PHYSICS

Paper 5054/11
Multiple Choice

Question Number	Key
1	B
2	C
3	A
4	B
5	D
6	C
7	A
8	D
9	A
10	A

Question Number	Key
11	A
12	D
13	B
14	C
15	C
16	B
17	A
18	A
19	D
20	B

Question Number	Key
21	B
22	C
23	C
24	B
25	D
26	A
27	C
28	A
29	C
30	D

Question Number	Key
31	B
32	D
33	D
34	C
35	A
36	C
37	C
38	D
39	D
40	A

General comments

Candidates need to manage their time carefully and should ensure that the time spent dealing with any one question is not a disproportionate fraction of the time available.

Comments on specific questions

Question 5

Each of the options was selected by a significant number of candidates and the correct response was not the most commonly chosen. There were two points to consider when answering this question. Firstly, that a reduction in volume leads to an increase in density and then that the volume of a cube, and thus the density of the material, depends on the cube of the length of one side.

Question 7

The correct option **A,** was most popular but a significant number of candidates chose one of the other options. The final option, **D**, was a common choice and there were certainly candidates who tried to use direct proportionality when answering this question on the relationship between the pressure and volume of a gas.

Question 8

Only stronger candidates answered this correctly and the incorrect option, **B**, was by far the most popular choice. Option **C** was also sometimes selected, possibly by those who were unaware that friction is not an energy store and cannot be equal to a change in energy.

Question 19

Only a few candidates chose options **A** or **C**. The most commonly selected option, **B**, was chosen by candidates who had not deduced the wavelength of the wave from the information in the question. The wavelength is twice the horizontal distance between a crest and the adjacent trough.

Question 24

The correct answer here was option **B.** The other options either relied on the numbers in the question being used incorrectly in an expression such as distance / time or, in the case of option **C**, on candidates recalling a value without carrying out the calculation.

Question 28

Although the correct answer, **A**, was often selected, each of the other options was chosen by some candidates.

Question 30

Only a few candidates chose responses **A** or **B** which showed that most candidates realised that when the electrons flow from one end of the rod to other, the departure point becomes positive and the destination negative. The number of candidates choosing **C** was very similar to those choosing the correct option, **D**. Electrons experience a force in the direction opposite to the electric field and so move to the left-hand end of the rod. Thus, it is the left-hand end that becomes negatively charged.

Question 35

This was usually answered correctly. There were some candidates who chose option **D**. They were perhaps aware that any danger must be related to the live wire but did not realise that the life wire did not only have to break but needed also to touch the casing either directly or through the earth wire.

Question 37

Only stronger candidates answered this correctly. Many other candidates chose option **B**. There are only two transformers in the question, and the output voltage of the first is the input voltage to the second. The fact that there are 100 turns on the secondary coil of the first transformer and 200 turns on the primary coil of the second transformer may have persuaded some candidates to introduce a factor of two at this stage, even those this is not a third transformer. This would have led to the answer 6.0 V.

Question 38

This question was correctly answered by only a few candidates. The difference between current and voltage was not fully understood. Although the primary benefit of high-voltage transmission was well known, there were still candidates who selected option **A** or **B**.

Question 39

Options **A** and **B** were chosen by a number of candidates. The force on the particle in a magnetic field is at right-angles to both the direction in which it is moving and to the magnetic field. Slightly more candidates selected the incorrect option, **C**, than the answer, **D**. Perhaps these candidates incorrectly used the right-hand rule or ignored the negative charge on the electron.

PHYSICS

Paper 5054/12
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	C	11	D	21	D	31	A
2	B	12	C	22	B	32	B
3	B	13	A	23	C	33	C
4	D	14	A	24	D	34	D
5	A	15	B	25	B	35	D
6	C	16	C	26	B	36	C
7	B	17	A	27	A	37	C
8	B	18	C	28	B	38	D
9	C	19	B	29	A	39	C
10	C	20	B	30	C	40	D

General comments

Candidates need to be sure that the answer they select addresses the question asked. Multiple Choice items often contain options which are correct statements but do not answer the question asked in the stem of the question and are therefore incorrect answers.

Comments on specific questions

Question 4

The most commonly selected answer to this question was option **A**. This, of course, is the resultant force on the passenger. However, the question asked for the force exerted on the passenger by the floor of the lift. This force is greater than the resultant force as the weight of the passenger has to be considered in the calculation. A value for the gravitational field strength is given in the question and this is not needed when determining the resultant force.

Question 7

Few candidates answered this correctly. The most frequent cause of error was to use the full width of the base (8.0 cm) when calculating the moment due to the weight of the block. The diagram shows the weight acting through the centre of mass which is at a horizontal distance of 4.0 cm from point P in a uniform rectangular block of width 8 cm.

Question 8

The majority of candidates chose option **B** or **D**. Placing any object on top of the block raises the centre of mass of the combination and so option **D** was incorrect.

Question 11

Many candidates correctly chose option **D** and realised that this apparatus measured the difference in pressure between the atmosphere and a vacuum whereas those who selected option **C** did not. Initially, the apparatus in response **A** resembles a manometer but both halves of the U-tube are open to the atmosphere and so the two liquid levels would be equal.

Question 13

A nuclear reactor can supply energy continuously for many decades and so the correct option here was **A**. This was the most popular response but all of the other options were chosen by some candidates.

Question 14

This question was quite well answered and many candidates realised that in the circumstances described in the question, where the times and distances moved are identical in all four cases, the greatest power is determined solely by the greatest force. The directions of motion are not important. A small number of candidates chose option **C** where the load is being moved uphill but the other incorrect options were not chosen often.

Question 28

Stronger candidates answered this correctly and chose option **B**. The other options either relied on the numbers in the question being used incorrectly in an expression such as distance / time or, in the case of option **C**, on candidates recalling a value without carrying out the calculation.

Question 31

Each of the four options was chosen by some candidates. Perhaps, those who chose **B** thought that all the charge on Y would be transmitted to X and that this would leave Y uncharged.

Question 33

The equations $V = W / Q$ or $V = P / I$ could be used to answer this question and many candidates obtained the correct answer. The small number of candidates who chose option **B** may not have had a clear understanding of the distinction between current and potential difference.

Question 32

This was a well answered question and most candidates chose the correct option.

Question 40

This question was correctly answered by only a minority of candidates.. Although the primary benefit of high-voltage transmission was generally well known, there were candidates who selected option **A** or **B**.

PHYSICS

Paper 5054/21
Theory

Key messages

- Candidates should show all relevant working in a calculation so that credit can be given for all parts of the question that are answered correctly.
- When numerical data is given in the paper to two significant figures, candidates should give their answers to two significant figures or more and include the unit to any final calculated value.
- Candidates need to plan their answers and take time to read the question.

General comments

Units should always be given for calculated quantities as full credit is not given without a unit, except where a unit is not required, for example, for refractive index. Simple units such as those for speed can be written as m/s or ms^{-1} but not as m/s^{-1}.

In general, the majority of responses were both legible and understandable. However, a few candidates wrote their answers in pencil and then overwrote the pencil answers in ink. This should be discouraged.

