PHYSICS

Paper 5054/11
Multiple Choice

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

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

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

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

General comments

Candidates need to read each question carefully to determine what is being asked, and should focus on the information supplied in the text. Whilst some questions may be similar to questions asked in previous papers, they do not necessarily ask for the same thing or give information in the same way.

Candidates need to check the units used in a question, which are not always the SI base units.

Comments on specific questions

Question 2

This question assesses knowledge of the fact that the distance travelled by a moving object is equal to the area under the speed-time graph for the motion. More candidates chose the correct option **B** than any other, but a significant number of candidates selected option **D**. This choice was obtained by multiplying the final speed by the total time which here led to a value greater than the distance travelled by the bicycle.

Question 7

This question asks for a single piece of knowledge. The correct answer was chosen by more candidates than any other. Some candidates appeared to confuse N m with N/m^2.

Question 8

The correct approach, of dividing the given impulse by the given time (which described how long the collision lasted), was followed by most candidates. Very few candidates chose either option **B** or option **D**. However, many candidates who divided the impulse by time did not convert the time of 70 ms into 0.070 s. Option **A** was almost as popular as the key.

Question 18

A common misunderstanding concerning thermal conduction in metals is that free (delocalised) electrons transmit energy through the metal by vibration and collision. This is not the case and electrons do not behave in the same way as the fixed particles in metals and in non-metals. In general, option **A** was more commonly chosen than the key, option **B**, but stronger candidate usually answered correctly.

Question 22

The lens in position 2 causes diverging rays to converge and the rays show clearly that this lens is a converging lens. However, the action of the other two lenses is less direct. The lens in position 1 causes diverging rays to diverge to a lesser extent and the lens in position 3 causes converging rays to converge to a lesser extent. Therefore, lens 1 is a converging lens and lens 3 is a diverging lens. The key, option **B**, was commonly chosen by stronger candidates.

Question 23

The stem does not state the value of any angles or of the refractive index of the water and so both refraction into the air and total internal reflection at the surface are possibilities. However, refraction from water to air is not shown on the diagram – the ray should refract away from the normal instead of towards, as shown in option **B** – and therefore option **C**, showing the ray of light reflecting internally, must be correct. Very few candidates selected options **A** or **D** which are both impossible but many candidates chose the incorrect option **B**.

Question 24

This question could have been approached in several ways. Candidates who are aware of one aspect of the use of a magnifying glass could have drawn a ray diagram and deduced the correct answer from it. Other candidates may simply recall the fact that a lens used as a magnifying glass produces an image which is virtual and upright. A number of candidates chose the key, option **D**, but all the options were chosen by some candidates.

Question 27

Most candidates realised that the distance x could be determined using the difference between the two times given in the question. This time could then be used to calculate the additional distance travelled by the pulse of ultrasound that reflects from the bottom of the sample rather than from the crack. Almost all candidates selected either option **A** or **B**. The correct option, option **A**, was chosen by candidates who also realised that the distance x is half of the additional distance travelled.

Question 28

There are three stages to this question. Candidates first need to determine the current in the circuit and then use the current and the time to deduce the current that flows through the resistor. However, the time is given in minutes and needs, at some point, to be converted to seconds. The key, option **B**, was most frequently chosen but candidates who left the time in minutes obtained an answer of 3.6 C and selected **A**. Only a small number of candidates selected either option **C** or option **D**. These two options arose from rearranging $Q = It$ incorrectly to $Q = t / I$.

Question 32

This question was answered correctly only by the strongest candidates. The first stage is straightforward as the graph suggests that there is a difference of 90° between the first two positions and a difference of 180° between the last two positions. This leads to the elimination of options **A** and **D**. It is then necessary to consider what happens to the magnetic field through the coil as it passes through the position where the angle between the field and the plane of the coil is 90°. At this position, the magnetic field through the coil reaches a maximum. Therefore, the magnetic field through the coil which has been increasing starts to decrease and so the rate of change of the magnetic field through the coil which was positive becomes negative. At the exact moment when the angle reaches 90°, the rate of change is instantaneously zero (it is neither increasing nor decreasing) and so there is no e.m.f. induced. Therefore, zero e.m.f. corresponds to a 90° angle between the coil and the magnetic field. This is shown by option **C**, which was the key.

Question 33

Reaching the answer to this question requires the application of a rule that relates the relative directions of force, magnetic field and current. One such rule is the Fleming left-hand rule but there are other similar rules. The majority of candidates applied such a rule and deduced that the force is perpendicular to the plane of the paper. Most candidates selected either option **C** or option **D**. Candidates who incorrectly chose option **D** had quite possibly not noticed that the particles referred to are beta particles. Beta particles are negative and so by moving downwards, they constitute an upward current.

Question 34

A transformer cannot deliver more power than it is supplied with. A step-up transformer delivers an output voltage greater than the input voltage and therefore, the output current must be less than the input current so that the product VI does not increase in size. Candidates who did not fully understand the difference between voltage and current, may have selected option **D** rather than the correct option, **B**. A small number of candidates selected an option that suggested that transformers function using d.c.

Question 36

One possible approach to this question was to select an imaginary isotope and to see how the proton number and the nucleon number were affected by the emissions in each of the options. This would have led to the key, which was option **D**.

PHYSICS

Paper 5054/12
Multiple Choice

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

General comments

Candidates need to read each question carefully to determine what is being asked and should focus on the information supplied in the text. Whilst some questions may be similar to questions asked in previous papers, they do not necessarily ask for the same thing or give information in the same way.

Candidates need to check the units used in a question, which are not always the SI base units.

Comments on specific questions

Question 7

This question required interpretation of the information given and the application of the definition of weight. The correct choice was option **D** which gave a value for density that is calculated using the numerical value of the mass of the rock in the defining expression. In everyday language, the two quantities 'mass' and 'weight' are rarely distinguished and this may explain the popularity of option **A**.

Question 11

Unlike liquids which transmit pressures, a solid object such as a nail, transmits forces unchanged and so the relationship between the forces is $F_W = F_H$. Since the areas of contact at the two ends of the nail are different, it is possible to deduce that $p_W > p_H$ and that option **A** is the correct choice. This was significantly more popular than any other option, but a few candidates selected one of the other options.

Question 13

The piston moves to the right in order to keep the pressure of the gas inside the cylinder equal to that of the surroundings. The increase in the temperature of the gas causes the average speed of the particles to increase and so as the particles collide with the piston, the average force exerted by each collision of a particle with the piston increases. As the piston moves to the right, the volume occupied by the gas increases and the particles are less densely packed and so collide with the piston less often. The effect of the increased force is cancelled by the decreased frequency of collision and so the pressure does not change. Few candidates chose the option that stated that the speed of the particles decreases but the other incorrect options were each chosen by a significant minority of candidates.

Question 19

This question could be approached using the equation $v = f\lambda$ but could also be answered more simply by considering what the graph indicates. In a time of 1.0 s, the oscillating cork completes two cycles of its oscillation and therefore travels a distance equal to two wavelengths. The graph indicates an amplitude of oscillation of 2.0 cm and the text states that the amplitude and wavelength are equal. Therefore, the wavelength is equal to 2.0 cm. The wave travels a distance of 4.0 cm in 1.0 s and so the speed is 4.0 cm / s. Some candidates selected option **A**. Option **D**, which is based on the misinterpretation of the term 'amplitude', was the least commonly selected option.

