

PHYSICS

Paper 5054/11
Multiple Choice

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

General comments

Candidates should ensure that they are sufficiently familiar with all of the learning objectives in the entire syllabus and should be able to apply their knowledge to specific and more general contexts. Candidates also need to ensure that they read each question carefully to fully understand what is required.

Question 11, **Question 14** and **Question 27** were all correctly answered by a large number of candidates.

Comments on specific questions

Question 3

The correct option **C** was chosen more often than any of the others. However, a significant minority of candidates selected option **D**.

Question 5

This question required an approach that consists of several stages. The principle of moments needed to be applied so that an expression for the force being applied by the athlete's hands could be calculated. This force then needed to be divided by two to obtain an expression for the force exerted by each hand and then the expression for the pressure could be worked out. It is possible to make a mistake at each stage and only a few candidates chose the correct final option, option **B**. The most commonly selected option was option **C** which was obtained by candidates who omitted to apply the principle of moments when the expression for the force applied by the athlete's hands was being found.

Question 9

This question required a very clear understanding of Newton's third law of motion and an appreciation that each of the forces in a Newton pair act on a different object. Options B and D refer to forces that are also acting on the man. Many candidates selected the incorrect option **D**. In the two remaining options, the force acts in opposite directions. Option **C** describes a force that is in the opposite direction to the one that is mentioned in the question and is therefore the correct option.

Question 12

The non-uniform object is balanced about the pivot that is vertically beneath point **C** when a weight is suspended from its left-hand end. If the weight is removed, then the anticlockwise moment that the weight applies to the object is removed and so the object will rotate in the opposite direction, namely, clockwise. It follows that the weight must appear to be acting through a point to the right of the pivot. The point that the weight of an object seems to act through is known as the centre of gravity and so the centre of gravity must be to the right of the pivot and the only possible position is point **D**.

Question 16

An important expression used in the question was 'during the process of melting'. This restricted the question to the period between the moment when a solid sample has just reached its melting point but is instantaneously 100% solid and the moment when the sample has just become 100% liquid but is still at the melting temperature of the substance. Between these two moments, the temperature of the sample, and therefore, the kinetic energy of its particles does not change. The correct option was **B**. **D** was selected by more candidates.

Question 17

The two most frequently given options for this question were option **A** and option **D**. These two choices are the can that is the best emitter of thermal radiation (**A**) and the can that is the worst emitter of thermal radiation (**D**). More candidates selected the incorrect option **D** than the correct option **A**.

Question 19

This question was answered well. The most frequently chosen incorrect option was option **B**. This represented the new angle between the incident ray and the normal. It is possible that some of the candidates who selected this option had not read the question with sufficient care.

Question 22

Three of the four diagrams shown were correct and the question asked candidates to select the diagram that was **not** correct. Option **D**, the key, shows light undergoing an incorrect refraction where it enters the lens and another incorrect refraction where it leaves the lens.

Question 30

The correct option, **A**, was the most popular choice but all of the incorrect options were chosen by some candidates. The most significant source of errors were the candidates not understanding the significance of the unit *ms* or not being sure how to enter a number in standard form into a calculator. Candidates who chose option **B** produced an answer that was 10 times too large. Candidates who chose option **D** divided the current by the time to obtain this value.

Question 31

There is a magnetic field surrounding each of the current-carrying conductors due to the current in it. The direction of these field can be deduced using a rule such as the right-hand grip rule. Each of the current-carrying conductors lies in the magnetic field that is caused by the other conductor. It is then possible to deduce the direction of the force on each of the conductors by applying a rule that relates the direction of the magnetic field (due to the other conductor), the current in the conductor and the force produced. When this is done, the two parallel conductors experience forces that are in opposite directions and which force the conductors together. The correct option was therefore **D**. This answer was only selected by a small minority of candidates. The most commonly chosen option was **A**.

Question 39

The correct option, **D**, was the most frequently chosen by candidates. The calculation that produces the correct answer is a series of multiplications and it is quite possible to omit one of the stages and to obtain one of the other options.

Question 40

This question tested a fact that is stated in the syllabus. Many candidates supplied the correct option, but others did not know what was expected. The most frequently chosen option was not the key but option **D**.

PHYSICS

Paper 5054/12
Multiple Choice

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

General comments

Candidates should ensure that they are sufficiently familiar with all of the learning objectives in the entire syllabus and should be able to apply their knowledge to specific and more general contexts. Candidates also need to ensure that they read each question carefully to fully understand what is required.

Question 6, Question 15 and Question 23 were all correctly answered by a large number of candidates.

Comments on specific questions

Question 5

The circumstances described in this question were fairly standard. The distance travelled by the pulse of ultrasound was correctly calculated by most candidates. The distance travelled was the distance of the double journey to the seabed and back and so the depth of the sea at this position is only half of the value calculated. More candidates selected option **B**, which ignored the halving of the distance than selected the correct option **A**, which allows for the double journey.

Question 9

This question proved to be challenging with all options attracting similar numbers of candidates. This suggests a significant rate of guessing by candidates who did not know how to proceed. The key, option **A**, was often selected by stronger candidates but was less often selected by other candidates. The graph in the question showed that the resultant force acting decreases to zero and then remains at zero for a short time. The key, **A**, is a speed-time graph whose gradient behaves in the same way as the resultant force. The

gradient of the speed-time graph represents the acceleration of the object which is directly proportional to the resultant force.

Question 13

The correct option, **C**, was selected more often than any other option, but both option **B** and option **D** were frequently chosen. Although the final choices cover ranges rather than specific values, at least some calculation is needed to ensure that the correct option is given.

Question 16

Some candidates did not read this question carefully. The rocket has a mass M and the fuel is treated as an additional load. Therefore, when the fuel is expelled, the mass of the rocket does not change. And so, the kinetic energy of the rocket increases by a factor of four when its speed doubles. Option **A** was quite popular with candidates who assumed that the mass of the rocket included the fuel. However, when the fuel is expelled it would also gain kinetic energy but since no information about the expelled fuel is supplied, this cannot be considered.

Question 19

The question tested knowledge of the unit of pressure which is the pascal (Pa). It is the standard SI unit of pressure and is equivalent to 1.0 N/m^2 . Pressure is defined as force/area and the newton (N) and the metre² (m²) are the standard SI units of force and area respectively. This leads directly to the correct option **D**. Many candidates selected option **D** but a significant number chose option **C** which replaced the metre² (m²) with the centimetre² (cm²).

Question 20

The most straightforward approach to this question was realising that the force exerted by the liquid on the base of the container is equal to the weight of the liquid in the container. The weight of the liquid is directly proportional to its mass and so there is no need to calculate the weight as the container that holds the greatest mass of liquid will lead to the correct option. It is sensible to calculate the weight for each of the four options but the numbers in option **D**, which was the key, suggested that their product is likely to give the largest value. An almost identical procedure would be to calculate the pressure due to the liquid on the base and to multiply it by the area of the base to give the force exerted.

Option **D** was the most popular option but option **A** was quite frequently chosen.

Question 25

The correct option, **D**, was given more often than any other and a large majority of candidates selected one of the two options that referred to a sphere at a temperature of 1000°C . In practice, the rate at which infrared radiation is emitted is directly proportional to the surface area of the object that is the source of the radiation, and the rate increases with temperature.

Question 33

A direct approach to answering this question involved calculating the combined resistance of the two resistors in the tube. This gives an answer $12\ \Omega$. The combination of resistors that produces a total resistance can then be determined by inspection. The two options that involve a series arrangement of resistors cannot produce a combined resistance of this value and therefore options **B** and **D** can be eliminated. The combined resistance of a parallel pair of resistances must always be smaller than the resistance of each of the two resistors that constitute the parallel pair. Therefore, option **A** can be eliminated, leaving the correct option, **C**. Option **C** was chosen by more candidates than any other option but a significant number of candidates made different choices.

Question 34

This question assessed understanding of the action of a potential divider. All options consisted of a range that began with a potential difference 0 and so the correct option could be deduced by considering what happens when the resistance of the variable resistor has reached $2R$. A few candidates chose the correct option **C**. Option **B** was chosen by more candidates and the other options were only rarely selected.