Comments on specific questions

Section A

Question 1

(a) (i) Most answers correctly suggested that the length of the rubber band becomes longer but fewer answers recognised that the band also becomes thinner.

(ii) Most candidates gave the correct form of energy, elastic potential energy. Some incorrect forms were given, such as kinetic energy. Potential energy alone was not sufficient as there are several different types of potential energy.

(b) (i) The principle of moments was stated correctly by less than half of the candidates. The major error was to mention that the principle only applies when the object is in equilibrium. A number of candidates gave a description of how to calculate a moment rather than giving the principle of moments.

(ii) Only stronger candidates provided a correct explanation of why the force from the rubber band is larger than the weight in terms of the distances involved.

(iii) The calculation is a simple application of the principle of moments. Candidates who performed well often started with a statement such as clockwise moment = anticlockwise moment or $F_1d_1 = F_2d_2$ then substituted in the relevant values, taking care that distances are measured from the pivot. Those candidates who simply relied on using a ratio often used the inverse ratio. The distance of the weight in the equation was sometimes taken as 16 cm rather than 18 cm.

(iv) Although most answers suggested that answer in **(iii)** will be increased if the weight of *section XY* is not negligible, there were few explanations of why this is so. The most convincing answers suggested that the weight of *section XY* contributes to the clockwise moment.

Question 2

(a) The formula for kinetic energy was well known and many candidates gave the correct answer.

(b) (i) The most common answer was that global warming or the greenhouse effect will be reduced if the amount of carbon dioxide in the atmosphere is reduced. However, a significant number of answers mentioned the ozone layer instead of the greenhouse effect.

(ii) There are a number of possible advantages of using a coal-fired power station compared with a wind turbine. The most common acceptable answer mentioned that the wind does not always blow or is not available in some places. A significant number of answers suggested that a coal-fired station produces more electrical energy. This depends on the size of the station and the number of wind turbines being used and was only accepted if the smaller land area associated with a coal-fired station was mentioned.

(c) (i) Ideally the definition of the kilowatt-hour should mention that the kW h is a unit of energy when a device of 1 kW power is used for 1 hour.

(ii) Many candidates obtained the correct answer by a simple use of proportion.

(d) There are a number of possible forms of renewable energy. Solar energy was the most common answer. Some answers were not explicit enough, for example when "light energy" or "water energy" alone were mentioned.

Question 3

(a) Many candidates had difficulty in explaining that the specific latent heat of fusion is the energy needed to change a solid to a liquid without change in temperature. A number of candidates explained that solid changes to a liquid without mentioning the energy required or only mentioned that there was a change of state without specifying the states involved.

(b) (i) A reasonable performance was seen in this question with the temperature rising from 100 °C to 250°C and a flat section later rising to 400 °C. A significant number of sketches started from 0 °C rather than from 100 °C and a small number of answers showed flat sections at other temperatures or none at all.

(ii) Stronger candidates were able to suggest that there is a longer flat section in the graph or a longer section at 250 °C but explanations of why this happens were often missing. Candidates needed to explain that more energy is required to change the state and since the energy provided per second is constant then it must take longer. Many candidates suggested that the gradient of the graph changes or that it takes longer to reach 400 °C but did not specify that the time for the change in state at 250 °C is longer.

Question 4

(a) (i) Most candidates were able to mark the angles of incidence and refraction correctly on the diagram. The angles were sometimes incorrectly marked as the angles between the rays and the surface of the prism or the angle of refraction was marked as the ray left the prism into the air, rather than at the point where the ray entered the prism.

(ii) Only stronger candidates drew a ray that reflects internally or emerges along the glass-air surface. Many candidates drew a ray refracted in the right direction but as the ray is incident on the glass-air surface at the critical angle, the ray should emerge along the surface or be reflected internally.

(iii) Candidates produced some good diagrams showing the red light refracted in the correct direction at both surfaces. Inside the prism the red light should not be parallel to the blue light as it should have deviated less from the original direction.

(b) (i) There are several possible definitions of the critical angle, but the most common acceptable definition was "the angle of incidence when the angle of refraction is 90°". Many answers did not make it clear that the critical angle is an angle of incidence at all or that it is the angle between the ray and the normal. Very good answers also suggested that the ray must travel from the dense to the less dense medium.

(ii) The relationship between the critical angle and the refractive index was well known and most candidates were able to produce the correct answer.

Question 5

(a) The majority of candidates knew the name of at least one of the parts of a d.c. motor. The split-ring was sometimes labelled as a slip-ring.

(b) (i) Although there were many correct statements some were rather brief, for example "the rotation increases" whereas stronger answers suggested that the rotation would be faster.

(ii) Many candidates suggested that the motor turns in the reverse direction when the magnetic field is reversed. A significant number of candidates specified the actual direction that the motor will now turn in, usually the anticlockwise direction, but the question did not show that the motor is initially turning clockwise before the field is reversed.

(c) (i) Descriptions of the motion of the toy car were generally good with most answers describing the acceleration, deceleration and constant speed sections adequately. Some answers incorrectly suggested that during the flat section of the graph, the toy car becomes stationary rather than having a constant speed.

(ii) Stronger candidates suggested that the toy car will have the same constant top speed but will travel for longer at that speed or will slow down more when the motor is switched off. Many answers suggested that the acceleration or deceleration would be larger rather than acting for longer.

Question 6

(a) (i) The correct circuit symbol for an LDR was drawn by most candidates, but common errors were to draw the symbol with arrows leaving the resistor or to draw the symbol of a thermistor or variable resistor.

(ii) Few candidates were able to suggest that the resistance of the LDR decreases, causing an increase in the voltmeter reading because the current increases or that there is more voltage across the LDR. Many candidates were not able to explain why the voltage increases.

(b) (i) This question was answered well. Candidates had to show that the current is 1.9 A and most were able to manipulate the numbers to show this figure. The most usual method chosen was to start with a calculation of the voltage across the 4.0 Ω resistor and then to use that voltage to find the current in the 5.0 Ω resistor. The working was required and was usually acceptable.

(ii) There were some good calculations shown, usually by obtaining the total resistance of the circuit, using the total current with the formula $V = IR$. Weaker candidates were unable to use the formula for resistors in parallel and in series to find the total resistance.

Section B

Question 7

(a) (i) Most candidates answered this correctly.

(ii) After calculating the distance, the majority of candidates were able to calculate the average speed correctly.

(b) (i) Although most answers suggested that displacement is a vector and distance is a scalar, some answers did not mention the difference between the two quantities. There were also incorrect statements about distance such as "distance is in a straight line" or "distance is area covered".

(ii) Most candidates gave the correct scale on the diagram but it was obvious that some candidates did not understand what was meant by the scale used to construct the diagram.

(iii) Candidates often used Pythagoras' theorem to calculate the resultant displacement but sometimes used the wrong value for one of the sides. Other candidates measured the length of the diagonal and used the scale for the diagram to obtain the displacement. Either method was accepted but working needed to be shown.

(iv) Many candidates appeared to guess the angle, which was approximately 41°, rather than measuring or calculating it. A protractor can be used or the angle can be calculated using trigonometry. The calculation was performed well by many of the stronger candidates.

