PHYSICS

Paper 5054/11
Multiple Choice 11

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

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

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

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

General comments

Candidates need to be sure that definitions and quantities referred to in the syllabus are well understood.

Candidates need to be sure that they are answering the question that is asked rather than a similar one which they have seen in a past paper, for example. Questions need to be read carefully and, especially in the more discursive questions, all the options need to be considered.

Questions 24, **31** and **39** were answered well.

Comments on specific questions

Question 5

This question was quite well answered with more most candidates supplying the correct option. The most commonly selected incorrect option was **D** which suggested that doubling the weight of the load attached to the spring doubles its length rather than doubling its extension.

Question 6

Although many candidates knew the expression *force times perpendicular distance times the perpendicular distance from the pivot* only a few candidates applied the term to an appropriate distance. In this question most candidates selected option **C** or option **D**. It seems likely that the significance of the term 'perpendicular distance' was not always fully understood.

Question 7

A straightforward approach to this question was to take moments about the 100 cm mark but it was also possible to answer it in two stages and to calculate *F* as an intermediate stage. Candidates selecting the incorrect option B used the distance between two forces in the calculation of a moment rather than the distance between each force and the pivot.

Question 14

The correct option, **B** was most commonly selected. The other options were chosen by candidates who either doubled or halved only the excess pressure of the gas. Candidates needed to consider that the excess pressure is not the actual pressure of the gas but merely the pressure measured relative to the atmospheric pressure.

Question 17

Many candidates realised that all three factors listed affect the rate at which thermal radiation is emitted and this question was well answered. The most popular incorrect choice was option **D** which suggested that the temperature of an object does not affect this rate.

Question 20

This question was quite well answered. The laws of reflection are often dealt with before refraction is encountered and is therefore usually only considered in terms of reflection from mirrors. The laws of reflection do apply to all types of reflection. Options **B** and **D** were chosen by some candidates but these were both incorrect.

Question 25

Only a minority of candidates selected either option **A** or **B** and so most candidates realised that the diode was preventing the current and that something needed to be reversed. However, reversing the connections to the lamp as suggested by option **D** would still have left the battery attempting to produce a backward current in the diode. Even so, option **D** proved popular with weaker candidates.

Question 30

This question, which tested an understanding of Lenz's law, proved to be quite challenging for most candidates. The frequencies with which the four options were selected were very similar and only a minority chose the correct option, **A**. The essential point being assessed was that the behaviour of the solenoid opposes the change and so as the magnet moves downwards and leaves the bottom of the solenoid, it is attracted upwards.

Question 33

The two terms *slip ring* and *split ring* can easily be confused and there is in general no real alternative to learning the difference and learning that the split ring is used with a d.c. device. In this question the fact that the diagram shows the commutator split into two is a help.

Question 34

This question was quite well answered and almost all candidates selected an option where the rod was made of iron. However, some of these candidates suggested that the transformer would operate with a d.c. power supply.

Question 37

Most candidates were able to deduce the correct deflection in the electric field which suggest that the negative charge of the b-particle was widely known. However, a few candidates selected the option that showed no deflection in either field. The behaviour of the b-particle in the magnetic field is harder to deduce and requires the application of an appropriate rule and the relationship between the motion of a negative particle and the conventional current.

PHYSICS

Paper 5054/12
Multiple Choice 12

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

General comments

Candidates need to be sure that definitions and quantities referred to in the syllabus are well understood.

Candidates need to be sure that they are answering the question that is asked rather than a similar one which they have seen in a past paper, for example. Questions need to be read carefully and, especially in the more discursive questions, all the options need to be considered.

Comments on specific questions

Question 2

In this question, the gradient of the distance–time graph shows that the speed of the car is constant and greater than zero and it follows therefore that its kinetic energy is constant and greater than zero. Only a small number of candidates selected the correct option, with more selecting option **A**. The acceleration of the car is, of course, constant but it is equal to zero as the car is travelling at constant speed.

Question 5

The question asked for the resultant force and although there is no specific reference to a resistive force, the fact that the downward speed of the submarine is constant reveals that there must be a resistive force. The crucial word was 'resultant' and the resultant force is 0. Option **D** was very commonly selected by weaker candidates.

Question 6

The situation here concerned a falling ball that will reach terminal velocity provided the distance fallen is large enough. Almost all candidates selected an option that referred to the velocity increasing during the first few seconds after release. However, as the velocity increases, so does the air resistance and so the acceleration decreases. The initial increase in the acceleration as it is released could be ignored as the question referred to what happens after the ball is released.