Question 35

Those candidates who knew that the changing magnetic field in the iron core of a transformer induces the output electromotive force that is found across the terminals of the secondary coil were able to deduce that the correct option was option **D**. This was the most commonly chosen option but option **B**, the electromagnet, was chosen by many candidates.

Question 36

This question concerned the forces that are produced on charged particles by electric and magnetic fields. The electric fields described in the options were either left to right or right to left across the page but the force on the charged beta particle was towards the top of the page. This direction is at right angles to the directions of the electric fields and so cannot be correct.

The remaining options referred to magnetic fields. Candidates needed to recall and use a rule that relates the direction of the force, the magnetic field direction and the current direction - the Fleming left-hand rule is one such rule but there are others. Stronger candidates recalled that the beta particle is negatively charged and so the current direction is in the opposite direction to its velocity. Applying this rule to the correct current direction shows that option **A** is the key. All of the other options were offered by a number of candidates.

Question 40

The correct option **C** attracted more candidates than any other, but all of the options were chosen by a significant number of candidates and there was considerable uncertainty about both of the statements given in the question. Red shift is due to the movement of stars and galaxies away from the Earth. The wavelengths of emitted electromagnetic radiations are stretched or made longer. If the electromagnetic radiation is within the visible spectrum, it appears 'redder' when received hence the name.

PHYSICS

Paper 5054/21 Theory

Key messages

- Candidates should ensure they are familiar with all sections of the syllabus content.
- Many candidates did not show sufficient understanding of the space physics section of the syllabus.

General comments

A significant number of marks were allocated to calculations, and these very often required the recall of an equation which may have needed to be rearranged to generate a different subject. This is a skill that needs to be acquired.

Candidates should ensure they are able to use calculators well to aid their answering of questions. In particular, the correct way of entering a number in standard form was not always understood and sometimes led to inaccurate final answers.

Candidates should ensure they read all questions carefully and provide responses that address what is being asked. In some cases, candidates gave answers which were not sufficiently focused on the question asked.

Comments on specific questions

Question 1

- (a) Most candidates made some progress with this question. The change in momentum of the car during the first 1.5s of its motion was usually read correctly from the graph. Those candidates who equated the change of momentum per second of the car to the resultant force acting on the car usually arrived at the correct answer.
- (b)(i) Only a minority of candidates were able to produce the equation relating the momentum of the car to its kinetic energy. Partial credit was given for quoting the two equations $p = mv$ and $E_k = 1/2mv^2$. The resulting algebra needed to arrive at the given expression was challenging for most candidates.
- (ii) Most candidates were able to substitute correctly into the equation and calculate the mass of the car. The most common error here was incorrect transcription of the equation to make mass m the subject.

Question 2

- (a)(i) The total weight of the boxes in the cage was almost always calculated correctly.
- (ii) The useful work done lifting the boxes vertically through 13m was again calculated correctly by most candidates. A few candidates were unable to recall the correct equation to use here.
- (b)(i) Many candidates were able to calculate the total energy transferred electrically to the motor. A common error was to confuse power with energy and use VI instead of VIt .

- (ii) The calculation of the efficiency of the lifting process proved to be challenging for many candidates. Candidates seemed to be unsure about the previously calculated values of work done and which energy to substitute into the efficiency formula. The equation was frequently written with the numerator and the denominator inverted, and so efficiencies of more than 100 per cent were quoted, usually without comment.
- (c) Candidates were asked to state two reasons why the efficiency of the lifting process is less than 100%. Most candidates only supplied one reason, which was usually incorrect. Few candidates were able to state two valid reasons. Where partial credit was obtained, it was usually for mentioning work done against friction/air resistance in the lifting of the load. Far fewer responses referred to the energy transferred thermally in the motor and no candidates realised that some work would need to be done to lift the actual cage which contains the boxes.

Question 3

- (a) Only stronger candidates answered this well and mentioned collisions between the water molecules and the ice molecules. Very few candidates stated that these collisions caused the molecules of ice to vibrate faster/with more energy or that the molecules pass vibrations on through the ice.
- (b) (i) The calculation of the energy transferred from the water in the cup to the ice was done well by most candidates. The most common error was to use the final temperature of the water in the cup in the chosen equation, instead of the decrease in the temperature of the water in the cup.
 - (ii) Few candidates were able to explain fully in terms of molecules/particles the difference in the molecular structure of water at 6°C to ice at 0°C. Some candidates compared the arrangement/separation of the molecules in each phase correctly. An answer such as that the molecules of water have no orderly arrangement and can slide over each other gained full credit.
 - (iii) This was answered well with most candidates stating that the temperature of the water would rise to room temperature more quickly in a metal cup compared to a plastic cup because plastic is a bad (thermal) conductor or that metal is a good (thermal) conductor. Some stronger candidates referred to the fact that there were no delocalised electrons in plastic.

Question 4

- (a) Some candidates gave good explanations of the fact that the ray of light refracts and changes direction on entering the glass lens. Many candidates gained partial credit by stating that the speed of light was different/slower in glass than it is in air. A smaller proportion of candidates stated that the light was entering a medium of different refractive index. Stronger candidates mentioned the change/decrease in wavelength of the light on entering the glass. Occasionally, there were comments about the constancy of the frequency of the light in air and in glass.
- (b) (i) Few candidates were able to state what is meant by the principal focus of a lens. Very few candidates mentioned parallel rays of light, and even fewer referred to the principal focus as being that point to which these parallel rays converge after passing through the lens.
 - (ii) Many candidates were able to state that the focal length of a lens is the distance between the principal focus and the (centre of) lens.
- (c) (i) A majority of candidates drew an arrow of the correct height and in the correct position on the principal axis on the grid provided.
 - (ii) The ray diagrams drawn to locate the position of the image of the object were generally very good and neatly drawn. The most common errors were reflecting, instead of refracting the rays incident upon the lens, or treating the lens as a diverging lens rather than a converging lens.
 - (iii) Candidates who correctly identified the image as being virtual were very often unable to offer a valid reason why. Only stronger candidates correctly identified the image as being virtual and explained this by saying that the refracted rays did not pass through the image, but merely seemed to come from it. The fact that the image could not be formed on a screen was also accepted.

Question 5

- (a) Some candidates were able to explain fully why the evaporation of a liquid causes a decrease in temperature of the liquid. Many candidates correctly stated that when a liquid evaporates, the fastest moving molecules/the molecules with the greatest kinetic energy escape from the surface of the liquid. Far fewer candidates linked this to the consequent decrease of the average (kinetic) energy of the molecules remaining, which caused the temperature of the liquid to decrease.
- (b) (i) Only stronger candidates were able to begin to explain how electromagnetic induction is responsible for generating a current in the base of the iron beaker placed on the induction heater. The fact that an alternating voltage in the coil of wire in the induction heater creates a magnetic field was known by most candidates. However, far fewer candidates stated that the magnetic field was alternating/continually changing. Only a minority of candidates went on to state that this changing magnetic field generated an induced electromotive force in the base of the iron beaker.
- (ii) Again, few candidates were able to explain fully, in terms of particles, why the density of the liquid in the beaker decreases as its temperature increases. Few compete and correct explanations were seen but most candidates gained partial credit. Full credit was obtained by stating that as the temperature of the liquid increases, the speed of the particles increases, causing the separation of the particles to increase, and therefore the volume increases.
- (iii) Here candidates needed to state that the less dense/heated liquid rises and the denser/cooler liquid sinks. Credit was given to candidates who stated the name of this method of heat transfer.

Question 6

- (a) Many candidates were able to state Ohm's law correctly. A common incorrect answer was that the potential difference across a component is directly proportional to its resistance, instead of the current.
- (b) (i) Most candidates chose a correct equation to calculate the current in the circuit. However, many of these candidates forgot to include the resistance of the 4.0Ω series resistor together with the 8.0Ω resistance of the cylinder of conducting modelling clay P. These candidates divided the electromotive force of the battery by 8 instead of by 12 to calculate the current.
- (ii) Most candidates chose an appropriate equation to calculate the power transferred to resistor P.
- (c) (i) Candidates found it very challenging to calculate the new resistance of the cylinder of conducting modelling clay. Candidates were unable to recognise that both the length and the area of cross section of the modelling clay had been changed. Only a very small minority of candidates realised that if the length of the modelling clay was halved, then its area of cross section would double, because the volume of the modelling clay was unchanged.
- (ii) Many candidates answered this question well.