(v) Acceptable answers to this question were usually "velocity is speed in a given direction" or "speed is displacement per unit time". Some candidates described acceleration rather than velocity or gave a definition of speed rather than velocity.

(vi) Few candidates successfully explained that the size of the displacement from A to D is smaller than the distance covered by the first helicopter, but many candidates successfully suggested that the second helicopter travels a shorter distance and since the magnitude of velocity is the distance covered per second, the velocity has a smaller magnitude.

(c) Answers to this question varied considerably. The strongest answers mentioned air resistance and weight and clearly stated that as speed increases the air resistance increases, the resultant force decreases and acceleration decreases. Eventually weight and air resistance become equal and the helicopter falls at constant speed. Weaker answers only mentioned the forces balancing and the helicopter falling at constant speed. A number of answers were confused and suggested that air resistance both decreases and increases or that the speed is decreasing as the helicopter falls. The weakest answers gave little information about the forces involved, sometimes not mentioning the force of gravity.

Question 8

(a) Most candidates were able to define pressure as force per unit area.

(b) (i) Many candidates correctly suggested that the pressure, usually quoted as atmospheric pressure, is the same on both sides of the manometer.

(ii) The strongest answers mentioned that the water levels change because the pressure of the gas in the container is larger than atmospheric pressure. There were many answers that just mentioned that the gas enters the manometer without mentioning that the pressure or the force was larger on one side of the manometer than the other.

(iii) Most candidates incorrectly suggested that the gas container has run out of gas instead of mentioning that the pressure of the gas in the container is balanced by atmospheric pressure and the pressure of the water in the manometer.

(c) Many candidates attempted to use the equation $P = F/A$ rather than pressure = density × gravitational field strength × height and often progressed no further. Stronger candidates used the correct formula and the strongest answers used the correct distance (40 cm) for the height of the water. There were many considerations for this question, choosing the right equation, determining the correct height and converting the height of water into metres for the calculation.

(d) Candidates were better able to describe the effect of the temperature change on the molecules and the effect on the manometer. Many candidates approached the explanation logically by describing how the molecules hit the surface of the water or container and the strongest answers mentioned that the collisions with the wall will be more frequent or produce a larger force on impact.

(e) (i) Many candidates just suggested that the pressure is too large and will break the manometer, rather than recognising that the manometer is too small and that water will emerge from the right-hand side.

(ii) Comparatively few candidates suggested the use of a liquid with a larger density. It is not feasible to use a longer tube as it would have to be more than 15 m long in order to measure a pressure of 2.5×10^5 Pa.

Question 9

(a) (i) Most candidates successfully realised that isotopes have the same number of protons and different numbers of neutrons. Weaker answers only mentioned that isotopes have the same number of protons or that they have different numbers of neutrons.

(ii) Some candidates had difficulty in explaining that Q is not an isotope of P, even though they had explained in **(i)** that isotopes have the same atomic number.

(b) Some candidates chose technetium-99 as the most suitable source for the medical procedure. Iridium was sometimes chosen as it is a gamma emitter and the explanation in **(ii)** that gamma radiation can be detected outside the body or has sufficient penetration was a common correct answer. The choice of a suitable half-life, either as being short enough to cause less damage in the body or long enough that the source did not need to be replaced or that the measurements could be taken, was harder to express convincingly.

(c) (i) Cosmic rays or rocks were the most common natural sources chosen.

(ii) Man-made sources such as nuclear weapons, nuclear waste or nuclear power stations were mentioned by some candidates but many answers were too vague, for example “in industry” or “in food” which was not considered as man-made.

(iii) The cancer caused by radiation was mentioned as a harmful effect in most answers but weaker candidates mentioned a number of incorrect effects such as “global warming” or “radiation pollutes the atmosphere".

(d) (i) The completion of the nuclear equation was straightforward but weaker candidates attempted to make the nuclide X into a beta particle or another incorrect particle.

(ii) Fewer candidates could name the particle as a neutron even where it had been given the correct nuclide notation in **(i)**. Some candidates could work out from the nuclide notation that the particle contains no protons but as it has one neutron and proton then it must be a neutron.

(iii) Many candidates suggested that fusion reactions occur in the Sun or a star. However, some candidates only suggested that fusion occurs in the nucleus, rather than where the nuclei have a very high temperature.

(e) Most answers clearly explained that alpha particles have a higher ionisation effect and lower penetration than beta particles. The comparison of their deflections in magnetic fields was often spoilt by the particles being attracted to the poles of a magnet, for example “beta particles are attracted to the N-pole and alpha particles are attracted to the S-pole”.

PHYSICS

Paper 5054/22
Theory

Key messages

- Candidates should show all relevant working in a calculation so that credit can be given for all parts of the question that are answered correctly.
- When numerical data is given in the paper to two significant figures, candidates should give their answers to at least two significant figures.
- Candidates need to plan their answers and take time to read the question thoroughly before starting their answer as succinct and logical answers generally show greater understanding.

General comments

Units should always be given for calculated quantities, unless it is a quantity that has no unit, for example refractive index. Simple units, such as those for speed, can be written as m/s or ms^{-1} but not as m/s^{-1}. Units for complicated quantities such as specific heat capacity can sometimes be deduced from the equation but units for quantities such as force and energy should be known as the N and the J.

It is advisable that candidates use a scientific calculator for numerical calculations, particularly those calculations involving very large or very small numbers or powers of 10.

A ruler and pencil should be used for questions where precision is required, for example in **Question 7(a)(iv**) where a horizontal line had to be drawn, and in **Question 8(c)(ii)** where crests should be drawn parallel to the wooden bar before they hit the boundary, and where the wavelengths should be constant.

Candidates sometime used non-standard abbreviations for common words or phrases such as “bw” for between and “td” for total distance. Such abbreviations should only be used where they are clear and should in general be discouraged.

Most candidates demonstrated a wide scientific vocabulary but sometimes in a way that demonstrated a misunderstanding of keywords and terms, for example, “frequency”.

In general, the majority of responses were both legible and understandable. However, a few candidates wrote their answers in pencil and then overwrote the pencil answers in ink. This should be discouraged.

Comments on specific questions

Section A

Question 1

(a) The correct answer was usually given, but sometimes with the wrong unit such as kg or N/kg.

(b) Answers showed a good understanding of the difference between mass and weight. The most commonly seen stated difference between mass and weight was that mass is a scalar and weight is a vector. Some answers made vague references such as “mass is constant but weight varies’ rather than better statements such as “weight varies as gravitational field strength varies whilst mass does not”. Some candidates mentioned that mass and weight have different units but this difference had already been mentioned in the question. Weaker candidates tended to give vague descriptions without enough detail.

(c) (i) The question asked for a description involving forces. The strongest answers mentioned the resistance or drag of the water or mentioned air resistance. There was a good understanding shown that the horizontal forces were equal but many answers did not make it clear that the forces actually cancel or that the resistive forces act in the opposite direction to the force on the waterskier from the boat. A number of answers suggested that vertical forces such as the weight cancelled the applied horizontal force.

(ii) Most candidates subtracted the 50 N force from the 70 N force before calculating the acceleration. Some candidates did not know the formula $F = ma$ and these candidates attempted to use acceleration as the change in velocity per unit time instead. A number of answers only gave the numerical value of the answer to 1 significant figure or left the answer as a fraction. Most candidates gave the correct unit for acceleration, but weaker candidates gave the wrong unit.