Question 10

The expression for impulse given in symbols in the syllabus was here asked for in words. This expression is, equivalent to $F = ma$ and could be deduced even if it had not been learned. Incorrect option **A** was frequently selected.

Question 11

Many candidates deduced that the resultant force on the box was 4.5 N. This could be obtained fairly directly by using the method suggested in the question. However, some candidates then subtracted the resistive force from this value rather than adding it on and this gave the incorrect option **B**.

Question 15

The correct answer was obtained by dividing the energy transferred by the power of the motor and then converting the answer in seconds to minutes. The incorrect option **A** was chosen more often than the correct answer, **D**. Very few candidates chose either of the other options.

Question 20

Few candidates selected the correct option here. A large proportion of candidates gave an answer that suggested that the average kinetic energy of the liquid particles in the boiling liquid increases. As the liquid is boiling, its temperature does not change and since temperature is dependent on the average kinetic energy of the particles that does not change either.

Question 31

The question assessed the distinction between electrostatic charging and magnetisation which are two phenomena that are sometimes confused Option **C** was selected almost as frequently as the correct option, **B**.

Question 34

There are essentially two main stages to this question. The first stage is a deduction of the ratio of the resistances of the two combinations and this, in the second stage, leads to the ratio of the currents. Weaker candidates mainly selected option **B** or **C**.

Question 37

This question assessed knowledge of the sign of the charge on the three particles referred to. The force is determined by the direction of the current that the movement of the particles are equivalent to and by the direction of the magnetic field. Therefore the force is only in the same direction as the force on the wire if the motion of the particles constitutes a current in the same direction as their motion. In short, the question was asking for the particles which have a positive charge and this was only the alpha particles.

Question 38

A number of candidates misinterpreted how the change in speed affected the number of oscillations shown and selected option **A**. The other two options indicated a confusion of the time-base with the Y-gain and only a small number of candidates selected either of these.

Question 39

A common error was the assumption that the 70 µg is the mass of the isotope remaining after 7.5 s has elapsed. It is, in fact, the mass of the isotope that has decayed.

Another error that was commonly made was the deduction that four half-lives were involved.

Each of the four options was chosen by a significant number of candidates.

PHYSICS

Paper 5054/21
Theory 21

Key messages

- Candidates should always give units, if required, when giving the final answer to numerical questions. They should also be encouraged to give answers to an appropriate number of significant figures (usually at least two), and for this reason, fractions are not accepted.
- A carefully drawn diagram can often show what candidates intend to convey much more accurately than just words. Whenever a diagram is asked for or suggested, it is usually worth drawing it carefully and neatly and then labelling it, so that its intention is clear.
- The number of marks shown and the amount of space provided for each part question gives a guide to the length of the answer required. Candidates who exceed the space provided may be wasting time giving unnecessary or irrelevant detail.

General comments

The majority of questions were accessible to all candidates. Most candidates were able to quote a relevant formula, either in words or symbols and substitute correctly into it. Occasionally candidates who had performed a correct calculation did not give the relevant unit or gave an incorrect unit when the unit was not specified on the answer line. Calculations were generally performed well.

Comments on specific questions

Question 1

(a) (i) Most candidates knew that the pressure of the air on the inside walls of the rocket was due to moving particles of air colliding with the walls. Only a few candidates continued and explained that it was the force of these collisions on the area of the rocket walls that created the pressure.

(ii) Only stronger candidates were able to explain why increasing the number of air particles inside the rocket would increase the pressure of the air inside the rocket. Most candidates realised that there would be more collisions between the air particles and the rocket wall. Few went further to attribute the increase of pressure to an increase in the rate of collision of the air particles with the walls.

(b) This question was challenging for all candidates. The principle of conservation of momentum was not well understood. An answer such as that the increase of (downward) momentum of the water is equal to the increase in (upward) momentum of the water gained full credit. Even a realisation that there was a (downward) force on the water and an (upward) force on the rocket gained partial credit. Newton's Third Law of motion was rarely mentioned.

(c) Many candidates were able to give at least one valid reason as to why the acceleration of the rocket changed, as water was expelled from it. Many candidates realised that the mass of the rocket would change, and also that the pressure of the air inside the rocket would change.

Question 2

(a) The definition of the term 'acceleration' was known by the majority of candidates. Occasionally candidates confused this with speed or velocity, and defined it as the rate of change of displacement/distance.

(b) (i) The statement of the equation that defines the term 'work' was challenging for many candidates. Most candidates stated that work = force × distance moved, but only a minority continued and stated that the distance moved was in the direction of the force.

