vague descriptions such as temperature without suitable qualification such as the initial temperature of the hot water.

(f) Comprehensive responses

- Many candidates gave a clear description of a change made using the equipment they were given.

Limited responses

- Some candidates did not change the apparatus and sometimes introduced new equipment.
- Some candidates gave descriptions which were vague, so it was unclear if the change resulted in one beaker having no lid nor insulation and the other insulation and no lid.
- A few candidates misread the instructions so had uninsulated beakers with and without lids.

Question 3

(a) Comprehensive responses

- Many candidates drew a clear circuit diagram using the apparatus listed with an ammeter in series and a voltmeter across the power supply or the gap where the resistor would be placed.
- Some candidates used sharp pencils and rulers and drew clear circuit symbols.

Limited responses

- Some candidates drew circuits which omitted components or included additional ones not listed.
- Some candidates drew lines through the symbols for the electrical meters or ambiguous circuit symbols for other components.
- Some candidates drew voltmeters in series with the power supply and resistor.
- A few candidates used incorrect symbols for cells or a battery.

(b) Comprehensive responses

- Most candidates recorded values for current and potential difference to a suitable precision.

Limited responses

- Some candidates recorded values for potential difference outside the acceptable range.
- Some candidates recorded current to only one decimal place.

(c) Comprehensive responses

- Candidates collected five sets of values of potential difference and current. The values showed the correct trend and were recorded to a consistent number of decimal places.

Limited responses

- Some candidates varied the number of decimal places within a column of data.
- Some candidates had values which did not follow the trend. Some candidates recorded values that did not follow the trend shown by the rest of their data.

(d) Comprehensive responses

- Most candidates plotted the correct graph containing all observations in the table and to the required accuracy.
- Many candidates used sensible and regular scales where all the data occupied more than half the graph grid.
- Points were plotted using neat crosses within half a small square.
- Candidates drew a thin straight line of best fit with an even spread of points on either side.

Limited responses

- Candidates plotted the correct graph and labelled both axes with the required quantities. A few candidates did not include correct units for the quantities.
- Some candidates used awkward scales such as multiples of 3. Some candidates started axes at zero, resulting in scales that did not make effective use of the graph grid.

- A few candidates reversed the axes.
- Some candidates drew points which were blob like. Some plotted points were larger than half a square in diameter, reducing plotting precision.
- Candidates drew a line of best fit that could have been improved by more careful drawing or by rotating or shifting. Some used damaged or short rulers, resulting in poor line quality. Common issues included lines needing rotation or shifting or having kinks or joins.
- Some lines of best fit appeared to be influenced by individual points rather than the overall distribution of the data. Candidate treatment of anomalous points was not always appropriate or clearly indicated.

(e) Comprehensive responses

- Candidates drew a triangle on their graph which used over half of the line between the extreme data points from the table or indicated the corresponding values used by drawing lines to the axes.
- Candidates showed a substitution of coordinates into an expression of change in y divided by change in x to find the gradient and evaluated this correctly.
- Candidates stated the value for the gradient G to at least two significant figures.

Limited responses

- Candidates drew a triangle or used points which did not cover in excess of half of the distance between the extreme data points.
- Some candidates used points from the table which did not sit on the line of best fit. Gradient calculations were expected to use points selected from the line of best fit.
- Some candidates gave a value to one significant figure.
- Some candidates found the change in x divided by the change in y .

(f) Comprehensive responses

- Some candidates rounded their value for the gradient G to the nearest integer value.

Limited responses

- Many candidates restated the value of G or rounded it to a non-integer value. Some candidates did not round their answers to the precision required by the question.

(g) Comprehensive responses

- Some candidates wrote detailed descriptions of what would happen to the equipment if the terminals touched.

Limited responses

- Most candidates wrote vague or incorrect descriptions. A common incorrect answer was stating a risk of electrocution when the supply used is a low voltage one. Some candidates referred to damaging the circuit without giving a specific type of damage or referring to the heating effect of a current without linking this to a detailed issue arising from the wired heating up.

Question 4

Comprehensive responses

- Most candidates stated that a stopwatch or timer was needed. Some candidates included a stopwatch in a diagram of the apparatus. Some diagrams included equipment that was not labelled.
- Some candidates referred to all necessary measurements and that the measurements needed to be repeated for different values of the independent variable.
- Most candidates were able to explicitly state several control variables.
- Few candidates produced a table which included all measured quantities and units.
- Most candidates described how to process their data to arrive at a conclusion. Drawing a suitable graph was the most common way for candidates to express this.
- Many candidates used the instructions to help structure their responses in a logical way and to include all salient points. Many candidates used paragraphs for different sections of their method producing clear accounts.