Question 2

(a) This question was very often answered completely correctly, but a few energies were given other than the accepted forms of energy, kinetic, thermal (heat or internal energy) or sound.

(b) (i) The equation for gravitational potential energy was well known, but many candidates did not convert the mass of 150 kg to 0.15 kg before using the equation.

(ii) Candidates who wrote the definition of specific heat capacity using the equation $Q = mc\Delta\theta$ did not always clearly distinguish between Q and θ and this sometimes meant that the values inserted into the equation were wrong. Those candidates who used the equation as $Q = mc\Delta T$ generally made fewer errors. Many candidates were not certain of what the letters represent in this equation. A significant proportion of candidate did not recognise that the tube was turned 80 times and many candidates did not give the correct unit for specific heat capacity.

(iii) There were a number of acceptable answers to this question, such as “more time for heat loss”, “thermal energy was shared with the tube” or “there is more friction with the tube” The most commonly seen acceptable answer suggested that the pieces of metal had less kinetic energy. Candidates that mentioned friction often did not make clear whether they were describing friction between the metal and the tube, which increases, or friction between the metal pieces themselves as they stop at the end of the fall, which is less.

Question 3

(a) Most candidates were able to correctly define pressure as force per unit area or correctly stated the formula, but some were confused by the trapped air in the syringe and described why there is a pressure in terms of the movement of molecules rather than defining pressure or sometimes they merely suggested that pressure is the amount of force on a surface. Definitions of pressure such as “force acting on a certain area” were not accepted.

(b) Most candidates were able to score partial credit by stating that the molecules move around and hit the walls of the cylinder. However, only those candidates who approached the question logically then went on to mention how the collisions caused a force on the walls and thus created the pressure. The strongest answers mentioned Newton’s laws, but this level of detail was not required. Many candidates made reference to the plunger moving, decreasing the volume and causing an increase in pressure, but this did not answer the question asked. Candidates who based their arguments on Boyle’s law sometimes did not mention the collision of the molecules. Weaker candidates gave vague answers that did not specify that the molecules collide with the walls of the syringe.

(c) (i) Most candidates correctly applied the formula to calculate the pressure due to the 10 N weight on the plunger but many did not add this value to the atmospheric pressure to find the pressure of the air inside the syringe. Many candidates showed their working correctly but were unable to give the correct power of ten and often gave 8.3×10^{-4} as the pressure caused by the 10 N weight rather than $8.3 \times 10^{+4}$. Occasionally units were forgotten.

(ii) Many candidates were able to gain full credit for this question, including those who had not considered atmospheric pressure in their responses to **(i)**. There was some very clear working shown. The correct formula $P_1V_1 = P_2V_2$ was well known and stronger candidates were able to rearrange the formula to make V_2 the subject of the formula. In contrast, those candidates that tried to use a ratio method to determine their answer, often used the inverse ratio. Occasionally units were changed from cm^3, usually correctly to m^3.

Question 4

(a) This question asks for a definition of the angle of refraction, which is the angle between the refracted ray and the normal. Few candidates provided an adequate definition but instead described what is meant by refraction itself, often scoring no credit, particularly if the normal was not mentioned.

(b) Most candidates knew and applied the equation for refractive index correctly. Weaker candidates divided angles rather than their sines and a significant number incorrectly gave their answer with ° as a unit for refractive index.

(c) This question proved challenging for many candidates. It was common to see responses such as "the angle of refraction for red light is more since red light bends more". In fact, the red light bends less.

(d) This question was answered well by most candidates but a range of incorrect answers from weaker candidates included the names of different colours or electromagnetic waves from the ends of the spectrum as well as alpha and beta radiation.

Question 5

(a) Many candidates responded correctly to this question.

(b) (i) Most successful outcomes for the calculation of power came from the use of $P = I^2R$. A significant number of candidates earned credit for using the formula $P = VI$ instead, but many used the e.m.f. of the battery rather than calculating the p.d. across the thermistor in their calculation.

(ii) There were various routes to the answer in this question, and those candidates who set out their working clearly arrived at the correct final answer with few difficulties. Many candidates used $V = IR$ but some did not recall that potential differences and resistances add in series. Occasionally units were forgotten.

(iii) The increase in the resistance of the thermistor as it cools was usually stated. Stronger candidates linked this either to a decrease in the current or a larger potential difference across the thermistor. Weaker candidates merely related temperature to potential difference without explanation. Where potential difference was mentioned, it was sometimes not clear whether the answer referred to thermistor X or resistor Y.

Question 6

(a) (i) Magnetic poles were almost always correctly added to the diagram. The most common error was the omission of the S pole at the top of the iron ring. The repulsion of like poles was commonly understood and explained Weaker candidates sometimes suggested that "like charges repel".

(ii) This question was less well answered with a common explanation being that the iron is attracted as it is magnetic. Stronger candidates recognised that magnetism is induced into the iron ring because of the permanent magnet. Some candidates stated that the iron ring is attracted to the magnet because it is made of metal.

(b) Most candidates drew, or attempted to draw, three circular field lines and the majority added arrowheads in the correct direction. The magnetic field patterns of bar magnets and electric field patterns of a charge were seen in some answers.

Section B

Question 7

(a) (i) There were some very detailed responses seen that showed that most candidates had a good understanding of the concepts. Many candidates gave a good description of the three sections of the graph, giving correct time intervals and values of the speed. Some candidates also gave a value for the acceleration or deceleration, including the correct units. Weaker candidates tended to omit details such as the time intervals or speeds. There were a few common errors, for example in the first section of the graph where some candidates stated that the car "accelerates at constant speed" or "has a constant speed for the first 10 s" and in the second section "the car is at rest for 10 s", "travels at different speed"' or "accelerates uniformly between 10 and 20 s".

(ii) There were many good answers which clearly showed the method used to determine the area beneath the graph. Candidates either calculated the area of a trapezium or worked out the area of three distinct sections separately adding them together to find the total distance travelled.

(iii) Most candidates clearly understood that the average speed was equal to the total distance divided by the total time and did well on this question. Candidates should be encouraged to use the full word equation in their working rather than "average speed = TD/TT".

(iv) This question was challenging for many candidates. Despite finding the correct average speed and being told in the question that the second car had a constant speed, many candidates incorrectly drew a diagonal line. The most popular incorrect response was to draw an identical shape to **Fig. 7.1** but with a lower middle section.

(b) Most candidates obtained the correct answer in **(i)** but often had difficulty in **(ii)** in expressing their ideas using data from the table. Most answers described the trend shown in the table with good answers showing that the value of time, the thinking distance divided by speed, is constant with some answers giving the value as 0.45 ($\times 10^{-3}$) hour or 1.6 s. Other acceptable answers commented on the direct proportionality between thinking distance and speed or illustrated the relationship by stating that when the speed doubles, the thinking distance doubles. It was very common to see weaker responses such as "as the speed increases the thinking distance increases" or "the difference between values of thinking distance is 9 m" which did not link clearly to a constant time. A number of candidates did not follow the information in the question to make use of the data in the table at all. They made general statements such as "the driver will observe a hazard and apply the brakes to stop the car". In **(iii)** many candidates stated that thinking distance increases and braking distance remains the same. The effect of tiredness on the thinking distance was usually correct but fewer candidates correctly stated that the braking distance remains the same. Weaker candidates merely described what is meant by thinking and braking distance.