Question 20

The frequency of the wave that reaches the boundary between the deep water and the shallow water is determined by the number of crests and troughs that were generated at an earlier time by the source of the wave. Frequency cannot change on passing into the second section of the tank. Candidates needed to know that the wave slowed down on entering the shallow region and this restricted the answer to either option **C** or option **D**. At this point, candidates could have applied the equation $\lambda = v / f$ to deduce that the wavelength decreased. More intuitively, they could have also reasoned that when a wave crest enters the shallow region and slows down, there is a short period of time in which the following wave crest is travelling faster, catching up on the first wave crest and that as a result, the wavelength decreases.

Question 23

Here, candidates were expected to use the grid to complete the ray diagram for the object of height 2.0 cm that was a horizontal distance of 2.0 cm from the optical centre of the lens. When this is done carefully and accurately, an image of height 6.0 cm is produced at a horizontal distance of 6.0 cm to the left of the optical centre. Either the distances or the heights can be used to calculate the magnification. The key was option **C** and this was by far the most commonly selected option.

Question 26

As the whale swims under the boat, the time for the return journey of the pulse decreases by 0.40 s. This allows candidates to calculate the decrease in the length of the return journey, which is 600 m. Many candidates selected this option. A smaller number of candidates went on the deduce the distance of the whale above the seabed as half of this value and these candidates then selected the key, option **A**. Option **B** also attracted a few candidates.

Question 29

There were several parts to this question. Candidates needed to interpret the diagram, then the resistance of the parallel pair needed to be calculated and the p.d. across the 6.0 W resistor on the right determined. This could be done by treating the circuit as a potential divider or by calculating the current in the circuit and using the equation $V = IR$. Candidates who attempted this either obtained the correct value and chose option **B**. However, the most popular choice was the incorrect option **D**. This was probably selected by candidates who were not fully aware of the distinction between current and voltage.

Question 32

In the position shown in the diagram, the magnetic field passing through the coil has just reached a maximum value. Therefore, the magnetic field through the coil has just stopped increasing and is just about to start decreasing. This can be stated as the rate of change of magnetic field through the coil has just stopped being positive and is about to become negative. From this, it follows that the rate of change of magnetic field through the coil is instantaneously zero and so the induced e.m.f. is also zero in the position shown. Therefore only option **A** and option **C** need be considered further. The coil then rotates through a half-revolution and so the e.m.f. induced passes through a half-cycle. Option **A** is the key. The majority of candidates selected either option **A** or **C** but more chose option **C** than chose **A**.

Question 35

This question highlighted several common misunderstandings about the operation of a transformer. These include the belief that the current in the secondary coil of a step-up transformer is greater than that in the primary coil and the belief that the current passes through the iron core. The correct answer was chosen by more candidates than any other option, but option **B** was almost as popular and option **D** was also commonly chosen.

Question 36

Almost all candidates chose an option that corresponded to an upward deflection of the alpha particle. This is consistent with the alpha particle having a charge whose sign is opposite to that of the charge of a beta particle. However, option **A** was much more popular than the correct option **B**.

Question 37

Few candidates chose an option that suggested that the charge on the electron is negative. However, many candidates selected option **B**, which suggests that the nucleus of an atom is uncharged. There may have been some confusion between the words ‘nucleus’ and ‘neutron’.

Question 38

Most candidates realised that a reduction in the count rate due to sample of the isotope to $1/16^{th}$ of its original value corresponded to four half-lives. This led directly to an answer of 24 000 years and to the selection of option **C**. Some candidates simply multiplied the half-life by 16 and chose the incorrect option **D**. Very few candidates selected either option **A** or option **B**.

PHYSICS

Paper 5054/21
Theory

Key messages

- In calculations, candidates must set out and explain their working correctly. It is advisable that a calculation starts with a formula, the insertion of data and finally the answer.
- Answers may be given to any number of significant figures equal to or greater than those given in the data. Therefore, they should be given to 2 or more figures. If candidates round answers they should take care to do so correctly and not, for example round 1.87 to 1.8.
- Candidates should read the questions carefully in order to understand exactly what is being asked and should plan their answers before starting to write.
- Candidates should ensure their language is clear and precise when answering questions requiring a description or explanation.
- Candidates should ensure they understand the command words used, such as 'explain'.
- Candidates are advised to use the acceleration of free-fall *g* as 9.8 m/s^2, as provided on the front page of the question paper.

General comments

Some excellent responses were seen, with most candidates displaying knowledge of the basic principles in the syllabus. Candidates must be familiar with the entire syllabus for accurate and complete answers.

Candidates appeared to have enough time for the examination.

Comments on specific questions

Section A

Question 1

(a) The graph should have shown a curve with the decreasing gradient becoming horizontal. Most candidates achieved some success, usually by drawing the horizontal section Weaker candidates drew a straight line that became horizontal at a single point. The labels A and B needed to be placed clearly at points where the speed was increasing and constant respectively and this was not always the case when the labels were placed at the junction between two sections of the graph.

(b) Many candidates correctly suggested that the slope is a measure of the acceleration but did not always suggest that the slope or gradient should be decreasing to show the decreasing acceleration.

(c) (i) Many candidates named air resistance, drag or friction caused by the air. Although the question asks for the other vertical force apart from weight, many candidates gave gravity or gravitational force, suggesting that they did not understand that weight is the force of gravity acting on the skydiver.

(ii) In explaining why the vertical force eventually becomes zero, most candidates recognised that the air resistance will equal the weight. However, a significant number of candidates did not make it clear that the air resistance increases until it is equal to the weight. Some candidates suggested that the weight changes until balance is achieved. Weaker candidates suggested that 'forces balance' without suggesting the names of the forces involved or even that the forces are acting upwards and downwards.

(d) Stronger candidates produced good diagrams here. The diagrams did not need to be drawn to scale, as the answer could be calculated from a right-angled triangle. The diagram did need to show a horizontal 100 N, a vertical 400 N force and the correct resultant acting in a direction between the two other vectors, completing a triangle of vectors or being the diagonal of a rectangle. Many diagrams showed the resultant in the wrong direction.

Pythagoras' theorem was used well to calculate the resultant. The determination of the angle to the vertical caused some difficulty with some becoming confused as to how to show the angle.

Question 2

(a) Although many candidates suggested that anticlockwise and clockwise moments are equal, the necessary condition, that the object is in equilibrium, was omitted in many answers.

(b) (i) This question was answered well and almost all candidates used *g* as 9.8 N/kg rather than 10 N/kg as directed on the front of the paper.

(ii) The most common approach was to calculate the weight of the suitcase as 52 N using a simple moment calculation, but it was also possible to calculate the moment of the maximum possible weight and show that this is larger than the moment created by the bags of sugar.

(c) (i) Many candidates were able to define the centre of gravity as the point where the weight or the force of gravity may be considered or taken to act. Weaker candidates suggested it was the point where forces act, rather than the force of gravity.

(ii) Most candidates found it challenging to explain why the bus falls over as the slope becomes steeper. The strongest candidates recognised that this is because the centre of gravity or the weight falls outside the base, or moves past P and so creates an anticlockwise moment about P to tip the bus. Many candidates suggested that the bus is unstable or not wide enough without explaining why the bus falls over.

Question 3

(a) Most candidates correctly stated that chemical store in the battery decreases or transfers to the gravitational store in the load. The transfer of some energy to the thermal store, either because of the electrical heating in a resistor or because of friction, was not mentioned very often. The load is being lifted and is likely to be at a constant speed while it is lifted. The amount of energy in the kinetic store then does not change *during* the lifting process and only differs at the start and end of the lifting process.