Question 7

- (a) Many candidates knew that the process of charging by friction was due to the movement of electrons/negative charge. Far fewer candidates continued the explanation to state that the electrons move from the cloth to the rod.
- (b) (i) Few candidates were able to explain, in terms of particles, the difference between an electrical conductor and an insulator. The fact that electrons are free to move in a conductor, but are fixed in place in an insulator was not well known.
- (ii) The mechanism by which a conductor becomes induced with charge was only fully understood by stronger candidates. As the negatively charged rod moves towards the uncharged conductor, many candidates realised that electrons in the conductor moved away from the negatively charged rod. The fact that like charges repel was rarely stated. Many candidates stated that positive charges are attracted and move towards the negatively charged rod, which was incorrect. The side of the conductor nearest the charged rod becomes induced with positive charge because electrons have been repelled away from it.

- (iii) There were some excellent responses to this question. Most candidates mentioned that opposite charges attract. Only stronger candidates realised that there would also be a force of repulsion between the negatively charged rod and the electrons at the far end of the conductor. Therefore, the attractive force on the conductor is greater than the repulsive force on it, so the resultant force on the conductor is towards the rod.

Question 8

- (a) Most candidates gained partial credit for this question. The fact that the two atoms of radon had different numbers of neutrons/nucleons was almost always recorded correctly. Far fewer candidates went on to quantify their answers by using the information supplied to state that radon-222 has 2 fewer neutrons than radon-224.
- (b) Many candidates completed the nuclide equation for the decay of radon-222 correctly. The main source of error here was an incorrect representation of the alpha-particle in the equation.
- (c) (i) The importance of alpha-particle scattering experiments in providing evidence for the nuclear model of the atom was not well understood. The small number of candidates who showed a good understanding of this topic had no difficulty stating that the count rate at position J was very small, but not zero, and the count rate at position K was very large.
- (ii) Many candidates who were successful in (c)(i) were unable to link the observations made there to the structure of a gold atom. Only the strongest candidates stated that the observations showed that the nucleus of a gold atom is positively charged, and that most of the rest of the atom is empty space.

Question 9

- (a) Most candidates gained partial credit by stating that because there were no external forces acting on the object as it travelled through space, the object was travelling at constant speed. Far fewer gained full credit by also stating that the object moved in a straight line.
- (b) (i) Only a small number of stronger candidates were able to explain why a force must be acting on Venus to keep it following an approximately circular orbit. The fact that this force was needed to continually change the direction of Venus in its orbit was not recognised by most candidates.
- (ii) Most candidates correctly stated that the gravitational field of the Sun caused the force on Venus, and the direction of this force was towards the Sun.
- (iii) Many candidates were able to calculate the average orbital speed of Venus around the Sun correctly. Most candidates selected the correct equation to use, but some candidates selected an incorrect distance to use in the equation. The answers of many candidates were out by a factor of 2π because they used the orbital radius and not the orbital circumference as the distance travelled by Venus in one orbit of the Sun.
- (iv) This was answered well. Most candidates knew that the planet closer to the Sun than Venus is Mercury. These candidates also almost always deduced that the orbital speed of mercury is greater than that of Venus.

PHYSICS

Paper 5054/22 Theory

Key messages

- Candidates should ensure they are familiar with all sections of the syllabus content.
- Many candidates did not show sufficient understanding of the space physics section of the syllabus.

General comments

A significant number of marks were allocated to calculations and these very often required the recall of an equation which may have needed to be rearranged to generate a different subject. This is a skill that needs to be acquired.

Candidates should ensure they are able to use calculators well to aid their answering of questions. In particular, the correct way of entering a number in standard form was not always understood and sometimes led to inaccurate final answers.

Candidates should ensure they read all questions carefully and provide responses that address what is being asked. In some cases candidates gave answers which were not sufficiently focused on the question asked.

Comments on specific questions

Question 1

- (a) (i) This question was answered well with many candidates supplying the correct value for the speed of the car at $t = 0$ s.
- (ii) To answer this, candidates needed to use the graph to deduce the time at which the car began to slow down and then to deduce the time between $t = 5.7$ s and this time. Since the speed had just been calculated for this period of time, the distance could then be calculated. One significant source of inaccuracy was the use of an incorrect time period. A common value used was 5.7 s. Another was the use of the speed 30 m / s. This error was sometimes made by candidates who had just answered (i) correctly.
- (iii) There were some good answers here with many candidates gaining full credit. There were several approaches used but the most common one was calculating the area of the trapezium under the line. As in the previous part, there were candidates who used a maximum speed that differed from the value used in (i).
- (b) There were some good answers. Many candidates gave an answer that stated a factor that only affected the braking distance and also stated a possible physical cause but of these only a small minority explained how this caused the braking distance to increase. Some candidates suggested factors that caused both the thinking distance and the braking distance to be affected and others stated a factor that could have caused an increase or a decrease in the braking distance.

Question 2

- (a) Some answers were very carefully constructed and referred to each stage of the motion from its initial acceleration to the final stage where the acceleration had decreased to zero. Other answers were very imprecise and lacked any reference to terms such as 'acceleration' or 'drag'. Some

answers that contained valid descriptions of some of the stages of the motion then referred to 'slowing down' or 'deceleration', using these terms to describe the stage where the acceleration is still positive but is becoming less positive. A few candidates referred to the effect of air resistance on the sphere. The drag is due to the resistive force of the water that the sphere is immersed in.

- (b) (i) This question was often answered well and many correct answers were seen. Candidates should be reminded to use 9.8 N/kg as the value for the gravitational field strength, as given on the front of the question paper.
- (ii) This question was often answered well. Some candidates confused energy and momentum or gave a specific example of the principle rather than a general statement. A significant number of candidates made reference either to energy not being created or to it not being destroyed, but not to both.
- (iii) Only stronger candidates answered this correctly. The term 'work done' was often omitted or inserted into an answer without any clear mention of how it featured in the energy transfer process. Few candidates stated that work was being done by the sphere against the resistive force of the water and very few candidates stated that the energy transferred from the gravitational potential store was transferred to the internal store of the water.

Question 3

- (a) (i) This was generally answered well. Some weaker candidates used incorrect definitions of density or speed.
- (ii) This was also answered well by many candidates but more errors were made here than in (i). Understanding momentum was problematic for many candidates, but most candidates knew the expression mv for momentum and the substitution of the correct numbers was done successfully by a significant number of candidates.
- (b) Only stronger candidates answered this correctly. Very few candidates related the decrease in the momentum of the water in one second to the rate of change of momentum of the water or to the force exerted on the water. Many answers referred to the third law of motion but that was not immediately relevant as the question concerned the change in momentum of the water and the force acting on the water.
- (c) The syllabus gives a very clear definition of Newton's third law that makes it very clear that it concerns a pair of forces and candidates should use and understand this wording from the syllabus. The relationship between the force on the wall due to the water and the force on the water due to the wall was only referred to by a few candidates.
- (d) This question was challenging for many candidates. Few candidates commented that the momentum of a given mass of water is doubled when the speed of the water doubles and that the time to strike the wall halves. Even fewer related it to the rate of change of momentum which increases by a factor of four.

Question 4

- (a) This was often answered correctly. Some candidates did not take note of the wording of the question and made no reference to **Fig. 4.1**.
- (b) (i) The calculation needed here required the use of the equation $\Delta E = mc\Delta\theta$ which, in a rearranged form, is given in the syllabus. Many candidates were able to use this equation correctly and obtained the correct final answer. One source of error concerned the confusion of the ΔE term and the c term. Many candidates were not clear which term was the energy transferred and which represented the specific heat capacity. The value to be substituted for $\Delta\theta$ was also problematic for some candidates who substituted a temperature from the question rather than a temperature difference. Other candidates misread the graph and calculated an answer based on the assumption that at $t = 220 \text{ s}$ the temperature of the wax was 44°C .