Question 8

(a) (i) Many candidates found this question challenging. Where candidates understood frequency and that a frequency of 2.0 Hz means that there are 2.0 waves per second, then the answer was easily accessible. Other candidates calculated the time for one wave as 0.5 s and then the answer was also easily found. However, many candidates tried to use both the frequency and the amplitude and were not successful.

(ii) Although most candidates knew that the shape of the graph should be roughly sinusoidal, only a few answers showed a wave amplitude of 3 mm and even fewer graphs showed one complete wave taking 0.5 s.

(b) (i) There were a number of acceptable answers to this question, including using more rubber bands or making them tighter or shorter but the most common acceptable answer was merely to move the bar up and down faster or more often.

(ii) Most candidates recognised that the wavelength decreases when the frequency increases, but there was considerable uncertainty regarding what happens to the speed of the wave, with fewer candidates recognising that the speed is unchanged.

(c) Many candidates seemed unfamiliar with a ripple tank used to show refraction and, in (**i**), using an object to change the depth of the water was only suggested by stronger candidates. Many candidates gave answers which confused refraction with reflection. Where candidates attempted a correct diagram of refraction in **(ii)**, some crests were not drawn carefully to show constant wavelength before the waves reached the boundary. The question asked for the boundary to be marked but this boundary was omitted in many answers, making it difficult to judge whether refraction had occurred. The boundary did not have to be at an angle to the incident crests as refraction could be shown by crests being closer together or further apart after refraction.

(d) (i) Many candidates were able to show the formula for speed = distance/time in their working, even if they failed to recognise that the distance travelled is 1120 km rather than 560 km or if they failed to convert the distance in km into metres. Weaker candidates found it difficult to rearrange the formula to time = distance/speed.

(ii) This question was generally answered well. The most common acceptable answer was that both infrared and microwaves are electromagnetic waves, are transverse or travel in a vacuum.

(iii) There were many vague answers, such as “more reliable”, “cheaper” or “less waste of energy”. Answers needed to be specific to the context, such as stating that satellites are expensive to place in orbit or maintain. The most commonly seen acceptable answers described how the data is less likely to be intercepted using an optical fibre or that optical fibres can carry more data per second. There were some misconceptions demonstrated, for example the idea that the speed of the light in the fibre is higher than the speed of microwaves in air.

Question 9

(a) (i) This question was usually answered well, with many candidates clearly understanding the difference between the helium atom and the ion. The difference lies in the number of electrons or the charge on the atom and ion. Many candidates added details concerning the proton and neutron composition which were mainly correct.

(ii) The structure of an alpha particle was not well understood. Many candidates incorrectly suggested that an alpha particle has two electrons and their descriptions suggested that an alpha particle and a helium atom are identical, which is not true.

(iii) Many candidates correctly gave 88 protons in the nucleus of X and 89 protons in the nucleus of Y was also often given. A few candidates treated the second decay as alpha-particle decay and a significant minority gave nucleon numbers rather than the neutron numbers in the third column.

(b) There were many excellent responses which scored full credit, most commonly using paper and a thin sheet of aluminium as absorbers and a GM tube as a detector. A few candidates used charged plates and deduced the presence of the two types of radiation from the deflections but commonly such answers were spoilt if no detector was used to actually show the deflections. Alternatively, a cloud chamber was often successfully described with candidates recognising that the shape and length of the tracks are different for the two types of particle. The least successful answers were long descriptions, often of how a GM tube works. The strongest answers were succinct and made good use of the space available.

(c) (i) Most candidates understood that half-life is the time period for the halving of a property but fewer candidates made it clear that it is the time for the number of atoms or the number of nuclei to halve or the time for the count rate or activity to halve.

(ii) The calculation was generally more successful when candidates began by halving the number of atoms from 4.0×10^{14} until 5.0×10^{13} is reached and dividing the total number of years by the number of such divisions. Many candidates tried a ratio approach between 4.0×10^{14} and 5.0×10^{13} but then failed to give the half-life in years or merely suggested there were three half-lives.

PHYSICS

Paper 5054/31
Practical Test

Key messages

- It is important that, whenever appropriate, repeat measurements are made and averages calculated.
- Numerical data should be recorded to a suitable and consistent level of precision. Readings taken from analogue instruments such as some ammeters and voltmeters should always be written down to the precision of the instrument used. In the case of digital instruments such as multimeters used to measure voltages or currents, the initial readings should be recorded to a precision such that the final answers may be rounded to the requested precision or the usual precision required (3 sig. figs).
- In some questions the required unit (e.g., mm) is given and in such cases candidates should ensure that their responses are given in that unit and not a related unit.
- Working for calculations should always be shown, and the quantities for units always be recorded.
- It is advisable that candidates look at the final numerical answers to a question and check that they are realistic values and not miscalculated by, for example, powers of ten. Calculations should be checked and final answers appropriately rounded, if necessary, so that they are written to a suitable level of precision.

General comments

This examination assesses candidates' skills in practical physics. These skills include following sets of instructions accurately and safely, using simple equipment to take measurements, collecting sets of data, making comments about the quality of the results and making valid conclusions based upon those results.

Candidates should have familiarity with basic skills in handling simple laboratory equipment.

In the strongest responses, candidates demonstrated that they are able to read and understand the questions and perform the required tasks using the equipment provided and that they are able to follow instructions and carefully record accurate observations and measurements at the time they are made. Measurements made in the examination were made to a level of precision appropriate to the equipment being used and measured. These candidates were able to explain how they checked that the equipment was set up in the correct way or how they ensured their measurements were accurate.

It is emphasised that equipment should comply with the specifications and should be set up in accordance with the Confidential Instructions. It is equally important that the details requested are written in the supervisor's report and are sent to Cambridge when the examination papers are dispatched. In some circumstances, if the apparatus does not comply with the specifications, the information contained in the supervisor's report allows us to ensure that the candidates are not disadvantaged by the use of non-compliant apparatus.

Stronger candidates were able to demonstrate good graph plotting skills. Candidates should not use a pen to mark the plotted points or to draw the best straight line or curve but should use a sharp HB pencil. Attention is drawn to the advice on plotting graphs issued by Cambridge. Scales which produce a graph which occupies over half the grid in the *x* and *y* directions and are based on a scale of 2, 5, or 10 units corresponding to 10 small grid lines are more appropriate than scales based on 3, 6, 7 and non-integers. Scales should be linear. The plotted points on graphs should be marked with small, fine, but visible crosses which are accurately placed, within half a small square on the grid.

The Cartesian axis system should be used, with values increasing from left to right in the *x*-direction and from lower to higher in the *y*-direction. The best fit straight line or curve should be a carefully drawn, smooth, thin line. Straight lines should be drawn as a single ruler-drawn line using a ruler which is sufficiently long to extend along the whole of the line drawn (15-centimetre rulers are often too short for this purpose).