(b) (i) Those candidates who started their answers by comparing the useful energy and the output energy, for example by stating "the output energy is less than the input energy" were more often successful.

(ii) The concept of the principle of conservation of energy was well known but most candidates did not apply it to the context of the question. The energy transferred from the battery is equal to the energy transferred to the load plus that transferred to the thermal store in the air, resistor etc.

(c) The calculation of the energy supplied to the load involved two stages. First, candidates needed to calculate the energy supplied to the motor, and then calculate the energy supplied to the load using the efficiency of the motor. Most candidates were able to do at least one of these stages but only stronger candidates were able to do both stages.

Question 4

(a) (i) The strongest answers suggested that particles with the greatest speed or kinetic energy escape the surface of the liquid to leave behind those particles with less energy. Weaker candidates suggested that particles are given kinetic energy to escape or to break bonds rather than the idea that particles in the liquid exist with a range of kinetic energies and those with the most energy escape.

(ii) The difference between evaporation and boiling was well known. The most common answer was that evaporation occurs at a range of temperatures whilst boiling occurs at only one temperature.

(b) (i) Many candidates explained that the cold air sinks because cold air is denser. A few candidates didn't mention density or stated that the particles become denser.

(ii) The formula relating energy, mass, temperature and specific heat capacity was well known. The simplest solution was to calculate the temperature difference, 14.8 °C, and then the final temperature by subtracting this value from 20 °C. Many candidates added rather than subtracted the temperature difference to produce the final answer.

Question 5

(a) The majority of candidates marked a compression and rarefaction correctly and explained that the particles were closer together in a compression or that the pressure is higher in a compression.

(b) (i) The calculation of the frequency was carried out well, with many candidates obtaining the correct result. Some weaker candidates divided 60 by 45 or tried to use the formula $f = 1/t$ without understanding that t is the rime for one complete oscillation.

(ii) Most candidates correctly suggested that the wavelength decreases but a few also suggested that the speed of the wave does not change.

(iii) Most waves drawn by stronger candidates in the shallow region were continuations of the incident wavefronts but were sometimes bent the wrong way, producing a wave with a larger wavelength despite the answer to **(ii)** suggesting that the wavelength had decreased. Candidates needed to make sure that the bending of the wave did not move so that the new wavefronts were on the wrong side of the normal.

(c) Although diffraction was very often correctly described as the bending of a wave, it was not always associated with the wave passing through a narrow gap or around the edge of an object. This is necessary to distinguish the bending caused by diffraction from the bending caused by refraction or reflection.

Question 6

(a) (i) Many candidates were able to complete the circuit by drawing the voltmeter across resistor X and the ammeter in series. Sometimes the voltmeter was drawn across the battery or across the complete circuit. As the e.m.f. of the battery was not known, the voltage across X could not be found if the voltmeter is across the battery.

(ii) There were many ways to explain the action of a potential divider. The most direct was to say that X and R share the voltage of the battery and that the larger resistor has more of the voltage or when, for example, R increases the p.d. across R increases and the p.d. across X decreases. Many answers described the current in the circuit and not the voltages across the two components.

(b) (i) Stronger candidates mentioned the direct relationship between the resistance of the wire and the length. Weaker candidates merely suggested that as the length increases, the resistance increases.

(ii) The resistance of the wire first needed to be found from the graph and most candidates did this correctly. The formula $V = IR$ was well known and applied to find the value of the current. The final answer calculated to 3 significant figures was 1.67 but a number of candidates incorrectly gave the value as 1.6 A.

(iii) The inverse relationship was given correctly by many candidates, with weaker candidates simply suggesting that as the length increases, the current decreases and not specifying the type of relationship.

(c) The inverse relationship between the resistance and the area of the wire was not as well known or was expressed as the relationship between the resistance and the length of the wire.

Question 7

(a) Many candidates had difficulty in explaining the action of a transformer. Many suggested that the current from the primary coil passes through the core to the secondary rather than suggesting that the primary coil produces a changing magnetic field which passes to the secondary coil and induces an output voltage in it.

(b) (i) Most candidates correctly suggested that the reading was larger than 10 V and would be outside the range of the voltmeter.

(ii) The calculation of the number of turns on the secondary was correct in most answers, showing a good knowledge of the relationship between the voltages and the turns on the coils. Only a few candidates remembered the formula incorrectly.

(c) (i) Stronger candidates were able to draw a simple alternating voltage on the screen with positive and negative values and an approximately constant frequency, ideally sinusoidal in shape.

(ii) The simplest approach, taken by stronger candidates, was to suggest measuring the number of divisions for the height or amplitude of the trace and then multiplying by the *Y*-gain value of 2.0 V/division. Weaker candidates did not make it clear that the height was determined and just stated "count the number of divisions" or tried to involve the timebase in some way. Some candidates did not answer this question.

Question 8

(a) The majority of candidates mentioned the presence of neutrons and protons in the nucleus and usually gave the correct number of each particle. Weaker candidates also mentioned electrons which are present in the neutral atom but not in the nucleus. The weakest candidates suggested that the nucleus contains alpha and beta particles.

(b) (i) The diagram showed the splitting of a plutonium nucleus and most candidates described the action of the neutron to cause this splitting. There was confusion between fission and fusion in some answers. Stronger answers described how at least one of the neutrons produced in a fission event needs to hit another plutonium nucleus for the chain reaction to proceed. Weaker candidates suggested that the neutrons hit the fission fragments or daughter nuclei rather than another plutonium nucleus.

(ii) The action of the control rods was only explained well by stronger candidates. Where a suggestion was made that the rods absorb neutrons, the strongest candidates mentioned the actual way that an increase or decrease in the reaction occurs by removing (raising) or adding (lowering) the rods.

(c) There are many possible differences between an alpha and a beta particle that could have been mentioned, either in their composition or in their properties. Sometimes a comparison was not made between the two particles or difference 1 stated a property of the alpha particle, e.g. "has a positive charge" and difference 2 was the corresponding property of a beta particle, e.g. "has a negative charge". Weaker answers were sometimes not specific enough, e.g. "alpha particles can only pass through a few mediums" or were incorrect, e.g. "alpha particles are less ionising".

(d) (i) Diagrams of the cloud chamber needed to contain a source of vapour inside a container with a means of cooling. A spark chamber needed a high voltage source between a wire or gauze and a plate. Diagrams of the cloud chamber produced the best results. However, many candidates gave a diagram of a GM tube and counter.

(ii) Few candidates stated that the tracks or sparks are caused by ionisation of the air.

Question 9

(a) The correct sequence in the life cycle of a star was given in most answers, with the most common error being to place a supernova before the red supergiant stage.

(b) (i) The majority of candidates correctly stated that gravitation provides the inwards force in a star.

(ii) The cause of the outwards force was less well known but sometimes correctly attributed to the nuclear fusion or described as being due to the very high temperatures or the pressure of the radiation or even the pressure of the Sun's atmosphere. Weaker candidates gave little detail, e.g. 'heat energy'

(c) (i) Many candidates stated that a light-year is the distance travelled by light in one year. Other answers suggested that a light-year is a time or the distance between Earth and other bodies.

(ii) Few candidates gave the answer of 8200 years. A common error was to give the time as 8200 light years, which is a distance rather than a time.

(iii) Many candidates knew that the redshift is caused by the movement of a star away from Earth but they did not apply this knowledge to the unfamiliar situation and state that SN185 has little velocity away from Earth, whereas SN2014J is moving fast away from Earth. Alternative answers in terms of the expansion of the Universe were sometimes seen.