- (ii) Some candidates produced thorough and accurate descriptions of the change in the behaviour of the molecules of the solid wax. However, few candidates mentioned that the increase in the energy in the kinetic store of the molecules was through the faster or more vigorous vibration of the molecules.
- (c) Many candidates were aware that energy is required to increase the separation of the solid molecules of the wax as they are moving against the attractive forces that they experience. However, the term 'latent heat' was rarely used and neither was the idea that increasing the separation of the molecules by moving them against the attractive forces constitutes work and that that is why the transfer of energy is needed.

Question 5

- (a) Many candidates answered this correctly but some placed one or other of the labels in the wrong section of the spectrum.
- (b) (i) Here candidates needed to recall and rearrange the equation $v = f\lambda$ and then calculate the correct answer using one number that was expressed using an SI multiplying prefix and another that was expressed in standard form. Many candidates made errors with this calculation.
- (ii) Many candidates gave answers that were not sufficiently detailed. Some made no reference to microwaves and concentrated instead on the physical infrastructure.
- (c) A major source of inaccuracy here was the statement that the microwaves used in microwave ovens are a type of radiation that causes cancer in humans. The switch operated by the door prevents microwaves striking the user or prevents the microwaves escaping the oven but only a few candidates included such comments in their answers.

Question 6

- (a) Only stronger candidates gave an answer that was focussed on the essential difference between a d.c. and an a.c. Some answers were related to d.c. motors and a.c. generators whilst others suggested that the difference lay in the size of the voltages involved.
- (b) (i) This was generally answered well. Some candidates used an incorrect equation such as $Q = I / t$ which did not lead to the correct calculation, and some others converted the time to minutes and obtained an answer that was too small.
- (ii) Many candidates attempted to use their answer to (i) here and although this was possible, it was not necessary to do it this way and was rarely successful. Many candidates were unsure of the significance of the value of charge on the electron that was included in the question, and it was often ignored and left unused in any calculation.
- (c) (i) Many candidates gave answers that were incomplete. Others stated Ohm's law in some form or confused the definition of e.m.f. with electromagnetic induction.
- (ii) The e.m.f. of the battery was very often stated correctly but some candidates divided the e.m.f. of one cell by the total number of cells in series.
- (iii) Only stronger candidates realised that the identical parallel voltages produced a final voltage that was the same as each of the individual voltages.

Question 7

- (a) (i) This calculation was very often correct and the correct current was also seen very frequently.
- (ii) Although the correct fuse rating was often given, explanations were rarely complete. Few candidates referred to the need for the fuse rating to be greater than the operating current of the kettle **and** to the need for the fuse rating to be less than the maximum safe current for the cable. Many candidates mentioned one or the other.
- (b) (i) Many candidates knew that the fuse had to be connected into the live wire but very few candidates could explain this. A very common answer was the suggestion that this is where the current enters the circuit. Answers that referred only to the current were not credited.
- (iii) A number of candidates referred to the outer casing becoming live or to the possibility of a serious electric shock or even of electrocution if the casing is touched. However, fewer candidates explained that a large current in the earth wire would blow the fuse and remove that danger.
- (c) This question was challenging for many candidates and only a few determined the correct final cost. Many candidates did not include the power of the kettle in the calculation at all.

Question 8

- (a) (i) Many candidates answered this correctly. However, candidates sometimes did not make any reference to the composition of the atom.
- (ii) Most candidates gave a suitable answer here.
- (b) (i) The correct numerical values were often given. However, some candidates reversed them or gave the neutron number rather than the nucleon number as the superscript. There were also answers that suggested that the number of electrons had been included in the deduction of the values.
- (ii) There were many correct answers but other descriptions were weak.
- (c) (i) An appropriate damaging effect was often given. Some candidates referred to a variety of different effects not attributable to nuclear radiation, such as global warming, or simply stated a type of nuclear radiation such as gamma rays rather than the damage that can be done by nuclear radiation..
- (ii) Many candidates did not state the meaning of the terms 'random' and 'spontaneous'. Sometimes the meanings given were essentially the same and sometimes they were reversed.

Question 9

- (a) (i) This was often answered well and many candidates gave the correct answer obtained by the correct method.
- (ii) Candidates found this question challenging. Many candidates tried to use $v = x/t$ in some way but did not necessarily relate this expression to $v = 2\pi r/t$. Many candidates found it difficult to express the answer in m/s when the orbital period of the Sun around the centre of the Milky Way was given in years.
- (b) (i) Some candidates gave convincing and accurate descriptions here but other answers were confused and sometimes contradictory. Few candidates clearly distinguished between the stage of stellar evolution that was asked for and other stages in the process.
- (ii) In general, the life cycle of a star was not well remembered. There was confusion and inaccuracy in many descriptions.
- (iii) Although many candidates had a clear idea of the way in which heaviest elements are produced, only a small number of these candidates actually described the essential aspect whereby small nuclei join together to produce the heavier nuclei.

PHYSICS

Paper 5054/31 Practical Test

Key messages

It is important that Supervisors send in a complete set of results for all measurements taken in the three practical questions. In some situations, the Supervisor's results may assist in candidates being awarded credit for work which could not be awarded without them, especially when the equipment used has not conformed exactly with the specifications made in the Confidential Instructions. It is also important that Supervisors record all relevant details of any apparatus which does not match those specified in the Confidential Instructions for example, the unextended length of a spring or the resistance of a component.

Candidates should be reminded that measurements and final answers should be rounded to an appropriate number of significant figures, with readings from instruments such as ammeters and voltmeters recorded to the precision of the instrument being used. When recording values in a table, data should be recorded to a consistent number of significant figures or, when appropriate, a consistent number of decimal places.

Candidates are advised to show all working and to check all their calculations and in particular measurements that appear to be unrealistically large or small. Candidates should be given opportunities to practise rounding numbers to the nearest whole number or magnitude of ten. Some candidates incorrectly translated numbers from their calculator when given in standard form, writing for example 2.5 instead of 2.5×10^2 .

General comments

Stronger candidates demonstrated that they were able to follow instructions carefully and made accurate observations and measurements, recording them to an appropriate number of significant figures. They were able to process their results by performing calculations and correctly rounding answers. They made sensible judgements or drew relevant conclusions from their data and wrote relevant evaluative comments.

Attention is drawn to the advice on plotting graphs issued by Cambridge. Candidates should remember that graphs are intended to make the interpretation of their experimental results clearer and that data should occupy at least half of the available grid on both the x and y axes. Some responses to questions involving the plotting of graphs included impractical scales such as using scales of 3 or using 3 grid divisions per unit. Using a non-integral scale makes it difficult and time-consuming to plot the points and it also makes it difficult to use (for example, to interpolate data). Candidates who use non-integral or other difficult scales are far more likely to make errors in plotting and interpretation of their graphs. It is better to choose a scale which produces a graph that may be a little smaller but still occupies over half the grid in the x and y directions and is based on a scale of 2, 5, or 10 units corresponding to 10 small grid lines. The more prominent grid lines are intended to be points along the axis corresponding to numbers ending in 0, 5, or 2 rather than numbers midway between. The plotted points on graphs should be marked with small, fine, but visible crosses and placed accurately to within half the length of the side of the smallest square made by the thinnest grid lines. The Cartesian axis system should be used, with increasing positive values from left to right along the x-axis and upwards along the y-axis. The best fit straight line or curve should be a carefully drawn single, thin, smooth line, suitably placed (with, as far as possible, equal numbers of points either side of the line and vertical distances of points from either side which compensate one another). A line drawn from the first plot to the last plot or forced to go through the origin is rarely suitable.

The use of consistent significant figures or decimal places when recording data in tables was generally good, as was explicit reference to variables to be controlled in the planning question.