When asked to compare two quantities and to state whether they are equal or not with justification, candidates should clearly specify the criteria they are using. For example, answers such as “they change”, “they are different”, “they vary” are too vague, whereas stronger candidates use phrases such as “as A increases, B decreases” or “the values of X are close enough to say that they are the same” or “there is too much difference between the values of Y to say they are equal. Candidates should be aware that if one quantity increases when another decreases, it does not necessarily mean that those two quantities are inversely proportional to each other.

Comments on specific questions

Question 1

(a) Candidates were required to measure the length and width of a standard school laboratory liquid-in-glass thermometer and to give those measurements in millimetres. Stronger candidates listed their results in the correct order to the nearest millimetre. Some weaker candidates gave measurements to an unrealistically high level of precision of better than a whole millimetre.

(b) The given formula was used to calculate the supposed volume of the thermometer. Stronger candidates performed the calculation correctly and the strongest answers showed a final value that had been rounded correctly to two or three significant figures.

(c) (i) Stronger candidates recognised that the volume was only an estimate of the actual volume because it was assumed that the thermometer was a perfect cylinder, but in fact it had an irregular shape, with rounded ends and in some cases the bulb could have a different shape from the body. Weaker candidates referred to the measurements being inaccurate or the value having been rounded up or down.

(ii) Stronger candidates discussed how the rounded ends or the bulb of the thermometer were small in comparison to the overall dimensions of the thermometer. Other acceptable response stated that the thermometer’s shape was close to that of a cylinder.

(d) Stronger candidates stated that the volume of the liquid would vary with the temperature and therefore the thermometer should be placed in an environment with a constant temperature. An alternative acceptable response was based on the relative thickness of the wall of the thermometer compared with the liquid column, or the considerable difference in thickness of the walls of the bulb and the main body of the thermometer.

Question 2

(a) Candidates were required to measure the length of a pendulum and acceptable responses were within a specified range as the length of the pendulum set up had been specified in the Confidential Instructions.

(b) Stronger candidates checked that the rule was vertical and then checked that the pendulum bob was lifted to the correct height (10 cm above its original height) above the ground. To check whether the pendulum was vertical, stronger candidates described how the rule and set square were used together, or how it could be checked that the rule and thread of the pendulum were parallel to each other, or how it could be checked that the thread was perpendicular to the floor (which was assumed to be level). Credit was also awarded for a diagram which was sufficiently well annotated to be self-explanatory. Weaker responses did not provide details about how the check was carried out.

(c) The strongest candidates determined the average time for one oscillation by measuring the time for their chosen number of oscillations (between 5 and 20 oscillations), taking that measurement at least twice and calculating the average for their chosen number of oscillations. From that value they calculated the time for one oscillation.

(d) Only stronger candidates answered this correctly.

Question 3

(a) (i) When using a component conforming to the required specification and the LED held approximately 30 cm above the LDR, stronger candidates recorded voltmeter readings in the range of 3.5 to 4.5 Volts and the value was given to at least 1 decimal place.

(ii) When the LED was slowly moved closer to the LDR, stronger candidates recorded that the voltmeter began to show a different (lower) reading when the height above the LDR was in the region of 5 to 25 cm.

(ii) As the LED was moved closer and closer, the voltmeter reading should have reached a constant voltage at some stage. Stronger candidates recorded this value of the voltage and the original voltage (for the starting position of about 30 cm), calculated the difference between them and gave the final answer to 2 or 3 significant figures.

(b) (i) Stronger candidates described how the LED could be held at a fixed distance from the LDR and the voltmeter reading noted when the LED was pointed directly at the LDR (i.e. in the X orientation). They then stated that the voltmeter reading with the LED rotated to the Y direction and held at the same distance should also be noted and lastly they described a comparison of the two recorded voltages that would show that the original claim being tested is correct.

(ii) Stronger candidates recorded voltages measured for each orientation of the LED and gave an appropriate statement ("yes, it is correct" or "no, it is not correct") supported by a justification in the form of an explanation for this decision. The statement and justification needed to be consistent with the results obtained by taking the further readings. Some candidates repeated the original experiment for each orientation and this was acceptable provided an appropriate statement and justification were given. Some weaker responses showed contradiction between the measurements, the statement and its justification.

Question 4

(a) Many responses showed that the image selected was not magnified. The other adjustments should have been made depending on whether the lens and light source cross-wire and screen were all perpendicular to the bench and parallel to each other and whether the lens needed to be raised or lowered in height (so that the centre of the cross wire, the centre of the lens and the centre of the image were all in the same straight line and that line was parallel to the rule/bench).

(b) Stronger candidates showed the value of *x* (the distance between the centre of the lens and the screen) was between 76 and 82 cm. Weaker candidates often showed the difference between 100 and the expected value, implying that the rule's scale had been used incorrectly.

(c) Stronger candidates measured the vertical wire of the target as 20 $\pm$2 mm and the length of the magnified image in the region of 87 $\pm$10 mm.

(d) The screen was moved to various positions, 8 cm closer to the object each time, new values of distance*, x* and height, *D* obtained and the magnification calculated for each. The values obtained from **(c)** and **(d)** were written into the table. Stronger candidates provided the correct headings for the table, six complete sets of readings, correct calculations of the magnification for each and the data for each quantity recorded to consistent levels of precision (to 2 or 3 significant figures).

(e) Stronger candidates had axes labelled with the quantity for *m* on the *y*-axis (with no unit) and *x*, with the unit of cm on the *x*-axis. Scales for the graph were chosen so that it occupied at least half of the page in both the *x* and the *y* directions.

Some weaker candidates used scales based on 3, 6, 7 and these scales made it more difficult for the candidate to plot points correctly. Some candidates used non-linear scales and these should never be used.

Graphs should be plotted using the Cartesian system and the quantities value should increase upwards on the y-axis and increase in the direction from left to right on the *x*-axis. Stronger candidates showed the plotted points clearly as fine points (which were sometimes circled) or crosses placed within half a small square of their correct position on the grid. These candidates found the graph to be a straight line and drew the straight line of best fit using a ruler.

(f) **(i)** Stronger candidates calculated the focal length of the lens using the value for *x* determined in **(b)**. Some weaker candidates did not follow this instruction and calculated the gradient of the line. The focal length of the lens should have been close to 15 cm, but in practice the values tended to be slightly larger.

(ii) The strongest candidates gave a statement agreeing or disagreeing with the student's claim, depending on and consistent with the value obtained by the candidate and justified that statement using an explanation to support it. In general, if the two values differ by more than about 10 per cent then they should not be considered equal, while if they differed by less than about 5 per cent they should be considered equal and if the difference between the two values lies in between those percentage differences then the quantities could have been regarded as equal or not, depending on the candidates definition of the border between equal or not, which should be stated.

Some weaker candidates allowed percentage differences of 20 per cent or even 50 per cent to make their judgements, but these margins were too large to be appropriate. Other weaker candidates made a more vague comparison without using percentages and this was acceptable provided the correct comparisons were made for the size of the difference.