(d) Candidates needed to mention nuclear fusion as the cause of the formation of heavier elements in a supernova or at the centre of a star. Many candidates correctly suggested that hydrogen and helium react but this was sometimes expressed as a chemical reaction rather than the combining together of the nuclei of these or other elements by fusion.

PHYSICS

Paper 5054/22
Theory

Key messages

- In calculations, candidates should set out and explain their working correctly. It is advisable that a calculation starts with a formula, the insertion of data and finally the answer.
- Answers may be given to any number of significant figures equal to or greater than those given in the data. Therefore, they should be given to 2 or more figures. If candidates round answers they should take care to do so correctly and not, for example round 1.87 to 1.8
- Candidates should read the questions carefully in order to understand what is being asked and should plan their answers before starting to write.
- Candidates should ensure they understand the command words used, such as 'explain'.
- Candidates are advised to use the acceleration of free-fall *g* as 9.8 m/s^2, as provided on the front page of the question paper.

General comments

Some excellent responses were seen, with most candidates displaying knowledge of the basic principles in the syllabus. Candidates must be familiar with the entire syllabus for accurate and complete answers.

Candidates appeared to have enough time for the examination.

Comments on specific questions

Section A

Question 1

(a) (i) The plotting of points was usually very accurate showing good plotting skills. It is advisable that points are plotted as crosses or dots that are circled and not just as dots. The main errors were taking one small square to be 1 and not 2 cm on the *y*-axis or not completing the graph to pass through the origin. Most candidates made an acceptable attempt at drawing a curve, but some graphs were just a single straight line or a series of straight lines joining points near the origin.

(ii) The majority of candidates demonstrated a clear knowledge of average speed and correctly applied the formula, earning full credit for their answer. Some candidates rounded to 200 which was acceptable in this case. A few candidates added together all the distances and times rather than using the distance and time at 0.40 s.

(iii) Many candidates had difficulty with this question but stronger candidates realised that a tangent should be mentioned, and that the gradient of the tangent should be found. However, many candidates just gave a description of their calculation in **(ii)** using co-ordinates from the table or graph. This calculated the average and not the instantaneous speed at t =0.40 s. There were also attempts to answer in terms of the area under the graph.

(b) (i) In general, a strong understanding was shown of the forces involved at terminal velocity and the concept that these forces balance when the acceleration is zero. Most candidates realised that the resistive force is air resistance. However, there was often no indication that this resistive force increases as speed increases, which was critical in explaining why the acceleration decreases.

One error was to equate the downward force with the acceleration, e.g. by stating that eventually air resistance becomes equal to the downwards acceleration. Those candidates who gave the names of the forces clearly and approached the question logically were usually successful.

(ii) The question asked for a description of the appearance of a distance-time graph when the acceleration of the ball becomes zero. Although the correct answer ‘a straight line’ was often seen, there was sometimes extra information included, such as a horizontal straight line, a vertical line or a line though the origin. In these cases, the ball would not be dropped or be falling. The significance of a constant slope in representing a constant speed was shown by many but not all candidates.

Question 2

(a) Power as the work done or energy change per unit time was well known.

(b) Candidates who started by writing the equation efficiency = power output ÷ power input were usually more successful than those who started with the data. These candidates often found 70 per cent of the output power using an incorrect form of the equation.

(c) (i) The formula for work as force × distance moved was well known. Most candidates realised that the force involved needed to be calculated using g as 9.8 N/kg, as given on the front of the question paper, rather than 10 N/kg.

(ii) The formula relating power, time and work done was widely known and quoted. However, a significant number of candidates used the wrong power in their calculation.

(d) The question asked for a description of the mechanism by which energy is transferred to the thermal store. The strongest candidates mentioned the work done against friction or air resistance as being the cause of this transfer. Many answers mentioned the release of ‘chemical energy as the fuel of the fork-lift truck is burnt, despite the question describing the truck as having an electric motor. The phrase ‘electrical store’ is not mentioned in the syllabus. Instead, the syllabus mentions that ‘energy is transferred between stores during events and processes, including transfer by forces (mechanical work done) and electrical currents (electrical work done)’. Therefore, electrical heating causing a transfer of energy to the thermal store was accepted.

Question 3

(a) (i) The majority of candidates showed a correct understanding of the formula for pressure.

(ii) Most candidates suggested that the area decreases and some additionally explained that force is inversely proportional to area.

(b) (i) The formula for momentum was well known but not always expressed clearly as mass times velocity or the product of mass and velocity. Answers such as ‘momentum is mass into velocity’ might be taken as meaning velocity divided by mass.

(ii) Many answers to this question did not involve the idea of momentum as asked for in the question. The force involved when a single particle collides with the wall causes a momentum change as the direction is altered. The strongest answers clearly linked force with the change in momentum per second.

(c) Candidates were more familiar with the answer for this question and usually detailed the increased speed or kinetic energy of the particles and the subsequent increase in the frequency of collision with the walls.

Question 4

(a) The strongest candidates clearly described the vibration of the air particles as parallel to the direction of the transfer of energy or described the particles moving backwards and forwards to create compressions and rarefactions. The vibration of the particles themselves was sometimes less clearly stated, e.g. “the particles move from the tuning fork to the microphone”. However, most candidates were able to describe the vibration of the particles or the formation of compressions and rarefactions.

(b) (i) The definition of frequency was well known as the number of wavelengths passing a point in one second or the number of oscillations in one second.

(ii) Many candidates correctly stated that frequency = 1/time but only the strongest realised that there were 2.5 waves in 0.050 s. The majority of candidates incorrectly suggested that there was 1 wave in the time of 0.050 s.

(iii) The most direct answer was to suggest that the loudness or volume of the sound decreases. Many answers were too vague, for example suggesting that the sound was 'lower' or 'starts to decrease' whereas a significant number of answers incorrectly suggested that the pitch decreases.

(iv) Although the trace drawn in many answers showed a lower frequency, the shape drawn did not usually have a frequency half that of the original wave. One complete cycle of the drawn shape needed to be completed in a time equal to two of the original cycles.

(c) (i) Most candidates drew three wavefronts that showed some element of diffraction. The shape of the wavefronts could have been straight opposite the gap in the wall and should have been the correct parts of a circle outside any straight section. Many answers showed straight sections that were far too long and extended far above or below the gap. Another major error in the diagrams was that the wavelength of the diffracted wavefronts was often far too small. Candidates needed to realise that the wavelength is not altered when a wave diffracts.

(ii) 'Diffraction' was the most common answer to this question, but answers such as 'refraction' and 'dispersion' were also seen. Correct spelling of some technical terms is important as they can be confused with other terms and, in particular, refraction and diffraction need to be spelt correctly. A significant number of candidates gave 'defraction', where one change of letter produces 'refraction' but two changes were needed to produce the correct answer 'diffraction'.

Question 5

(a) Most candidates recognised that the meters were not in the correct places. The strongest candidates suggested that the meters should have been swapped with each other, or alternatively, that the ammeter should have been in series with the length of wire and the voltmeter in parallel. A significant number of candidates incorrectly placed the voltmeter across the variable resistor or across the battery. Most candidates did not recognise that the cells are not connected properly or had difficulty in explaining how to arrange the cells, either with all cells having their left-hand or positive side on the left of the bank of cells in the battery or by just reversing one or two cells.

(b) (i) The formula for resistance was known by most candidates and correct readings were usually taken from the graph to obtain the result. A few candidates did not write down the formula but proceeded directly to find the gradient of the graph, which was not the resistance in this case.