Comments on specific questions

Question 1

- (a) Most candidates were able to gain at least partial credit for this question for drawing a voltmeter in parallel across their wire heater. Common errors were drawing lines through symbols such as a battery or ammeter. Some candidates did not draw circuits using straight line connectors or drew beakers around the wire but these were ignored.
- (b) Most candidates recorded a sensible value for the temperature of the water before heating.
- (c) (i) Candidates were usually able to record both values but some only gave values to one significant figure or transposed the current and voltage.
- (ii) Most candidates were able to record the temperature and process results to find the change in temperature.
- (iii) Many candidates were able to explain that the temperature of the water should be uniform before taking measurements. Common errors were to discuss an even spread of heat energy or allowing the temperature to remain constant.
- (d) (i) Many candidates were able to calculate the energy supplied.
- (ii) Most candidates were able to calculate the energy gained by the water but some candidates selected incorrect values to substitute or obtained an answer greater than the energy supplied.
- (iii) Many candidates calculated a correct value of efficiency based on their energy values. Some candidates chose to convert their value to a percentage which was acceptable provided the percentage sign was shown.
- (e) Only a few candidates gained this credit for a comment relating to insulating the beaker or adding a lid. Common uncreditworthy responses referred to changing the volume of water or the power supply or heater.

Question 2

This question proved challenging for the majority of candidates suggesting that more practice with a range of optical experiments would be helpful to candidates.

- (a) (i) Most candidates were able to draw an accurate normal on the diagram provided.
- (ii) Most candidates placed a line on the correct area to the left of the normal above **XY** but many measured the angle of incidence from the block rather than to the normal.
- (b) (i) Most candidates drew a correct outline but weaker responses showed that the block had been placed on a smaller face suggesting lack of experience using blocks for refraction experiments.
- (ii) Stronger responses had small and thin crosses drawn at least 5 cm apart on the path of the refracted ray. Weaker responses had crosses drawn too close together or on a weak reflected ray which again indicated a lack of experience with such experimental procedures.
- (iii) Many candidates who had drawn crosses in the correct region below the block were able to draw an accurate ray to the block.
- (iv) Most candidates were able to complete the path of the ray within the block even if **P** was incorrectly placed.
- (v) There was credit available for accuracy here and only the strongest responses gained this for completing accurate ray diagrams and using a protractor carefully. Common uncreditworthy answers were between 30° and 45° .

- (c) Candidates were often able to perform the calculation successfully. Some candidates had difficulty in using trigonometric functions on calculators. Common errors were not stating an answer to two significant figures or incorrect substitution/evaluation.
- (d) Many candidates referred to steps they had already taken such as using a protractor rather than describing a change to the procedure itself. Some candidates referred to repeating measurements but not for a range of angles and finding a mean.

Question 3

- (a) (i) Most candidates recorded a sensible mass.
 - (ii) Almost all candidates recorded a correct value for the mass of one marble.
- (b) (i) Many candidates were able to record three time intervals and calculate a mean. A common error arose from using a calculator incorrectly so that only the final value was divided by 3 instead of the sum of all 3 values.
 - (ii) The strongest responses had a complete table with all values recorded to 3 significant figures. Most candidates gained partial credit for a correct trend in the data.
 - (iii) A graph of average time against height should have been plotted and very few candidates incorrectly reversed the axes or plotted an incorrect variable but a significant minority forgot to label the axes or omitted at least one unit. Many graphs were plotted using far less than half of the available space often caused by starting at the origin. Another common mistake was using a multiple of 3 in a scale. Stronger candidates drew good lines of best fit which showed an equal number of points above and below the line. Weaker candidates had lines which did not extend to cover the full range of data or intended a point to be counted as anomalous as it was so far from the line but did not indicate this. Candidates should be reminded that they need to clearly indicate any points they are ignoring when plotting a line of best fit. This could be done circling the point and writing 'anomaly' alongside it.
 - (iv) Most candidates were able to state a correct relationship between the variables.
- (c) (i) To gain full credit for this question, candidates needed to indicate on the graph where they were taking their readings. The strongest answers had both vertical and horizontal lines drawn from a height of 7 cm. Weaker candidates often had difficult scales to interpret or drew lines which were too thick resulting in inaccurate readings.
 - (ii) Many candidates were able to correctly perform the calculation but a significant minority substituted the height, 7 cm, instead of the distances travelled, 90 cm. Many candidates gained credit for the unit as it was a straightforward derivation but a common error was using figures in cm and giving a unit in m / s or vice versa.

Question 4

This question was answered quite well with the majority of candidates gaining at least partial credit. There were few blank or irrelevant responses simply restating parts of the question. Many candidates had a systematic approach to the question, which enabled them to apply knowledge to new situations and gain credit more consistently than those who did not use such an approach.

Candidates were required to plan an experiment to investigate the relationship between the brightness of light falling on a solar cell and the power output of the cell.

Marking point 1 was awarded if candidates described a valid method to vary the brightness. The strongest candidates described varying the distance from the cell to the lamp by moving the lamp alongside a metre rule. Some candidates did not make use of the lamp and described uncreditworthy methods such as placing it outside in the sun. Candidates should be reminded that their variables need to be ones which can be measured.

Marking point 2 was awarded for correctly adding an ammeter and voltmeter to the diagram or a clear description of where to place them. Some candidates interpreted the solar cell as the power supply for the lamp and so incorrectly added additional components to the circuit.

Marking point 3 was awarded if candidates described measuring current and voltage for at least two light intensities.

Marking point 4 was awarded for a correct control variable but candidates often struggled to accurately describe a variable, giving vague responses such as 'power of lamp'.

Marking point 5 was awarded for a table with correct headers including units. Candidates should be reminded that all continuous variables should have a unit stated and that any independent and dependent variables they are measuring should be included in the table. A common error was having a column for power instead of both current and voltage which were the measured quantities. Power is found by processing results not by direct measurement so was an incorrect heading and was ignored.

Marking point 6 was awarded for detailed explanation of how to reach a conclusion. Candidates who stated that a graph should be drawn for power against distance gained this credit. Candidates who attempted to explain how to draw a conclusion were successful if they remembered to make a conditional statement such as 'to see if the power changed as the intensity changes'. Common errors were stating predictions or expected conclusions or giving incomplete statements such as 'plot a graph using the table'.

PHYSICS

Paper 5054/32 Practical Test

Key messages

It is important that Supervisors send in a complete set of results for all measurements taken in the three practical questions. In some situations, the Supervisor's results may assist in candidates being awarded credit for work which could not be awarded without them, especially when the equipment used has not conformed exactly with the specifications made in the Confidential Instructions. It is also important that Supervisors record all relevant details of any apparatus which does not match those specified in the Confidential Instructions for example, the unextended length of a spring or the resistance of a component.

Candidates should be reminded that measurements and final answers should be rounded to an appropriate number of significant figures, with readings from instruments such as ammeters and voltmeters recorded to the precision of the instrument being used. When recording values in a table, data should be recorded to a consistent number of significant figures or, when appropriate, a consistent number of decimal places.

Candidates are advised to show all working and to check all their calculations and in particular measurements that appear to be unrealistically large or small. Candidates should be given opportunities to practise rounding numbers to the nearest whole number or magnitude of ten. Some candidates incorrectly translated numbers from their calculator when given in standard form, writing for example 2.5 instead of 2.5×10^2 .

General comments

Stronger candidates demonstrated that they were able to follow instructions carefully and made accurate observations and measurements, recording them to an appropriate number of significant figures. They were able to process their results by performing calculations and correctly rounding answers. They made sensible judgements or drew relevant conclusions from their data and wrote relevant evaluative comments.

Attention is drawn to the advice on plotting graphs issued by Cambridge. Candidates should remember that graphs are intended to make the interpretation of their experimental results clearer and that data should occupy at least half of the available grid on both the x and y axes. Some responses to questions involving the plotting of graphs included impractical scales such as using scales of 3 or using 3 grid divisions per unit. Using a non-integral scale makes it difficult and time-consuming to plot the points and it also makes it difficult to use (for example, to interpolate data). Candidates who use non-integral or other difficult scales are far more likely to make errors in plotting and interpretation of their graphs. It is better to choose a scale which produces a graph that may be a little smaller but still occupies over half the grid in the x and y directions and is based on a scale of 2, 5, or 10 units corresponding to 10 small grid lines. The more prominent grid lines are intended to be points along the axis corresponding to numbers ending in 0, 5, or 2 rather than numbers midway between. The plotted points on graphs should be marked with small, fine, but visible crosses and placed accurately to within half the length of the side of the smallest square made by the thinnest grid lines. The Cartesian axis system should be used, with increasing positive values from left to right along the x-axis and upwards along the y-axis. The best fit straight line or curve should be a carefully drawn single, thin, smooth line, suitably placed (with, as far as possible, equal numbers of points either side of the line and vertical distances of points from either side which compensate one another). A line drawn from the first plot to the last plot or forced to go through the origin is rarely suitable.