Limited responses

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- Some candidates wrote responses which were not structured in a logical manner so that key points were more likely to be omitted.
- Many candidates did not explicitly refer to all the necessary measurements. A common omission was the initial temperature of the water.
- Some candidates implied control variables within a method and did not state them explicitly as required.
- Most candidates omitted time from their table headings. Some tables did not include columns for all measured quantities. It is not necessary to include columns for processed values such as the change in temperature or rate of temperature change.
- Some candidates did not write a description of how to process the data to arrive at a conclusion. A common issue was writing a prediction or a conclusion based on a similar experiment candidates had conducted in class.

PHYSICS

Paper 5054/41 Alternative to Practical

Key messages

Make and record observations, measurements and estimates

What candidates did well

- Many candidates recorded measurements to an appropriate degree of precision.
- Many candidates described changes in observations in detail.

What candidates needed to improve

- Some candidates did not interpret analogue scales correctly.
- Some candidates used incorrect or non-standard units for quantities.

Interpret and evaluate experimental observations and data

What candidates did well

- Many candidates were able to process results using stated equations.
- Many candidates were able to plot points accurately on graphs using regular scales with data covering at least half of the grid.

What candidates needed to improve

- Some candidates recorded calculated values that were inconsistent with the data obtained.
- Some lines of best fit did not accurately reflect the pattern shown by the data.
- Some candidates did not use data effectively to support conclusions.

Evaluate methods and suggest possible improvements

What candidates did well

- Candidates were able to identify control variables.
- Many candidates were able to describe common techniques to ensure accurate results.

What candidates needed to improve

- Some suggested improvements were not sufficiently specific to the method or apparatus.

Plan experiments and investigations

What candidates did well

- Many candidates were able to identify all of the apparatus needed to conduct a specific experiment.
- Many candidates were able to identify the dependent and independent variables and how they should be measured.
- Many candidates were able to write well-structured plans.

What candidates needed to improve

- Some candidates omitted measured quantities or units from their results tables.
- Some candidates did not explain clearly how results would be processed to reach a conclusion.

Comments on specific questions

Question 1

(a) (i) Comprehensive responses

- Most candidates recorded a value of length to the required precision.

Limited responses

- Some candidates recorded a value to two decimal places so not to the nearest millimetre.

(ii) Comprehensive responses

- Most candidates doubled their measured value correctly.

Limited responses

- Some candidates divided the length by two instead of multiplying by two.

(iii) Comprehensive responses

- Some candidates measured the diameter correctly and recorded it to the nearest millimetre.

Limited responses

- Many candidates recorded the diameter as an integer value so not to the nearest millimetre.

(iv) Comprehensive responses

- Most candidates measured the diameter correctly and recorded it to the nearest millimetre.

Limited responses

- Some candidates recorded the value to more than one decimal place.

(v) Comprehensive responses

- Most candidates calculated and recorded the average diameter to the nearest millimetre.

Limited responses

- Some candidates recorded the average diameter to a precision other than to the nearest millimetre.

(b) Comprehensive responses

- Many candidates correctly rounded the value of mass on the balance and recorded it to the nearest gram.

Limited responses

- Some candidates copied the value of mass from the balance and did not round it to the nearest gram.

(c) Comprehensive responses

- Some candidates were able to use their data to find a value for the density and stated this value to the required number of significant figures and with an appropriate unit.

Limited responses

- Many candidates did not round their value to the required number of significant figures.
- Some candidates made arithmetic errors when calculating the density such as not squaring the diameter.
- Some candidates stated an incorrect unit for density such as g/cm^2 or g/cm^{-3}

(d) Comprehensive responses

- Some candidates were able to describe how the cylinder was non-uniform and how this would affect measurements of diameter at different places along the cylinder.

Limited responses

- Many candidates referred to obtaining accurate results or increasing accuracy without linking their comments to the context given in the question.

Question 2

(a) (i) Comprehensive responses

- Many candidates drew a clear circuit diagram using the correct symbols for all apparatus shown including three cells.
- Some candidates used sharp pencils and rulers and drew clear circuit symbols.