(ii) In this question, candidates had to recognise that different lines on a graph represented wires of different resistance and link this to the different lengths of the wire. Most candidates correctly suggested that wire Q was shorter but sometimes then failed to explain this conclusion.

(iii) In this question, candidates calculated the length of wire Q using the proportionality between resistance and length. Most candidates were successful and their working, if shown, usually displayed a knowledge of direct proportionality.

Question 6

(a) This question involved the choice of a fuse in a heating circuit, and most candidates successfully calculated the current in the heater as 8.7 A. The choice of fuse was most often 13 A but a fuse rating of 5 A or 8 A was sometimes chosen. There were also some suggestions made that the current in the lighting circuit should be added to give the total fuse rating. The explanation usually made it clear that the fuse rating should be larger than the current in the heater but often did not make it clear why the 30 A fuse was not suitable. Weaker candidates tended to choose a rating of 8 A because it was 'closest to the current in the heater' or 5 A because it was 'safer', rather than recognising that both of these fuses would blow under normal operation of the heater. The strongest answers suggested that the rating should be slightly larger than the current so that the heater works with the normal current but blows if the current is slightly larger whereas, with a 30 A fuse, the circuit or heater may be damaged before the fuse blows.

(b) An understanding that a fuse melts was very well known.

(c) (i) The current in the lighting circuit fuse was obtained by adding the current in Q to twice the current in a lamp P. Candidates who did not obtain this answer sometimes added to or subtracted the value obtained from the stated fuse rating for the circuit.

(ii) The rating for the lighting circuit fuse was given as 5 A and candidates were asked to determine the maximum number of additional lamps that could be connected to the lighting circuit. The strongest candidates divided 5 by 0.26 and then subtracted 2, the number of lamps already connected in the circuit. It appeared that many candidates did not recognise that two lamps were already connected and so the answer 19 was also accepted.

(d) Most candidates showed some knowledge of an advantage of using a trip switch. The most common advantage was that a trip switch can be reused, unlike a fuse which has to be replaced. Other advantages seen were that a trip switch responds faster, is more sensitive or can be seen to have tripped unlike a fuse which cannot easily be seen to have blown.

Question 7

(a) Many candidates responded correctly to this question indicating that the split ring commutator reverses the current in the coil every 180° or when the coil is vertical, and that the brushes connect the coil to the battery, provide current to the coil or avoid the wires becoming tangled. However, there were some errors, e.g. 'the coil reverses in direction every half turn'. The simple action of the brushes was given in most answers but candidates needed to give more detail. Rather than just writing 'to complete the circuit' it was better to say 'to connect the battery to the commutator' or 'to pass current to the coil'.

(b) Candidates were required to state the direction of the magnetic field and to explain how they determined this direction for the simple d.c. motor. Most candidates displayed a good understanding. However, others attempting the question using the left-hand rule were unable to match each of the relevant three digits of the left hand correctly with the directions for force, field and current. The strongest candidates gave a convincing account of the direction of the current, usually on the left-side of the coil as being from positive to negative or along the left-side of the coil towards the commutator. In general, many candidates could give a sensible account but weaker candidates sometimes knew the rule but could not link the fingers with the correct quantities. A few candidates used the right-hand grip rule and could not arrive at the expected answer.

(c) Many candidates did not realise that the two changes cancel each other to leave the rotation unchanged and many candidates incorrectly suggested that 'the motion is reversed' or sometimes that 'the coil stops altogether'.

(d) (i) The majority of candidates were able to calculate the moment of a force but a large number did not realise that the two moments must be added. A small minority of answers suggested that the moment of the two forces cancels to give a zero resultant or attempted to write a moments equation in some form e.g. $2.3 \times 0.15 = 2.3 \times X$, rather than calculating the moment directly. The correct SI unit for moment was often seen, but a significant number of units were written as N/m or Pa rather than Nm.

(ii) This question required candidates to explain why the turning effect becomes smaller as the coil becomes more vertical. Only stronger candidates answered this question correctly, linking their responses to the decrease in the perpendicular distance between line of action of the forces. The motor was often confused with the generator leading to many references to ‘cutting field lines’ or ‘change in flux’. Many answers also suggested that the current in the side of the coil becomes parallel to the magnetic field when the coil is vertical, whereas it is perpendicular to the field. Stronger candidates realised that the idea of moments was relevant to the answer and suggested the perpendicular distance decreases. A few answers correctly mentioned that the coil is in a weaker magnetic field as it becomes more vertical.

Question 8

(a) In this question, candidates were required to state the purpose of the concrete shielding, control rods, and moderator in a nuclear reactor. Many candidates showed a good knowledge by using some of the expected responses which included that concrete shielding absorbs radiation or protects workers or stops escape of radiation, while control rods absorb neutrons, and the moderator slows down the neutrons. However, some candidates found this question challenging and suggested the shielding was to hold the uranium in, act as an insulator to keep the heat in, control the temperature or to speed up the reaction. Candidates needed to recognise that neutrons are absorbed by the control rods so that the reaction can be reduced or enhanced and that the moderator reduces the speed of the neutrons so that they are more effective in causing the fission of nuclei.

(b) There were many very good answers explaining the fission process with the majority of candidates mentioning that fission involves the splitting of a nucleus. Stronger answers mentioned that this was caused by the absorption of a neutron and that it results in the formation not only of daughter nuclei but also of other neutrons. One common misunderstanding was that the neutrons produced went on to cause fission of the daughter nuclei rather than fission of other urnanium-235 nuclei. Candidates also needed to be clear that it is the nucleus that is involved in the fission process rather than the splitting of the whole atom or molecule.

(c) (i) Candidates showed a good understanding of the definition of specific heat capacity as the energy required for a rise in temperature of one degree but fewer answers also mentioned that it is the energy per unit mass for a rise of one degree, i.e. realising the difference between heat capacity and specific heat capacity.

(ii) Candidates needed to apply their knowledge of the specific heat capacity to a real-life situation in this question. Candidates were required to suggest and explain whether the coolant given in the question should have a large or a small specific heat capacity and many found this challenging. Some candidates were able to suggest reasons for a high specific heat capacity, e.g. causing a smaller or slower rise in temperature, or to suggest that the coolant should have a low specific heat capacity, e.g. causing a higher temperature rise or warming up faster and being able to transfer energy quicker when the reactor starts. Few candidates gave complete suggestions.

Question 9

(a) This question part was well attempted. The majority of candidates drew circular, or nearly circular, orbits for Mercury and Mars, but some needed to be more careful in labelling them correctly.

(b) This question was answered very well with sensible comments about the Sun blocking the view of the comet from Earth. Stronger answers even described the size of the Sun and the light emerging from it as dominating this part of space.

(c) (i) Gravitational force from the Sun was the most common answer. Candidates needed to ensure that they were giving the name of a force rather than a form of energy or a field. Centripetal force was a common answer but this force is perpendicular to the orbit at any position in the orbit which is not circular.

(ii) Most candidates responded correctly to this question and drew arrows from each point, 1 to 4, directly towards the Sun. However, some arrows were carelessly drawn with no possibility of them coming anywhere near the Sun. The arrow at position 4 was the worst drawn or omitted. Many candidates believed the direction of the force is along the direction of the orbit.

(iii) The strongest candidates clearly suggested that the force increases from position 1 until position 3 and then decreases to position 4. A little more detail was required from some candidates who only suggested that the force increases and then decreases but did not say where the maximum occurred. The reason for the change in the force on the comet was well understood but sometimes poorly expressed, e.g. "as the comet moves the force loses its strength". There was also an emphasis in many answers on energy transfers which was not helpful in a question on the strength of the force. It was also important to make it clear that the distance involved was the distance to the Sun.