The use of consistent significant figures or decimal places when recording data in tables was generally good, as was explicit reference to variables to be controlled in the planning question.

Comments on specific questions

Question 1

- (a) Most candidates correctly drew a series circuit but very few were able to select the correct circuit symbols for the components in the circuit in front of them. A significant number of candidates used symbols that were not given despite a clear instruction to use the symbols provided.
- (b) (i) Most candidates recorded a sensible value to the precision of their voltmeter.
(ii) Almost all candidates recorded a lower voltmeter reading than (i) as required.
- (c) Candidates were usually able to perform this calculation successfully. Common errors were using the incorrect voltmeter reading, making an error recording the standard form value given on a calculator or incorrectly entering values on the calculator.
- (d) Most candidates were able to calculate and correctly round a value for resistance using the equation provided.
- (e) Most candidates were able to correctly reposition the voltmeter and follow the instructions to obtain a value greater than in (b)(i).
- (f) Very few candidates were awarded this credit as most gave very general statements about a change in resistance without explicitly referring to a change in the resistance of the LDR. It was insufficient to make generalised comments and candidates should be encouraged to be as precise as possible in their explanations and descriptions.
- (g) Most candidates gained partial credit for a statement that the voltmeter reading increased as the card moved downwards but very few discussed how the reading varies very little for the first 10 to 15 cm change in height. Candidates should be encouraged to look at how many marks are available to help them decide how much detail to include in an answer.

Question 2

- (a) Most candidates were able to record a correct set of increasing temperatures in the table provided. Most candidates correctly recorded the temperature to the nearest degree but the nearest 0.5 degree was accepted. Weaker responses stated values to the nearest tenth of a degree or to two decimal places. Candidates should be reminded that values read from a thermometer should be given to the nearest degree.
- (b) Most candidates recorded a sensible range of temperatures with a greater change in temperature than in (a).
- (c) Candidates were usually able to perform the calculations successfully. Some candidates had difficulty in giving the correct the unit. Common errors were the use of sec instead of s for seconds, C° instead of °C or dividing by an incorrect time.
- (d) Most candidates were able to use their data to form a correct conclusion.
- (e) Many candidates were able to make two correct suggestions for control variables. A few candidates wrote suggestions which were insufficient such as 'same distance' without specifying which distance was to be controlled or made the same point twice, e.g. referring to same intensity of light from the bulb and same voltage from the power supply. Another common error was to refer to the same type of bulb instead of the same bulb. 'Same type' could refer to another lamp having a different power but still being a filament lamp.

Question 3

- (a) (i) Most candidates recorded a sensible distance to the nearest mm. Some candidates were confused about the instruction regarding precision and gave an answer in m such as 0.435 instead of 43.5.
(ii) Almost all candidates recorded correct values for **a** and **b** showing the ability to interpret diagrams and process information.

- (b)(i) Most candidates gained full credit here with common errors being inconsistent precision in values or an inconsistent trend.
- (ii) Very few candidates were able to give a creditworthy answer which described the process in sufficient detail. Credit was most commonly awarded for a comment that the hole or slit in the mass could be aligned with the 5 cm mark thus ensuring it was central. Candidates who attempted to describe aligning the edges usually made an assumption about the width of the mass, most commonly 2 cm, but did not state this, simply saying that the edges of the mass should be at 4 and 6 cm. Others drew diagrams showing the position of the mass but without reference to finding the radius or finding the mean scale reading.
- (c) Candidates were usually able to perform this calculation successfully but a significant number of candidates only recorded the values to 1 significant figure instead of 2 or 3 consistent significant figures. Some candidates clearly gave values to 2 decimal places which was also accepted even if this meant one value had a different number of significant figures because $r > 1$.
- (d) A graph of ratio against mass should have been plotted and very few candidates incorrectly reversed the axes or plotted an incorrect variable but a significant minority forgot to label the axes or gave a unit of cm for r which was dimensionless. A common mistake which prevented the awarding of credit for selecting an appropriate scale was using 3 small squares for 10 g, an example of using a multiple of 3 in a scale. Stronger candidates drew good lines of best fit which showed an equal number of points above and below the line. Weaker candidates forced the line to go through the origin or their first and last points.
- (e)(i) Most candidates knew how to calculate a gradient but did not follow the instruction and show the values used on the graph itself. This could be done by drawing a triangle or lines from the points used to each axis. Some candidates used values which were too close together or taken from the table rather than the line of best fit. The gradient needed to be calculated using values covering at least 50% of the range of data plotted. Many candidates were able to get a value in the correct range showing the observations were accurate but some candidates did not give their value to at least 2 significant figures.
- (ii) Many candidates gained this credit but common errors were not stating to the nearest gram giving values such as 112.4 or 112.0 or incorrectly rounding values e.g. calculating 107.6 and stating 110 on the answer line.
- (f) Most candidates were awarded this credit if it was clear that the pivot was at 50 cm and there was a reference to the ruler balancing. Some candidates described adding masses to each side of the ruler, but this was insufficient without stating the masses and distances from the pivot were identical. Some candidates described how to find the centre of gravity, not how to verify it was at the position stated so candidates should be reminded to read the questions carefully.

Question 4

This question was answered quite well with the majority of candidates gaining at least partial credit. There were few blank or irrelevant responses simply restating parts of the question. Many candidates had a systematic approach to the question, which enabled them to apply knowledge to new situations and gain credit more consistently than those who did not use such an approach.

Candidates were required to plan an experiment to investigate the relationship between the thickness of insulation and the rate of cooling.

Marking point 1 was awarded if candidates mentioned the use of a stopwatch either in their plan or shown on a labelled diagram.

Marking point 2 was awarded for timing water cooling and was gained by most candidates who referred to taking an initial and subsequent temperature.

Marking point 3 was awarded if candidates described using at least two thicknesses of cardboard. The strongest answers referred to using an incremental range of thicknesses such as 1, 2, 3, 4 and 5 mm of cardboard but very weak and uncreditworthy responses were those where a lagged and unlagged beaker were used.

Marking point 4 was awarded for a correct control variable and the same volume of water was the most common correct response. The strongest candidates gave several correct variables. Weaker responses often referred to the same temperature of hot water but not the same initial temperature.

Marking point 5 was awarded for a table with correct headers including units. Candidates should be reminded that all continuous variables should have a unit stated and that any independent and dependent variables they are measuring should be included in the table. A common error was having a column for change in temperature instead of (final) temperature. Change in temperature is found by processing results not by direct measurement so is an incorrect heading.

Marking point 6 was awarded for detailed explanation of how to reach a conclusion. Candidates who stated that a graph should be drawn for rate against thickness gained this credit. Candidates who attempted to explain how to draw a conclusion were successful if they remembered to make a conditional statement such as 'to see if the rate changed as the thickness changes'. Common errors were stating predictions or expected conclusions or giving incomplete statements such as 'plot a graph using the table'.

PHYSICS

Paper 5054/41 Alternative to Practical

Key messages

Candidates should be made aware that it is important to record measurements to the correct precision and that the precision required is often stated in the question.

Candidates are advised to show all working and to check all their calculations and in particular values that appear to be unrealistically large or small. Candidates should be given opportunities to practise rounding numbers to the nearest whole number or magnitude of ten. Some candidates incorrectly translated numbers from their calculator when given in standard form, writing for example 2.5 instead of 2.5×10^2 .

Candidates should be advised to read the questions carefully to ensure that they are answering the question as written and not simply recalling the answer to a different question or stating a generic answer such as 'repeat the measurements'.