Limited responses

- Some candidates drew circuits which omitted components or included additional ones not listed.
- Some candidates drew ambiguous or incorrect symbols or included an incorrect number of cells.

(ii) Comprehensive responses

- Most candidates drew a correct symbol for a voltmeter across the resistor.

Limited responses

- Some candidates drew a line through the voltmeter symbol or placed it across an incorrect component.

(iii) Comprehensive responses

- Most candidates read and recorded the potential difference correctly.

Limited responses

- Some candidates misread the scale with a common incorrect answer being 2.25 V.

(iv) Comprehensive responses

- Most candidates were able to substitute their values into the equation provided and calculate the resistance.

Limited responses

- Some candidates substituted incorrect values into the equation.

(v) Comprehensive responses

- Some candidates calculated the value for current to at least two significant figures.

Limited responses

- Some candidates did not evaluate the current correctly or did not round the value correctly.
- A few candidates did not record their value correctly. A common issue was attempting to convert to standard form and omitting $\times 10^{-3}$.

(b)(i) Comprehensive responses

- Many candidates were able to repeat the process correctly using the new data.

Limited responses

- Some candidates did not evaluate the new resistance leaving their answer at the substitution stage.

(ii) Comprehensive responses

- Most candidates correctly described a directional change in both variables.

Limited responses

- Some candidates did not state a direction of change in both variables so that the relationship between them was not given.

(iii) Comprehensive responses

- A few candidates correctly described a change in the total resistance of the circuit and linked this to Ohm's law.

Limited responses

- Most candidates only referred to the resistance of the thermistor or stated a generic relationship between current and resistance such as when current increases resistance decreases.

(iv) Comprehensive responses

- Most candidates correctly described a directional change in both variables.

Limited responses

- Some candidates did not state directions of change in both variables so that the relationship between them was not given.

(iv) Comprehensive responses

- Most candidates quoted a value less than the resistance they calculated for room temperature.

Limited responses

- A few candidates quoted the same value for resistance as that obtained for room temperature.
- A few candidates gave a value for resistance greater than that at room temperature.

Question 3

(a) (i) Comprehensive responses

- A few candidates read the thermometer scale correctly and stated the temperature to the required precision.

Limited responses

- Many candidates recorded the temperature as an integer value.
- Some candidates misread the scale on the thermometer.

(ii) Comprehensive responses

- Most candidates were able to describe how to correctly read a thermometer scale.

(b) (i) Comprehensive responses

- Many candidates gave an accurate explanation referring to the temperature of the water throughout the beaker.

Limited responses

- Some candidates referred to the spread of thermal energy throughout the beaker or mixing the water.

(ii) Comprehensive responses

- Most candidates suggested a suitable value approximately midway between the adjacent readings of temperature.

Limited responses

- A few candidates gave a reading outside of the acceptable range.

(iii) Comprehensive responses

- Most candidates plotted the correct graph containing all observations in the table and to the required accuracy.
- Some candidates used sensible and regular scales where all the data occupied more than half the graph grid.
- Points were plotted using neat crosses within half a small square.
- Candidates drew a thin curve line of best fit avoiding the point at 5 minutes.

Limited responses

- A few candidates did not include correct units for the quantities.
- Many candidates used an inappropriate scale on the y axis where the starting temperature was too low resulting in the data covering less than half of the available grid space.
- A few candidates reversed the axes.
- Some candidates drew points that were blob-like. Some plotted points were larger than half a square in diameter, reducing plotting precision.
- Candidates drew a line of best fit that could have been improved by more careful drawing so that the curve passed close to or through most of the points.

(iv) Comprehensive responses

- Most candidates were able to draw a second curve of best fit positioned above the first line.

Limited responses

- Some candidates drew lines that joined each point. Lines of best fit probably do not pass through all points.

(c) Comprehensive responses

- Most candidates made a correct comparison of the difference in rates referring to both beakers.

Limited responses

- Some candidates referred only to the water cooling faster without reference to the rate of cooling or temperature decrease per minute.

(d)(i) Comprehensive responses

- A few candidates recognised that the water would probably be cooler near the surface of the beaker so would not give the average temperature of the water.

Limited responses

- Most candidates gave inaccurate responses such as referring to measuring an exact temperature or taking a correct measurement.