(d) Candidates were required to calculate the number of orbits that Earth makes around the Sun in the time that Jupiter makes one orbit. They were provided with the orbital radius in km of the Earth and Jupiter with the orbital speed in km/s of the Earth and Jupiter respectively. There was good use made of the circumference of a circle in the formula for the speed of the orbit and stronger candidates started with a formula. It was common for the time for one or both planet's orbit to be calculated correctly but not the ratio between the two times to find the number of orbits.

PHYSICS

Paper 5054/31
Practical Test

There were too few candidates for a meaningful report to be produced.

PHYSICS

Paper 5054/32
Practical Test

Key messages

It is important that Supervisors send in a complete set of results for 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 length of a spring or the resistance of a component.

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 readings in a table, data should be recorded to a consistent number of significant figures or, when appropriate, a consistent number of decimal places. Units should be given if not already given on the answer line of the question paper.

Candidates are advised to show all working and to check all calculations and in particular measurements that appear to be unrealistically large or small.

The ability to produce a good line graph and to use it to calculate the gradient or interpolate or extrapolate points are valuable skills for candidates to develop.

For the planning question, candidates should ensure the experiment they describe actually answers the question set and should refer back to the question throughout their planning to focus on giving details addressing the bullet points.

General comments

Stronger candidates demonstrated that they were able to follow instructions carefully and closely and they performed the required tasks by making accurate observations and measurements and recording them to an appropriate number of significant figures. They were able to process their results by performing calculations and made judgements or drew relevant conclusions and wrote relevant evaluative comments.

Candidates should be reminded 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. Candidates should 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) 10's, 5's or 2's 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 is rarely suitable.

Comments on specific questions

Question 1

(a) The normal line was drawn well and the correct angle accurately measured in most cases.

(b) Most candidates drew crosses as instructed but they were usually far too close together. Crosses should be placed as far apart as possible within the space provided and not less than 3 cm apart. Crosses should be drawn with a pencil.

(c) Most lines specified were drawn but some candidates had difficulty connecting the specified points. Candidates should be reminded to draw rays using a pencil and a ruler and that all lines drawn should be thin so pencils should be sharpened to a point before use. There were many inaccurate values recorded for this question. Many of these were caused by inaccurate plotting of crosses or drawing rays. Most candidates recorded data to the nearest mm but some recorded values to an inappropriate number of decimal places.

(d) (i) This was credit for accuracy awarded here and so only values within a certain range were accepted. Candidates who drew accurate rays and measured lengths carefully gained this credit.

(ii) Candidates gained credit for dividing the correct pair of lengths and correctly rounding their answer. Some candidates truncated the numbers rather than rounding.

(e) Candidates were asked to determine whether the values obtained in **(d)** were within the limits of experimental accuracy. Candidates had to demonstrate whether the values were within 10 per cent of each other. The commonly seen correct methods of doing this were by:

- dividing the difference between the values by one of the values and converting to a percentage
- dividing one value by the other and converting to a percentage and then subtracting from 100
- working out 10 per cent of one value to determine the maximum and minimum value, i.e. the range.

Having obtained the percentage, candidates then needed to comment on whether or not this was less than 10 per cent or whether the second value lay in the acceptable range of the other. Common errors were dividing the difference by the mean value of measurements or working out a percentage (or range) but then not making a comparison or giving a supporting statement.

(f) Many candidates were able to explain that the rays of light produced were too thick to be able to place crosses accurately. Credit was given to candidates who explained that the ambient light levels made it difficult to clearly distinguish the rays on light on paper. A significant number of candidates made invalid references to the condition of the blocks, parallax error, the thickness of pencil lines or to careless measurement which was stated in the question.

Question 2

(a) (i) Most candidates correctly recorded the temperature to the nearest degree, but the nearest 0.5 degree was accepted. Weaker candidates gave 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. Most candidates recorded a sensible value of the potential difference to at least one decimal place. The acceptable ranges for all values of potential difference in this question allowed for candidates who were provided with a set up that did not use the thermistor specified in the Confidential Instructions.

(ii) Most candidates were able to record a sensible value. A common error was transposing the measurements in **(i)** and **(ii)**.

(b) (i) Most candidates gave a sensible value for the temperature of hot water, but some values recorded suggested that the water was not heated to the temperature specified in the Confidential Instructions.

(ii) Most candidates were able to record a sensible value.

(c) Most candidates correctly recorded the voltmeter reading using a consistent number of decimal places throughout.

(d) (i) Candidates who made a correct reference to the thermometer needing time to adjust to reach its maximum value gained credit here. Weaker, non-creditworthy responses made reference to the water needing time to reach a maximum value or waiting for the thermometer to reach a constant value.

(ii) Many candidates were able to gain credit for a reference to the water reaching a uniform temperature throughout. A commonly seen insufficient response was that the water needed to be mixed.

(e) Many candidates were able to perform the calculation correctly and state answers to an appropriate degree of precision. Common errors were recording values to one significant figure or using an incorrect value of voltage from the table.

(f) Many candidates used their data appropriately.

(g) Candidates should be reminded to show full substitutions in calculations.

Question 3

(a) (i) Most candidates read the lengths correctly and stated them to the nearest mm, but some readings appeared inverted. Some read from the ends of the loops rather than the ends of the spring itself or had springs that were placed at an inappropriate position against the ruler. Centres are reminded of the need to condition springs before use as described in the Confidential Instructions.

(ii) Only stronger candidates gained credit here for showing the set square with one edge along the rule and the other under the lower edge of the spring. Many incorrect responses placed the set square on the bench or rotated so that it was not perpendicular to the ruler and the spring.

(iii) The question specified that working should be shown but many candidates did not follow this instruction so did not gain the credit available.

(b) This question was answered well with a full set of readings present. Common errors in **(ii)** were having values of R_b that decreased rather than increased with load or stating values to an inconsistent number of decimal places.

(c) A graph of length against load should have been plotted and very few candidates incorrectly reversed the axes or plotted an incorrect variable such as R_b. Candidates should be reminded of the need to ensure data covers at least half of the available grid space in both the *x* and *y* directions. A common mistake which prevented the awarding of the credit for selecting an appropriate scale was using 3 small squares for 1 N, an example of 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 should not start from their first reading such as 2.7 leading to labels such as 2.7, 4.1 etc. Most candidates were able to correctly label the axes, but plotting was not always accurate. Candidates should be encouraged to use sharp pencils to draw small crosses for each point and not to use circled points or blobs where the points cover over half a square in either direction. 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.

(d) A significant minority of candidates calculated a gradient rather than reading the value for the length of the spring from the graph at 3.5 N using their line of best fit. Candidates who read off this value often forgot to subtract the initial length of the spring to determine the extension. A common error was attempting to use $F = kx$ despite being told to use the graph to determine the value.

(e) Only stronger candidates answered this well. Other candidates assumed that a straight line indicated direct proportionality or answered incorrectly because they had forced their line of best fit to go through the origin. Those who realised that it was not directly proportional because the correct line did not go through the origin explained it well and gained credit.

(f) Candidates were well prepared for this question and noted that the ruler should be viewed perpendicularly.

Question 4

Candidates were required to plan an experiment to determine the relationship between the density of a liquid and the average speed of a ball falling through the liquid. Most candidates who attempted the question were able to gain at least partial credit and few blank or irrelevant responses simply restating parts of the question were seen.