PHYSICS

Paper 5054/32
Practical Test

Key messages

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General comments

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Question 4

(a) Many responses showed that the image selected was not magnified. The other adjustments should have been made depending on whether the lens and light source cross-wire and screen were all perpendicular to the bench and parallel to each other and whether the lens needed to be raised or lowered in height (so that the centre of the cross wire, the centre of the lens and the centre of the image were all in the same straight line and that line was parallel to the rule/bench).

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(c) Stronger candidates measured the vertical wire of the target as 20 $\pm$2 mm and the length of the magnified image in the region of 87 $\pm$10 mm.

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Some weaker candidates used scales based on 3, 6, 7 and these scales made it more difficult for the candidate to plot points correctly. Some candidates used non-linear scales and these should never be used.

Graphs should be plotted using the Cartesian system and the quantities value should increase upwards on the y-axis and increase in the direction from left to right on the *x*-axis. Stronger candidates showed the plotted points clearly as fine points (which were sometimes circled) or crosses placed within half a small square of their correct position on the grid. These candidates found the graph to be a straight line and drew the straight line of best fit using a ruler.

(f) (i) Stronger candidates calculated the focal length of the lens using the value for *x* determined in **(b)**. Some weaker candidates did not follow this instruction and calculated the gradient of the line. The focal length of the lens should have been close to 15 cm, but in practice the values tended to be slightly larger.

(ii) The strongest candidates gave a statement agreeing or disagreeing with the student's claim, depending on and consistent with the value obtained by the candidate and justified that statement using an explanation to support it. In general, if the two values differ by more than about 10 per cent then they should not be considered equal, while if they differed by less than about 5 per cent they should be considered equal and if the difference between the two values lies in between those percentage differences then the quantities could have been regarded as equal or not, depending on the candidates definition of the border between equal or not, which should be stated.

Some weaker candidates allowed percentage differences of 20 per cent or even 50 per cent to make their judgements, but these margins were too large to be appropriate. Other weaker candidates made a more vague comparison without using percentages and this was acceptable provided the correct comparisons were made for the size of the difference.

PHYSICS

Paper 5054/41
Alternative to Practical

Key messages

- Candidates should be reminded to include units when quoting the values of physical quantities. They should be reminded to check that the unit they have provided is appropriate for the calculated or measured quantity.
- Candidates should be made aware that it is important to record measurements to the correct precision. In particular, measurements made with a rule should be given to the nearest millimetre. If a measured length is, for example exactly 5 cm, the value should be quoted as 5.0 cm.
- Candidates should ensure they pay attention to detail when drawing or annotating diagrams. The accuracy of straight lines on diagrams could be greatly improved by using a sharp pencil and a ruler.
- Candidates should be advised to avoid using vague phrases, such as, "to make it more accurate" or "to avoid parallax error". These comments need to be linked to the practical situation being considered, and candidates should state how the accuracy is improved or how a parallax error is avoided.
- Candidates should be reminded that, when plotting a graph using data obtained from practical work, there will almost always be some scatter about the line of best fit. Forcing the line through all points will often produce a curve that is not smooth, and candidates should be discouraged from doing this.

General comments

The aim of the examination is to enable candidates to display their knowledge and understanding of practical Physics techniques. These include:

- handling practical apparatus and making accurate measurements
- tabulating of readings
- graph plotting and interpretation
- manipulating data to obtain results
- drawing conclusions
- understanding the concept of results being equal to within the limits of experimental accuracy
- dealing with possible sources of inaccuracy
- control of variables
- choosing the most effective way to use the equipment provided.

Candidates should have as much personal experience of carrying out experiments themselves as possible. They should be aware that as this paper tests an understanding of experimental work, explanations will need to be based on data from the questions and practical rather than theoretical considerations.

Many candidates dealt well with the range of practical skills being tested. Stronger candidates were able to follow instructions, record observations clearly and perform calculations accurately and correctly. Candidates should be advised to read the questions through very carefully to ensure that they are answering the question as written, and not simply recalling the answer to a different question.

Numerical answers should be expressed clearly, to the appropriate number of significant figures and with a correct unit, where applicable. Candidates should know that these techniques will be tested at some point in the paper

Comments on specific questions

Question 1

(a) Candidates could take an accurate volume measurement from a measuring cylinder.

(b) (i) Relatively few candidates could suggest a safe and sensible method of ensuring that the water added to a beaker was a particular temperature each time it was added.

(ii) Taking an average of three values caused little difficulty and most candidates recorded their answer in the table correctly to 2 significant figures.

(iii) Although most candidates drew their graph well, some used large blobs to plot their points and this caused some inaccuracy. The line of best fit was a curve which was drawn well in many cases.

(iv) The stronger candidates realised that the fact that the graph shown was a curve indicated that the relationship could not be directly proportional.

(c) The stronger candidates drew graph lines with similar curves to the original drawn using the data in Table 1.1, starting from the same point and above the original line.

Question 2

(a) The strongest candidates drew neat circuits using the correct symbols with all the wires connected to show the battery, switch, resistor, and ammeter connected in series, in that order clockwise, and with a voltmeter connected across the battery.

(b) (i) Processing values of potential difference and current to find resistance presented few difficulties. A few candidates did not give their final answer to the nearest whole number as instructed.

(ii) Candidates were able to take a reading from an ammeter accurately.

(iii) This calculation was usually done correctly.

(c) Stronger candidates found the percentage difference between the values and, if it was within10 per cent, stated that the values were equal within experiment error. Weaker candidates found this question more challenging.

Question 3

(a) (i) This question was usually answered correctly.

(ii) This particular instruction was not carried out correctly by many candidates.

(b) Most candidates were able to join the points W and X with a straight line. Weaker candidates did not project the line backwards until it met the edge of the transparent block.

(c) (i) Most candidates answered this question correctly.

(ii) This was a simple measurement. Stronger candidates realised that the unit given was cm and therefore the measurement recorded should be to one decimal place, reflecting the usual precision of a 300 mm or 150 mm ruler.

Question 4

(a) Many candidates found this question challenging. Only stronger candidates could explain how to find the diameter of a wire using a ruler. The expected answer was to cut it into several pieces, line them up together and measure the diameter across at least five thicknesses of wire.

(b) Nearly all candidates correctly suggested using a micrometer (screw gauge) or callipers to find the diameter of a single wire.

PHYSICS

Paper 5054/42
Alternative to Practical

Key messages

- Candidates should be reminded to include units when quoting the values of physical quantities. They should be reminded to check that the unit they have provided is appropriate for the calculated or measured quantity.
- Candidates should be made aware that it is important to record measurements to the correct precision. In particular, measurements made with a rule should be given to the nearest millimetre. If a measured length is, for example exactly 5 cm, the value should be quoted as 5.0 cm.
- Candidates should ensure they pay attention to detail when drawing or annotating diagrams. The accuracy of straight lines on diagrams could be greatly improved by using a sharp pencil and a ruler.
- Candidates should be advised to avoid using vague phrases, such as, "to make it more accurate" or "to avoid parallax error". These comments need to be linked to the practical situation being considered, and candidates should state how the accuracy is improved or how a parallax error is avoided.
- Candidates should be reminded that, when plotting a graph using data obtained from practical work, there will almost always be some scatter about the line of best fit. Forcing the line through all points will often produce a curve that is not smooth, and candidates should be discouraged from doing this.