(ii) Comprehensive responses

- Many candidates suggested and described suitable control variables in detail.

Limited responses

- Candidates often referred to using the same beaker which was stated in the method so an inappropriate choice.
- Some candidates referred to using the same temperature without a suitable qualification such as the same starting temperature of the hot water.

(iii) Comprehensive responses

- Some candidates suggested covering the top of the beaker, for example by using a lid.

Limited responses

- Candidates suggested a change that was not related to the apparatus such as changing room temperature or changing the initial temperature of the water.

Question 4

Comprehensive responses

- Some candidates stated that an ammeter was needed to measure the current and described where it should be placed in the circuit or drew a suitable circuit diagram.
- Some candidates referred to all necessary measurements and that the measurements needed to be repeated for different values of the independent variable.
- Many candidates were able to explicitly state several control variables.
- Some candidates produced a table which included all measured quantities and units.
- Most candidates described how to process their data to arrive at a conclusion. Drawing a suitable graph was the most common way for candidates to express this.
- Many candidates used the instructions to help structure their responses in a logical way and to include all salient points. Many candidates used paragraphs for different sections of their method producing clear accounts.

Limited responses

- Some candidates wrote responses which were not structured in a logical manner so that key points were more likely to be omitted.
- Many candidates did not explain how to change the current in the circuit to enable different measurements to be taken.
- Some candidates implied control variables within a method and did not state them explicitly as required.

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- Most candidates omitted the unit for current from their table headings. Some tables did not include all measured quantities.
- Some candidates described how to make an electromagnet using a nail and a coil of wire.
- Some candidates did not write a description of how to process the data to arrive at a conclusion. A common issue was writing a prediction or a conclusion based on a similar experiment candidates had conducted in class.

PHYSICS

Paper 5054/42 Alternative to Practical

Key messages

What candidates did well

- Most candidates followed instructions correctly and recorded measurements clearly.
- Most candidates performed calculations accurately.
- Many candidates related the number of significant figures in a calculated quantity to the number of significant figures in the raw data.
- Units of physical quantities were almost invariably included with numerical answers when required.
- Most candidates avoided line-of-sight errors when reading scales and described how such errors can be avoided.

What candidates needed to improve

- Full working was not always shown in numerical exercises, and corrections were not always made clearly.
- In graph questions, scales chosen did not always allow plotted points to occupy at least half of the given grid.
- Lines of best fit were not always smooth and accurate.
- The chosen independent variable was not always stated explicitly when planning an investigation.
- Care and attention to detail were not always evident when drawing or annotating diagrams. Straight lines on diagrams were not always drawn accurately.
- Rote phrases such as 'to make it more accurate' or 'to avoid parallax error' were sometimes seen without explanation linked to the practical situation being considered. Reasons for improvements in accuracy or methods used to avoid parallax error were not always stated.

Comments on specific questions

Question 1

(a) (i) Comprehensive responses

- Many candidates recorded the length of the pendulum correctly to the nearest millimetre.

Limited responses

- Dimensions were not always recorded to the nearest millimetre.
- Some candidates rounded their answers to the nearest centimetre, whilst others gave answers such as 7.00 cm. Clearly, this precision cannot be obtained when using a ruler graduated in millimetres.

(ii) Comprehensive responses

- Many candidates calculated the actual length L of the pendulum in metres correctly, given that Figure 1.1 had been drawn to a scale of one-fifth full size.

Limited responses

- Some candidates divided their measured length by 5, instead of multiplying by 5.
- Some candidates converted their measured length in centimetres incorrectly to metres, as requested in the question.

(b) (i) Comprehensive responses

- Some candidates recorded the reading on the stopwatch, correctly rounded to 3 significant figures in Table 1.1.

Limited responses

- Many candidates rounded the reading of the stopwatch incorrectly.
- Many candidates did not give the reading to 3 significant figures, as requested.

(ii) Comprehensive responses

- Most candidates calculated the period T of the pendulum correctly.

Limited responses

- Some candidates divided the time for the oscillations by 10 instead of by 20.
- Some candidates rounded their value for the period incorrectly.
- Some candidates did not express their answers to 3 significant figures, as requested.

(c) Comprehensive responses

- Some candidates used the data from Table 1.1 correctly, to show that the period T was not proportional to L .
- Some candidates showed that the ratio T/L was not constant.
- Some candidates used the data to show that doubling L did not double T .