Marking point 1 was awarded if candidates mentioned the use of a metre rule and a stopwatch either in their plan or shown on a labelled diagram. Many weaker responses did not mention using a ruler and so incorrectly used the scale on the measuring cylinder in subsequent parts.

Marking point 2 was awarded for stating a correct method to determine the time and height of the fall to the bottom of the cylinder. Many candidates did not refer to measuring the height or distance, or as stated above used values of the volume on the measuring cylinder, so did not gain this credit. Some candidates mistakenly referred to the ball stopping midway down the cylinder or measuring the distance the ball falls in a specified time period.

Marking point 3 was awarded for making a correct reference to repeating the method for liquids of different densities and most candidates gained this credit. Some candidates did not read the question carefully and so spent time describing how to determine the densities of the different liquids which was unnecessary.

Marking point 4 was awarded for candidates referring to a relevant control variable. Candidates showed a good understanding of control variables and there were many correct alternatives for this point.

Marking point 5 was awarded for a suitable table with units. Candidates should be reminded that the table needs to have columns for each of the quantities measured with correct units. Stronger candidates were more likely to gain this credit. Many overlooked one of the variables, usually time.

Marking point 6 was awarded for detailed explanation of *how* to reach a conclusion. Candidates who stated that a graph should be drawn for speed against density were likely to gain 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 speed increases as the density 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 reminded to include units when quoting the values of physical quantities. They should be encouraged 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 take care and pay attention to detail when drawing or annotating diagrams. The accuracy of straight lines on diagrams is greatly improved by using a sharp pencil and a ruler.
- Candidates should be advised to avoid using set 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 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.
- Candidates should be advised to read the questions very carefully to ensure that they are answering the question as written.

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
- manipulation of data
- 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.

Many candidates showed a good understanding of physics, but some had difficulty in describing practical techniques. Most candidates attempted all questions and there was no evidence of candidates having insufficient time. Stronger candidates were able to follow instructions, record observations clearly and perform calculations accurately. However, some candidates were unable to round their numerical answers correctly or to give an answer to a sensible number of significant figures. The standard of graph drawing was not always strong.

Comments of specific questions

Question 1

(a) (i) Candidates were asked to take readings from a voltmeter and from an ammeter. This was answered well with most candidates gaining at least partial credit and stronger candidates gaining full credit.

(ii) Candidates were asked why the switch in the circuit should be opened between readings. Few candidates gave a correct response; to prevent the overheating of the wires or to prevent the cell from running down.

(iii) The majority of candidates used the equation given correctly to find the resistance of the lamp, but some did not give their answer to 2 significant figures.

(b) (i) Most candidates drew a correct circuit here, adding in a fixed resistor in series and a voltmeter connected across both the lamp and resistor. A few candidates gave incorrect circuit symbols or did not place the voltmeter in the correct position.

(ii) This was usually answered well with just a few candidates making mistakes in the calculation.

(iii) This was also answered well

(iv) This question was only answered well by stronger candidates who understood that the brightness of the lamp would be reduced. Few candidates related this to the increased resistance in the circuit.

Question 2

All parts of this question proved challenging for most candidates. Candidates struggled to use a protractor correctly and frequently measured the angles from the wrong point. There were many incorrect diagrams. Stronger candidates were able to follow the instructions given and gained credit for most parts of the question. Many weaker candidates left parts of the question unanswered and gained little credit overall. Candidates should be reminded of the importance of reading questions carefully and following instructions given.

Question 3

(a) (i) Nearly all candidates could read the time on the stopwatch correctly.

(ii) This question was often answered well but weaker candidates did not give their average to the nearest 0.1 s and so could not gain credit.

(iii) Most candidates used the equation given and gained partial credit, but some candidates incorrectly rounded their answers. The unit was usually correctly given.

(b) This was usually answered well. Candidates were able to insert the correct quantities and units in the headings of the table. Averages were mostly correctly calculated, and most candidates ordered their answers well to a sensible number of significant figures.

(c) Few candidates gained full credit for their graph. Candidates were given an A4 space to produce their graph on and had to work out a suitable scale. They found this difficult and very few scored all the available credit. Scales should be in logical multiples and candidates should be reminded not to use scales which go up in multiples of 3 or 7. Most scales did not use a suitable width or height of the graph paper. Weaker candidates used the data points along the axes. Candidates would benefit from practice in drawing a smooth curve.

(d) Few candidates could give a sensible reason why it would not be practical to measure times for a volume of less than 50 cm^3. The strongest candidates realised that the time would have been much longer or the pressure of the water in the can would be too small for enough water to be collected in the measuring cylinder.

(e) Candidates were expected to draw a curved line below the line of their graph, but this was rarely seen. Many candidates did not give an answer to this question.

Question 4

Candidates were asked to describe an experiment to see how the height from which a ball was dropped affected the percentage of GPE lost in the bounce. Only stronger candidates gained full credit on this question, and some candidates did not give any answer at all.

Initial credit was given for measuring dropping the ball from a known height and measuring the rebound height. Further credit was awarded for naming the additional equipment required. Calculation of the GPE would require the mass of the ball to be known and this meant that a balance was needed. Candidates needed to recognise that the experiment should be repeated for different drop heights. Few candidates covered all of these points. However, most candidates gained credit for suggesting a variable which needed to be controlled.

The results table needed to show at least two columns, one for the drop height and one for the rebound height. Both column headings should also have had the units. It is important that results tables have the quantities that are being measured.

Finally, a description of *how* the results could be used to draw a conclusion was required. It was not expected that candidates say what that conclusion would be as they did not carry out the experiment. Candidates were expected to say that they needed to compare the results in the table or give the details of suitable graph to plot, stating which variable goes on each axis. The simple statement ‘plot a graph of the data’ was not sufficient. The variables plotted needed to match the investigation, so in this case a graph showing percentage change of GPE lost (on the y-axis) against the drop height (on the x-axis) was required.

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 encouraged 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 take care and pay attention to detail when drawing or annotating diagrams. The accuracy of straight lines on diagrams is greatly improved by using a sharp pencil and a ruler.
- Candidates should be advised to avoid using set 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 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.
- Candidates should be advised to read the questions very carefully to ensure that they are answering the question as written.

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
- manipulation of data
- 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.

Candidates need to have experience of practical work during the course, including reflection and discussion on the precautions taken to improve reliability and control of variables. Candidates 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.

Numerical answers should be expressed clearly, to the appropriate number of significant figures and with a correct unit, where applicable.

Only a very small number of candidates did not attempt all sections of each of the questions. 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 and ideas were expressed logically.

Comments on specific questions

Question 1

(a) The normal to the block at point R was usually drawn correctly, but many candidates did not extend the normal 6 cm above side AD and below side BC, as instructed. The angle θ between SR and the normal was usually measured correctly to be 30°. An accuracy tolerance of ± 1° was allowed. Some candidates were unsure of how to read the scale of the protractor, and it was not uncommon to see answers of 60° and 150°.

(b) The majority of candidates followed the instructions correctly and drew lines EF and ER in the correct positions.

(c) Although many candidates measured the distances *a* and *b* correctly to ± 0.1 cm, the tolerance allowed, some measurement was not careful enough.

(d) Again, some of the measurements of the length *c* of the line EG were not precise enough.

(e) Candidates were asked to use the results they had collected in **(c)** and **(d)** to calculate two values n_1 and n_2 for the refractive index of the transparent block. Most candidates gave values of the refractive index to an appropriate number of significant figures, but answers were often incorrectly rounded and could not be credited.