General comments

The aim of the examination is to enable candidates to display their knowledge and understanding of practical Physics techniques. These include:

- handling practical apparatus and making accurate measurements
- tabulating of readings
- graph plotting and interpretation
- manipulating data to obtain results
- drawing conclusions
- understanding the concept of results being equal to within the limits of experimental accuracy
- dealing with possible sources of inaccuracy
- control of variables
- choosing the most effective way to use the equipment provided.

Candidates should have as much personal experience of carrying out experiments themselves as possible. They should be aware that as this paper tests an understanding of experimental work, explanations will need to be based on data from the questions and practical rather than theoretical considerations.

Many candidates dealt well with the range of practical skills being tested. Stronger candidates were able to follow instructions, record observations clearly and perform calculations accurately and correctly. Units were well known and usually included where needed and ideas were expressed logically. The standard of graph plotting was generally good. Candidates should be advised to read the questions through very carefully to ensure that they are answering the question as written, and not simply recalling the answer to a different question. Numerical answers should be expressed clearly, to the appropriate number of significant figures and with a correct unit, where applicable. Candidates should know that these techniques will be tested at some point in the paper.

Comments on specific questions

Question 1

(a) Many candidates drew a neat, well-labelled diagram showing clearly how the wooden blocks could be used with the ruler to obtain a value for the external diameter of the test-tube. Some candidates drew the blocks inside the test tube or on either side of the rim, or suggested using vernier callipers which did not gain credit. Other candidates did not draw a diagram at all, and their descriptions did not contain enough detail to gain full credit.

(b) The height of the water in the test-tube was usually measured correctly to the nearest 0.1 cm.

(c) (i) The reading of the water level in the measuring cylinder was almost always correct. The most common incorrect answer was 91 cm^3.

(ii) The majority of candidates carried out the correct subtraction to find the volume of water that had been poured into the test-tube.

(d) The graph question was answered well. Most candidates chose sensible scales and followed the instruction to start both axes from the origin. Only a small number of candidates used scales on the axes that were multiples of 7, etc. Attempts at drawing a line of best-fit were usually very good. Candidates should be reminded that they need to plot to the nearest half square, so placing all the points on grid intersections will sometimes mean an error in the plot. Candidates with an incorrect value from **(c)(ii)** in their table had an anomalous point which they usually ignored when drawing the best fit line. Candidates should be reminded that it is good practice to indicate an anomalous point by circling, and then ignoring it.

(e) (i) In many responses the points chosen to make the gradient calculation were too close to each other. Candidates should be taught to use at least half the space between the plotted extremes when calculating the gradient of a line. Many candidates did not make it clear on their graphs which points they had used, despite being asked to do so in the question. Occasionally, candidates chose not to use the graph, as instructed, but chose their values from the table of results, even when the points they chose did not lie on the line of best fit they had drawn.

(ii) Most candidates substituted correctly into the given equation. The main problem that candidates seemed to have, was deciding which value to use for π. It was expected that candidates would use the π button on their calculators, but many candidates used 3.14, 3.142 or even 22 / 7 here. Candidates were not penalised for this if it was clear from their working that this had happened.

(f) (i) Candidates found it difficult to state one difficulty in measuring the height *h* of the water in the test-tube. Many candidates suggested changing the equipment, for example by using a graduated test tube, measuring cylinder or callipers. Candidates should not suggest alternative equipment in this type of question, when they are specifically asked about the apparatus used in the experiment. Parallax error was often suggested but gained no credit here. The most common creditworthy suggestions were that it was difficult to hold the ruler stable and parallel to the test-tube while taking the height measurement or that the test-tube had a round bottom, so it was difficult to judge where the actual bottom of the test-tube was. A few candidates suggesting clamping the ruler or using a fiducial aid.

(ii) Only stronger candidates gave a valid reason as to why the value for the internal diameter of the test-tube was approximate. Correct answers referred to the fact that the test-tube was not a perfect cylinder and that the value for *m* in the equation used was the gradient of their best-fit line, which by its nature is subjective.

(g) (i) Most candidates measured the external diameter *D* of the test-tube from the given diagram correctly to the nearest 0.1 cm.

(ii) Only stronger candidates answered this correctly. Although most candidates subtracted the internal diameter of the test-tube from the external diameter, only a few candidates divided their answer by 2 to determine the thickness of the glass from which the test-tube was made.

Question 2

(a) Few candidates understood why the student waited for 30 s before reading the initial temperature of the water. Many candidates simply reworded the question or stated vaguely that it would improve accuracy. What was required here was that the student waits for the temperature reading on the thermometer to stop increasing or allows the temperature to reach its maximum value.

(b) (i) The calculation of the cooling rate was done well by most candidates. The most common errors were incorrectly rounding the answer to 0.10, or only quoting the answer to one significant figure (0.1).

(ii) The cooling rate was again almost always calculated correctly.

(c) Most candidates were successful in comparing the two cooling rates of the water and writing an appropriate conclusion about the rate at which hot water in a beaker cools. Stronger candidates quoted data from their calculations to reinforce their answers.

(d) Most candidates realised that after sufficient time had elapsed, the final temperature of the water would be room temperature / 24°C. Some candidates gave other values for the room temperature, but it was stated to be 24°C in the question. A few candidates tried to calculate room temperature from the data given in the table, and often temperatures in excess of 500°C were quoted.

(e) Few candidates were able to suggest how the temperature readings of the cooling water can be made as accurate as possible. There were many references made to parallax, without qualification, which did not gain credit. Many candidates repeated the point made earlier in the question about waiting 30 s to take a reading. Only stronger candidates suggested stirring the water before taking a temperature reading and reading the thermometer scale at 90°.

Question 3

(a) The majority of candidates knew how to calculate the mean value of the three values of time and obtained the partial credit. The instruction to give the value to two significant figures was often not followed.

(b) (i) Most candidates gave one of the correct options for a measuring device that could be used to measure the distance between the two students.

(ii) The calculation for the velocity of sound in air was usually correct. The most common mistake was rounding the answer incorrectly.

(c) Most candidates realised that there would be a reaction time error in the values recorded on the stopwatch. This was sometimes abbreviated to human error, which did not gain credit. Some candidates mentioned that an average time is an approximation and no credit was awarded for this. Few candidates commented that it would be difficult the measure the distance between the students accurately with a tape.

Question 4

(a) The standard of the circuit diagrams produced by candidates was good, with most symbols correct and the circuit neatly drawn. Most candidates rearranged the circuit correctly to show the voltmeter connected in parallel with the lamp and the ammeter in series with the lamp.

(b) (i) Only a minority of candidates stated the obvious answer, namely checking that the ammeter gives a reading to see if the lamp is broken or not. Incorrect suggestions included feeling the lamp to see if it was hot or looking at the filament.

(ii) Many candidates made sensible suggestions as to why the lamp might not light up. Correct answers included, the resistance of the variable resistor was set too high, the current was too low or that the lamp rating was higher than the voltage supplied to it. Common errors were that the current was "used up" by other components in the circuit, or that the open switch in the circuit needed to be closed. A few candidates referred to the variable resistor as a diode or a thermistor.