General comments

Candidates need to have had thorough experience in practical work during the course, including reflection and discussion on the precautions taken to improve reliability, and control of variables. Stronger candidates demonstrated that they had gained suitable practical experience and were able to follow instructions carefully and they made accurate observations and measurements, recording them to an appropriate number of significant figures. They were able to process their results by performing calculations and correctly rounding answers. They made sensible judgements or drew relevant conclusions from their data and wrote relevant evaluative comments.

Attention is drawn to the advice on plotting graphs issued by Cambridge. Candidates should remember that graphs are intended to make the interpretation of their experimental results clearer and that data should occupy at least half of the available grid on both the x and y axes. Some responses to questions involving the plotting of graphs included impractical scales such as using scales of 3 or using 3 grid divisions per unit. Using a non-integral scale not only makes it difficult and time-consuming to plot the points but it also makes it difficult to use (for example, to interpolate data). Candidates who use non-integral or other difficult scales are far more likely to make errors in plotting and interpretation of their graphs. It is better to choose a scale which produces a graph that may be a little smaller but still occupies over half the grid in the x and y directions and is based on a scale of 2, 5, or 10 units corresponding to 10 small grid lines. The more prominent grid lines are intended to be points along the axis corresponding to numbers ending in 0, 5, or 2 rather than numbers midway between. The plotted points on graphs should be marked with small, fine, but visible crosses and placed accurately to within half the length of the side of the smallest square made by the thinnest grid lines. The Cartesian axis system should be used, with increasing positive values from left to right along the x-axis and upwards along the y-axis. The best fit straight line or curve should be a carefully drawn single, thin, smooth line, suitably placed (with, as far as possible, equal numbers of points either side of the line and vertical distances of points from either side which compensate one another). A line drawn from the first plot to the last plot or forced to go through the origin is rarely suitable.

Comments on specific questions

Question 1

- (a) Most candidates were able to gain credit for this question for drawing a voltmeter in parallel across the wire heater. Voltmeters drawn across the power supply were also accepted as the circuit did not contain additional resistive components. A common error was drawing a line through the

symbol. Candidates should be reminded to follow the instructions carefully as some candidates drew a new circuit which was unnecessary and time consuming.

- (b) (i) Most candidates recorded an accurate value for the volume. Incorrect responses were due to misreading the scale, stating answers such as 50.2 instead of 52.
- (ii) Most candidates were able to record the values correctly with only a few unable to deduce the scale divisions.
- (c) (i) Candidates were usually able to record a correct value of temperature. The most common error was stating the reading as 20.1 °C instead of 21 °C.
- (ii) The majority of candidates were able to perform this calculation.
- (iii) Many candidates were able to explain that the temperature of the water should be uniform before taking measurements. Common errors were to discuss an even spread of heat energy or allowing the temperature to remain constant.
- (d) (i) Most candidates were able to calculate the energy supplied and the value was usually stated in full rather than rounded to two or three significant figures.
- (ii) Most candidates were able to calculate the energy gained by the water but some candidates selected incorrect values to substitute, often using the initial temperature rather than the change in temperature, or obtained an answer greater than the energy supplied.
- (iii) Many candidates calculated a correct value of efficiency based on their energy values. Some candidates chose to convert their value to a percentage which was acceptable provided the percentage sign was shown. Some candidates incorrectly rounded their value
- (e) Very few candidates gained credit here for a comment relating to insulating the beaker or adding a lid. Common uncreditworthy responses referred to changing the volume of water or the power supply or heater.

Question 2

This question was less well answered than **Question 1**, suggesting that more practice with a range of optical experiments would be helpful to candidates.

- (a) (i) Most candidates were able to draw an accurate normal on the diagram provided.
- (ii) Most candidates placed a line in the correct area to the left of the normal above **XY** but many measured the angle of incidence from the block rather than to the normal.
- (b) (i) Most candidates drew a correct line between the crosses and extended it back to the block. Candidates should be reminded that rays should be drawn with thin lines using a sharp pencil and a ruler.
- (ii) Most candidates were able to complete the path of the ray within the block even if **P** was incorrectly placed.
- (iii) The strongest responses gained credit here for completing accurate ray diagrams and using a protractor carefully.
- (c) Candidates were often able to perform the calculation successfully. Some candidates had difficulty in using trigonometric functions on calculators. Common errors were not stating an answer to two significant figures, usually 1.52, or an incorrect substitution/evaluation.
- (d) Many candidates referred to steps they had already taken such as using a protractor rather than describing a change to the procedure itself. Some candidates referred to repeating measurements but not for a range of angles and finding a mean.

- (e) Many candidates drew a correct normal on the lower surface of the block and so gained at least partial credit. Most candidates who measured the angle correctly were able to give a sensible comment about whether the result agreed with the theory. The strongest candidates recognised that the values being within 10% of each other was a good way to determine agreement but it was sufficient to say that the values were close or identical. Candidates who stated that the values were not identical, so the measurements disagreed with the theory, were also given full credit as the key skill was comparing the values and drawing a conclusion from them.

Question 3

- (a) (i) Most candidates recorded the correct mass.
- (ii) Almost all candidates recorded a correct value for the mass of one marble to two or three significant figures.
- (b) (i) Many candidates were able to calculate the mean time. A common error arose from using a calculator incorrectly so that only the final value was divided by 3 instead of the sum of all 3 values.
- (ii) The strongest responses had a complete table with all mean values recorded to 1 or 2 decimal places. A common error was using an inconsistent number of decimal places.
- (iii) A graph of average time against height should have been plotted and very few candidates incorrectly reversed the axes or plotted an incorrect variable but a significant minority forgot to label the axes or omitted at least one unit. Many graphs were plotted using far less than half of the available space often caused by starting at the origin. Another common mistake which prevented the awarding of credit for selecting an appropriate scale was using a multiple of 3 in a scale. Candidates should also be reminded that scales need use sensible values e.g. 2, 4, 6, ... and not start from their first reading such as 2.7 leading to labels such as 2.7, 4.1, for example. Stronger candidates drew good lines of best fit which showed an equal number of points above and below the line. Weaker candidates had lines which did not extend to cover the full range of data or intended a point to be counted as anomalous as it was so far from the line but did not indicate this. Candidates should be reminded that they need to clearly indicate any points they are ignoring when plotting a line of best fit. This could be done circling the point and writing 'anomaly' alongside it.
- (iv) Most candidates were able to state a correct relationship between the variables. Credit was not given for generic comments about proportionality and candidates should be reminded to describe the relationship in as much detail as possible.
- (c) (i) To gain full credit for this question, candidates needed to indicate on the graph where they were taking their readings. The strongest answers had both vertical and horizontal lines drawn from a height of 7 cm. Weaker responses were often due to candidates having to interpret difficult scales or drawing lines which were too thick resulting in inaccurate readings.
- (ii) Many candidates were able to correctly perform the calculation but credit was only given for a final answer within a certain range which demonstrated good graph skills. A common error was giving a unit in cm/s instead of m/s .

Question 4

This question was quite well answered with the majority of candidates gaining at least partial credit and there were few blank or irrelevant responses simply restating parts of the question. Many candidates had a systematic approach to this type of question, which enabled them to apply knowledge to new situations and gain credit more consistently than those who did not use such an approach.

Candidates were required to plan an experiment to investigate the relationship between the brightness of light falling on a solar cell and the power output of the cell.

Marking point 1 was awarded if candidates described a valid method to vary the brightness. The strongest responses described varying the distance from the cell to the lamp by moving the lamp alongside a metre rule. Some candidates did not make use of the lamp and described uncreditworthy methods such as placing it outside in the sun. Candidates should be reminded that their variables need to be ones which can be measured.

Marking point 2 was awarded for correctly adding an ammeter and voltmeter to the diagram or a clear description of where to place them. Some candidates interpreted the solar cell as the power supply for the lamp and so incorrectly added additional components to the circuit.

Marking point 3 was awarded if candidates described measuring current and voltage for at least two light intensities.

Marking point 4 was awarded for a correct control variable but candidates often struggled to accurately describe a variable, giving vague responses such as power of lamp.

Marking point 5 was awarded for a table with correct headers including units. Candidates should be reminded that all continuous variables should have a unit stated and that any independent and dependent variables they are measuring should be included in the table. A common error was having a column for power instead of both current and voltage which were the measured quantities. Power is found by processing results not by direct measurement so is an incorrect heading and was ignored.