(f) Candidates were asked to state whether their values of n_1 and n_2 in **(e)** could be considered to be equal within the limits of experimental accuracy, having been told that this is true if their values are within 10 per cent of each other. Many candidates answered this well. The easiest way to show this was to calculate the ratio of the smaller of the two values to the larger. If the value obtained was 0.9 (90 per cent) or greater, then the quantities could be considered to be equal. Another equally acceptable method was to calculate the ratio of the difference between the two values to either of these values. If the answer obtained was 0.1 (10 per cent) or less, them the quantities could be considered to be equal. Other acceptable methods of doing this were also seen and credited. If both values of *n* recorded by candidates were equal, it was sufficient to state just that to obtain full credit.

(g) Only stronger candidates were able to suggest a relevant source of inaccuracy in the experiment. Most candidates referred to optical pins, the difficulty of aligning these, and of ensuring that the pins were vertical. This did not answer the question set because in this question it was not pins that were used, but a ray of light from a ray-box. Candidates who were successful here referred to the thickness of the light rays and the difficulty of placing crosses on them accurately to locate their direction.

Question 2

(a) The scale reading of the thermometer was recorded correctly by almost all candidates. When the reading was incorrect, 20.1 °C or 39 °C were usually recorded.

(b) The scale reading of the voltmeter was usually recorded correctly as 3.1 V. The circuit in **Fig. 2.1** was almost always redrawn correctly, with the voltmeter connected in parallel with the 220 Ω resistor. Where lines were drawn through the voltmeter symbol, credit could not be awarded

(c) Few candidates understood why the student waited for 30 s before reading the initial temperature of the water. Many candidates reworded the question or made a vague statement that it would improve accuracy without saying how it would improve accuracy in this case. Here, candidates needed to indicate that the student waited for the temperature reading on the thermometer to stop increasing or allowed the temperature to reach its maximum value. Most candidates understood that the importance of stirring the hot water before taking its temperature is to ensure that the water is at a uniform temperature.

(d) Candidates were required to examine the data in **Table 2.1** and explain why the potential difference across the thermistor decreased when the thermistor was placed in hot water. Only stronger candidates stated that this was because the resistance of the thermistor had decreased. A commonly-seen incorrect answer was that the resistance had decreased. This was not credited because the thermistor was connected in series with a resistor. Candidates were required to state in which of the two circuit components the resistance had decreased.

(e) The current in the circuit was usually calculated correctly, using the equation supplied and the relevant values from **Table 2.1**. Candidates should be advised to round their answers and give them to the same number of significant figures as the data is given. A significant minority of candidates rounded their answers to only 1 significant figure, which was not credited .

(f) The resistance of the thermistor at room temperature and at the temperature of the hot water was usually calculated correctly, using the relevant values from **Table 2.1** and the equation supplied.

(g) The average change in the resistance of the thermistor per degree Celsius was usually calculated correctly. However, many candidates did not follow the instruction to give the answer to 2 significant figures, and obtained only partial credit for this question.

Question 3

(a) Candidates were required to take readings from a diagram to determine the positions of the top and bottom of the coiled part of a spring. This exercise required careful reading of the ruler scale on the diagram, preferably by drawing straight lines across from the spring to find the exact readings on the ruler. Many candidates took approximate readings by eye. The position of the top of the spring was very often written as 39 cm instead of 39.0 cm. Candidates were then required to draw on the diagram to show how a set square could be used to take a reading on the metre rule level with the bottom of the spring. Many candidates represented the set-square as a square or rectangle and not as a right-angled triangle. The set-square drawn often did not span the gap between the metre rule and the spring.

(b) The majority of candidates calculated the length l of the coiled part of the spring correctly by subtracting the readings they obtained in **(a)**. The length l of the spring when a load L = 1.0 N was placed on it was almost always calculated correctly.

(c) Graph-plotting skills were of a reasonable standard, but many candidates gained only partial credit. The most common sources of error were:

- awkward scales, such as 3 or 7.
- missing labels and/or units on the axes, even though they were included in the table of results
- choosing scales so that the plotted points did not span at least half of the given grid
- not using linear scales
- poor choice of a best-fit line, often forced through the origin, when there was no data to indicate that this was not the case.

There were some excellent, carefully plotted and drawn best-fit lines produced.

(d) The majority of candidates used their graph to determine the length of the spring when a load of 3.5 N was added to the spring. Only a few of these candidates completed the calculation to determine the extension of the spring for this load by subtracting the unstretched length of the spring from their answer.

(e) In the Mathematical Requirements section of the syllabus, it states that ‘candidates should be able to recognise direct proportionality from a graph’. Most candidates stated that their graphs showed that the stretched length l of the spring was proportional to the load L, despite the fact that there was an intercept on the l– axis.

Candidates should be aware that a straight-line graph between two physical quantities is not sufficient to conclude direct proportionality. Two quantities are only directly proportional if the straight line passes through the origin. Another test for direct proportionality is that the ratio of the two quantities is constant. Stronger candidates used values of l and L from the table of results to show that this was not the case in this experiment.

(f) The majority of candidates were able to explain how to avoid line of sight (parallax) errors when taking readings from a metre rule.

(g) This more challenging final part of the question was only answered correctly by the strongest candidates. Most candidates incorrectly stated that repeating a procedure and averaging the readings makes the result more accurate or reliable. Repeating a procedure and averaging the results reduces the effect of random errors and improves the precision. It can also help to identify (and reject) anomalous results.

Question 4

There were some very good attempts at this question. Most candidates understood the instructions given and described a suitable method. The most comprehensive approach for candidates is to address each of the bullet points in the question in the order given.

Marking point 1 was awarded for identifying additional apparatus needed to do the experiment. Most candidates realised that a stopwatch/timer would be required to measure the time taken by the metal ball to fall from the surface of the liquid to the bottom of the measuring cylinder. Fewer mentioned that a ruler/measuring tape would be required to measure the distance the metal ball fell. Many candidates simply listed all the apparatus that they could see in the diagram in the question.

Marking points 2 and 3 were awarded for a brief description of how to do the experiment. Firstly, candidates needed to measure the height of the liquid, drop the ball and measure the time taken for the metal ball to travel from the top of the liquid to the bottom. Some answers did not state that the distance travelled by the ball also needed to be measured. Candidates needed to state that the procedure must be repeated for liquids of different density. Overall, there were many detailed, well-written accounts of how to take the required measurements.

Marking point 4 was awarded for stating a suitable control variable. The majority of candidates gained credit here. Stronger candidates stated that the mass of the ball should be kept constant. Fewer noted that the height/volume of the liquid should be kept constant.

Marking point 5 was awarded for drawing a results table to show how the measurements made would be recorded. Tables were usually well set out with appropriate headings and units given. Candidates should be advised that the results table headings must contain the physical quantities that need to be actually measured during the experiment. In this particular case, the only quantities that needed to be measured were the time taken to fall through a liquid of known density and the distance fallen. The average speed of the ball could then be calculated from the time, together with the distance fallen by the ball. Candidates were not penalised for having extra columns in their tables, as long as columns for the quantities that need to be measured were present.

Marking point 6 was awarded for stating *how* to process the results to draw a conclusion. There were some strong answers, but many candidates made predictions rather than simply describing how the results are used. Sometimes candidates attempted to back predictions with relevant theory.

In general, if the investigation is likely to produce a line graph, then this is one of the more straightforward ways of gaining credit for this marking point, provided that the axes are correctly specified. In this case proposing to plot a graph of density against the average speed gained credit.