Limited responses

- Most candidates thought that because T increased as L increased, that the two quantities were proportional. Understanding of direct proportion was not always evident in responses.

(d)(i) Comprehensive responses

- Many candidates calculated the first value for the acceleration due to gravity, g_1 correctly, and also gave the answer to 2 significant figures, as requested.

Limited responses

- Answers were not always given to 2 significant figures.
- Some candidates did not square the value of T in the given equation.

(ii) Comprehensive responses

- Many candidates calculated the second value for the acceleration due to gravity, g_2 correctly.

Limited responses

- Some candidates rounded their value for g_2 incorrectly.

(e) Comprehensive responses

- Some candidates compared the values of the acceleration due to gravity obtained by the two different methods and stated whether they could be considered equal.
- Most candidates backed up their statements with a calculation.
- Some candidates showed whether the two values for g could be considered equal by calculating the ratio of the smaller value to the larger value. If the value obtained is 0.9 (90 per cent) or greater, then the quantities can be considered to be equal.

Limited responses

- Many candidates calculated the difference between the two values and did not continue the comparison.

(f) Comprehensive responses

- Some candidates stated a technique used when conducting the experiment.
- Techniques stated by candidates included placing the ruler close to the pendulum when measuring its length, perpendicular viewing of the ruler, and use of a fiducial aid to count the oscillations.
- Responses also included repeating and averaging measurements or timing a larger number of oscillations.

Limited responses

- Some responses referred only to repeating the timing.

Question 2

(a) (i) Comprehensive responses

- Most candidates recorded the reading on the thermometers correctly.

Limited responses

- Common incorrect answers were 80.9 °C and 91 °C.

(ii) Comprehensive responses

- Most candidates added correct units to the headings in Table 2.1.

Limited responses

- C and C° were common incorrect units given for the temperature θ .
- sec was a common incorrect unit for the time t .

(b) (i) Comprehensive responses

- Most candidates calculated the temperature decrease of the hot water in beaker P and in beaker Q correctly.

Limited responses

- There were insufficient incorrect responses to pick out common errors.

(ii) Comprehensive responses

- Some candidates calculated the rate of temperature decrease of both beakers correctly.
- Some candidates recorded their answers to 2 significant figures, as requested in the stem of the question.

Limited responses

- The unit for the rate of temperature decrease, °C / min, was supplied for candidates on the answer line. Despite this, many candidates divided the temperature decreases by 240 (s) rather than by 4 (min).
- Answers were not always given to 2 significant figures.

(iii) Comprehensive responses

- Some candidates deduced correctly that since the water in beaker Q had the slower cooling rate, using a lid was a more effective way of insulating a beaker than lagging the sides.

Limited responses

- Many candidates stated incorrectly that beaker P had the more effective method of insulation because its rate of cooling was greater than that of beaker Q .

(c) Comprehensive responses

- Most candidates stated two valid factors that needed to be controlled so that a valid comparison between the rates of cooling of the water in both beakers could be made.

Limited responses

- Some candidates only stated one factor.

(d) Comprehensive responses

- Most candidates stated that removing the lid from beaker Q or adding a lid to beaker P would enable the new comparison to be made.

Limited responses

- Some candidates suggested removing both the lagging from beaker P and the lid from beaker Q . This did not allow the intended comparison to be made.

(e) Comprehensive responses

- Most candidates suggested using tongs or wearing gloves as a safety precaution when handling beakers containing hot water.

Limited responses

- Some candidates stated that they should stand as far away from the beaker of hot water as possible.

Question 3

(a) (i) Comprehensive responses

- Most candidates drew the correct standard symbol for a resistor connected between terminals *P* and *Q*.

Limited responses

- Some candidates drew a line through the middle of the resistor symbol.
- Some candidates drew the symbol for a variable resistor connected between *P* and *Q*.
- Some candidates drew the symbol for a thermistor connected between *P* and *Q*.

(ii) Comprehensive responses

- Most candidates drew the correct standard symbol for a voltmeter connected across the resistor.
- Most candidates drew the voltmeter connected in parallel with the resistor.

Limited responses

- Some candidates drew a square rather than a circle for the voltmeter symbol.
- Some candidates connected the voltmeter in series into the circuit.
- Some candidates drew a line through the middle of the voltmeter symbol.

(b) (i) Comprehensive responses

- Most candidates recorded the potential difference *V* across the $12\ \Omega$ resistor correctly.