Marking point 6 was awarded for detailed explanation of how to reach a conclusion. Candidates who stated that a graph should be drawn for power against distance gained this credit. Candidates who attempted to explain how to draw a conclusion were successful if they remembered to make a conditional statement such as 'to see if the power changed as the intensity changes'. Common errors were stating predictions or expected conclusions or giving incomplete statements such as 'plot a graph using the table'.

PHYSICS

Paper 5054/42 Alternative to Practical

Key messages

- Candidates should have as much personal experience of carrying out experiments themselves as possible. They need to have a thorough understanding of practical work during the course, including reflection and discussion on the precautions taken to improve reliability, and control of variables.
- 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.
- Candidates should be aware that as this paper tests an understanding of experimental work, explanations need to be based on data from the question and practical rather than theoretical considerations.
- Candidates should be reminded to include units when quoting the values of physical quantities. They should 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, say, exactly 5 cm, the value should be quoted as 5.0 cm.
- Candidates should be reminded to 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 rote 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 why the accuracy has improved or how parallax error was 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.
- 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.

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.

The level of competence shown by the candidates was good but some candidates approached this paper as they would a theory paper, and not from a practical perspective. Almost all candidates attempted all sections of each of the questions and there was no evidence of candidates suffering from a lack of time. 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, writing was legible, and ideas were expressed logically.

Comments on specific questions

Question 1

- (a) Candidates were required to draw a circuit diagram from a written description of the circuit, choosing from a given list of standard symbols. The majority of candidates gained partial credit for drawing a series circuit. Further credit was scored by many candidates for drawing a series circuit consisting of a power supply, an LDR, a fixed resistor and a switch. The correct symbol for the LDR was most challenging, with many candidates choosing the symbols for an LED, thermistor or rheostat from the list of standard symbols supplied.
- (b) (i) Most candidates drew the symbol for a voltmeter, correctly connected in parallel with the LDR, to measure the potential difference across the LDR. However, many voltmeters were connected in series into the circuit.
- (ii) The reading on the scale of the voltmeter was almost always recorded correctly.
- (iii) Only stronger candidates were able to suggest why the switch in the circuit is opened after the reading is recorded. Vague answers, such as 'to prevent overheating' were not accepted. Candidates needed to specify where in the circuit overheating might occur. Answers such as 'to stop the resistor/components overheating' were accepted as was 'to stop the battery running down'.
- (c) (i) The current I in the circuit was usually calculated correctly. Occasionally candidates used the wrong value of V in the equation provided.
- (ii) The majority of candidates proceeded to calculate a correct value for the resistance of the LED under normal lighting conditions, using the equation provided.
- (d) Few candidates were able to explain why the potential difference across the LDR increased when the piece of card was placed on top of the LDR. Most candidates stated that the resistance would increase. This was not credited because there was also a resistor connected in series with the LDR. Candidates were expected to say that the resistance of the LDR increased.
- (e) Many candidates were able to examine the results in Table 1.1 and describe the relationship between d and V in sufficient detail to score partial credit. These candidates could see the general trend, namely that as d decreased, V increased. Only stronger candidates also spotted that initially, for values of d decreasing from 30 cm to 20 cm, the value of V was (more or less) constant. Responses simply stating that the quantities are directly/ inversely proportional did not get credit.

Question 2

- (a) (i) The majority of candidates read the scale of the thermometer correctly as 21 °C, which gave the temperature of the white card at time $t = 0$. Common incorrect answers were 20.1 °C and 39 °C.
- (ii) The completion of the time column in **Table 2.1** was done correctly by almost all candidates.
- (b) (i) The temperature increase of each card was deduced correctly by most candidates by simple subtraction of the temperatures supplied in the table.
- (ii) The rate of temperature increase of each card was usually calculated correctly, but the unit quoted was often given as °C or s / °C instead of °C / s. It is worth noting that sec or secs is not an acceptable alternative unit for second.

- (iii) Again, almost all candidates used their answers to (ii) to reach a correct conclusion comparing the rates of absorption of thermal radiation by the black and white cards.
- (iv) This question asked candidates to compare the rate of temperature increase of the black card at the beginning of the experiment and at the end of the experiment. Stronger candidates used the values in **Table 2.1** to calculate the increase in temperature of the black card at various stages during the experiment and correctly concluded that the rate of temperature increase is greater at the start of the experiment than at the end. Despite the instruction to justify their answers by referring to the results, a majority of candidates stated a correct conclusion, but gave no numerical evidence.
- (c) Nearly all candidates were able to provide at least one of the two variables that needed to be controlled in the experiment so that the comparison between the absorbing properties of white and black surfaces was valid.

Question 3

- (a) (i) The position of the pivot on the metre rule at balance was read and recorded correctly by almost all candidates.
- (ii) Many candidates used their answer to (a) to correctly deduce the required distances a and b .
- (b) Only the strongest candidates were able to describe a strategy to ensure that the centre of each of the masses placed on the metre rule was directly over the 5.0 cm mark on the rule. The way to do this was to take the scale reading from the rule at both sides of the mass and adjust the position of the mass until the mean of these readings was 5.0.
- (c) Most candidates calculated the value of the ratio $r = a / b$ correctly. However, there were occasional rounding errors. The instruction to record the answer to 2 significant figures was also sometimes ignored.
- (d) The graph axes were almost always labelled and the correct way around. Despite the fact that in the header of **Table 3.1**, the ratio r was shown to have no units, many candidates gave r the label 'cm' when they labelled the y -axis. Most candidates chose scales that allowed at least half of the grid to be filled. Point-plotting was accurate, with most candidates placing their dot or cross within one-half of a small graph square of the exact location of the point. There were many excellent, carefully drawn, best-fit straight lines produced. However, there were some graphs where the attempt at a best-fit line resulted in all points which did not lie on the drawn line, being on the same side of the line. There were also some graphs where the points were joined dot-to-dot. The concept of best fit was not well understood by all candidates.
- (e) (i) Most candidates obtained a value for the gradient of the graph that was within the allowed tolerance. As expected, candidates who drew a large triangle to determine the gradient G of their graphs obtained the most accurate values for the gradient of the line. Some candidates showed no clear indication on the graph of how the information to determine the gradient had been obtained, despite the instruction being given to do so.
- (ii) The mass M of the metre rule was usually calculated correctly from the value of the gradient G calculated in (i). The instruction given, to record M to the nearest gram, was frequently ignored.
- (iii) Not all candidates were able to name a piece of apparatus that can be used to measure the mass of the rule directly. Devices such as (electronic) balance, beam balance or weighing scales were accepted, but spring balance, force meter or newton meter were not.
- (f) Many candidates found this question challenging. To check that the centre of mass of the metre rule is at the 50.0 cm mark, all that was required was to check to see if the rule balanced at this point when a pivot was placed there.

Question 4

Credit was available for stating any other apparatus, apart from the apparatus listed in the question, that candidates would need to do the experiment. Most candidates realised that they would also need a stopwatch or timer.

Further credit was available for giving a brief explanation of how the investigation would be carried out. Most candidates gave a description of an experiment which involved hot water cooling down. Many went on to describe wrapping cardboard insulation around the beaker before timing the hot water cooling and then repeating the experiment using different thicknesses of insulation. In a number of plans, only one thickness of insulation was used, making it impossible to investigate the relationship between the rate of cooling of the hot water and the thickness of the insulation.

Candidates had little trouble in suggesting a key variable to control during the experiment. The most popular answers were the mass/volume of the water or the initial temperature of the hot water in the beaker.

Most candidates drew a table of results with clear columns for thickness or number of sheets of cardboard and temperature and/or time with units, if appropriate. It should be noted that 'secs' is an inappropriate unit for time and 'm' is an incorrect unit for minutes.

Fewer candidates explained well how they would use their results to reach a conclusion because they made predictions about the outcome. An answer such as 'compare the results to see if/how/whether the thickness of the cardboard insulation affects the rate of cooling of the hot water in the beaker' was required. Many stronger candidates also suggested plotting a graph of thickness/number of sheets against temperature/time/rate of cooling.