Limited responses

- There were insufficient incorrect responses to pick out common errors.

(ii) Comprehensive responses

- Most candidates recorded the potential difference *V* across the $12\ \Omega$ resistor correctly.

Limited responses

- The pointer position halfway between two scale divisions was not always taken into account.
- This resulted in answers of 0.32 A or 0.34 A, instead of 0.33 A.

(c) Comprehensive responses

- Most candidates labelled the axes of the graph with quantity and unit.
- Some candidates selected a linear scale which was simple to use and occupied at least one-half of the given grid.
- Most candidates plotted the points correctly to within one-half of a small grid square.
- Most candidates drew a thin, continuous best-fit line.

Limited responses

- The units for *V* and/or *I* were often missing.
- There was some evidence of scales which were awkward to plot and check. For example, scales of 3.
- The *y*-axis was sometimes started from $V = 0$. This resulted in plotted points which occupied only a small portion of the grid provided. Scales chosen did not always produce plotted points occupying at least half of the grid.
- Some candidates who used dots rather than crosses to plot their points, drew large dots which sometimes occupied more than one small square. Some plotted dots occupied more than one-half of a small grid square.

(d) Comprehensive responses

- Some candidates indicated on the graph, the coordinates they had chosen to make their gradient calculation and also showed their working.
- Some candidates chose coordinates with a distance between them of at least half of the graph line, between the extreme plotted points.

- Some candidates obtained a value for the gradient which was within the allowed accuracy tolerance of 2.0 ± 0.2 .

Limited responses

- Some Values chosen for the gradient calculation and associated working were not always shown.
- Some candidates chose points on the best-fit line which were too close together.
- Some candidates inverted the gradient formula and calculated $\Delta x / \Delta y$.

(e) Comprehensive responses

- Few candidates recorded their value of the resistance of the battery r to the nearest ohm.

Limited responses

- Values of the resistance r of the battery were not always recorded to the nearest ohm.
- Some candidates did attempt to round their value of r to the nearest ohm but then recorded a value with a .0 at the end. For instance, a gradient G value of 2.2 was recorded as 2.0 instead of 2. Answers recorded to the nearest ohm were not always given as integers.

(f) Comprehensive responses

- A minority of candidates described that a voltmeter must be connected across/in parallel with a battery to measure its electromotive force.

Limited responses

- Some candidates stated that a series connection between the battery and the voltmeter was required.
- Most candidates stated that the voltmeter must be connected to the battery, giving no further detail of how the connection should be made.

(g) Comprehensive responses

- Few candidates stated that a very high current would flow in the circuit if P and Q touched.
- Answers seen included damage to the cells, overheating of the wires, damage to the ammeter, or overheating of the circuit.

Limited responses

- Many candidates gave answers such as causes a short circuit, causes sparks, or causes electrocution.

Question 4

Comprehensive responses

- Most candidates stated that a stopwatch or timer would be required.
- Most candidates described a suitable method for doing the investigation which included details of the measurements they would take.
- Most candidates measured the initial temperature of the hot water, the final temperature of the water and the time of cooling.
- Most candidates named a control variable which was appropriate for the independent variable.
- Many candidates drew a results table that was appropriate for the method chosen.
- Most candidates included units in the column headings of the table.
- Many candidates explained how to use their readings in order to reach a conclusion. A commonly used method was to plot a graph with specified axes.
- Common choices of axes were fan speed and rate of cooling, although fan speed against temperature (decrease) was equally acceptable.

Limited responses

- Some candidates did not name any additional apparatus needed to carry out the investigation. Most candidates understood that the time taken for the hot water to cool had to be measured. Many of these candidates did not state how they would measure the time, and what instrument they would use to do this.
- Many candidates started the stopwatch at the instant the initial temperature was recorded but omitted to say that the final temperature of the water was measured when the stopwatch was stopped.

- Many candidates included one column in the results table for the change in temperature of the water, instead of separate columns for the initial temperature and the final temperature of the water.
- Quantities recorded in the table were not always limited to those measured directly.
- Some candidates did not include units in the table headings.
- Explanations of how the readings would be used to reach a conclusion were not always included. Instead, they made a prediction about how the independent variable would affect the time taken. For example, many candidates stated that the greater the fan speed the greater the change in temperature or the rate of cooling of the hot water.