(ii) Most candidates calculated the work done on the lorry by the driving force correctly. Occasionally because of the large numbers involved, there was a power of 10 error in the final answer.

(iii) The formula for kinetic energy was well known and most candidates were able to calculate the mass of the lorry. Occasionally, candidates who wrote down the correct equation forgot to square the velocity in their calculation.

Question 3

(a) Most candidates stated that as a liquid expanded, the particles moved further apart. Few candidates continued by explaining that to move apart, the particles needed to overcome the forces of attraction/weaken the bonds between them.

(b) (i) Only stronger candidates correctly stated that the process of energy transfer from the heater through the base of the kettle to the water inside it was due to conduction. The majority of candidates confused this with what was happening to the water inside the kettle, and stated convection.

(ii) The process of convection in the water was well known, and most candidates scored at least partial credit. Most candidates knew that the heated water rises and cold water sinks to establish a convection current. Few candidates stated that on heating, the density of the water decreased.

(iii) Almost all candidates were able to state that the boiling temperature of water at standard atmospheric pressure is 100 °C / 373 K.

(iv) The majority of candidates selected the correct equation to calculate the increase in the internal energy of the water, but not all candidates arrived at the correct answer. Most of these candidates did not substitute the increase of temperature of the water into their equation, but used the final temperature of the water (100 °C).

Question 4

(a) The equation $v = f\lambda$ was known and used by most candidates. The most common error was either due to the incorrect transposition of the formula to make wavelength the subject, or not coping with the manipulation of the large powers of ten in the mathematics.

(b) (i) Many candidates were able to correctly state what happens to the speed, frequency and wavelength of light as it passed from air into the glass block. The most common error was to state that the frequency of the light increased/decreased.

(ii) Most candidates were able to choose the correct equation and used the angles marked on the diagram to calculate the refractive index of the glass. Occasionally the unit ° or cm was included in the answer.

(c) Most candidates gained partial credit for completing the ray diagram showing the path of the ray of light until it strikes the bottom surface of the block. Fewer candidates went on to show the path of the light as it emerges into the air. The emergent ray from the parallel-sided glass block needed to be shown to be parallel to the incident ray.

Question 5

(a) (i) Most candidates named the correct three regions of the electromagnetic spectrum which accounted for most of energy emitted by the Sun. Of these candidates, some were able to correctly list the three regions in order of increasing frequency.

(ii) Most candidates were able to name one damaging effect of ultraviolet radiation on the human body. However, few of these candidates were able to name the property of ultraviolet radiation that caused the damage. The fact that ultraviolet radiation is ionising was rarely seen.

(b) Only stronger candidates gave a correct description of the difference between a transverse wave and a longitudinal wave. Few candidates linked the vibration direction to the direction of propagation of the wave. Answers needing more specific detail such as "in a transverse wave the particles move at right angles to the wave" were very common.

Question 6

(a) Only stronger candidates answered this question correctly and stated that both ammeter readings are the same because they are connected in series in the circuit.

(b) (i) Most candidates were able to calculate the total resistance of the circuit. However, not all then went on to calculate the resistance of the thermistor by subtracting the values of the two fixed resistors in the circuit from this total. The fact that the two 1.5V cells were connected in parallel confused some candidates. Many thought that the e.m.f. of the battery was 3.0V instead of 1.5V.

(ii) The majority of candidates thought that the resistance of the thermistor increased with increase of temperature and could go no further. Even those candidates who stated that the resistance of the thermistor decreased with increasing temperature, were unable to explain why the p.d. across the resistor decreased. Only a small number of totally correct explanations were seen.

Question 7

(a) (i) Few candidates were able to name the two labelled components of the simple a.c. generator correctly. Component P was a (carbon) brush and component Q was a slip ring. Where the names were correct, the labels were often reversed. Many incorrect labels such as split ring, commutator and magnet were also seen.

(ii) The purpose of the components P and Q was only explained correctly by stronger candidates who knew that the brush P connected the output terminals to the coil. Few candidates realised that the purpose of Q was to prevent the wires twisting/becoming tangled.

(b) (i) Many candidates were able to write a letter X on the given trace to indicate one point when the coil is vertical. However, the letter X was often not placed anywhere near the trace at all. There were 5 positions on the trace where the output e.m.f. was zero, and a letter X anywhere close to any one of these was awarded credit.

(ii) The answers to this question showed that the majority of candidates did not understand what was meant by the statement that the Y-gain of the oscilloscope is set to 5.0 V/cm. Many candidates who read the amplitude of the trace correctly did not continue and multiply their answers by 5 to calculate the maximum value of the e.m.f. generated.

(iii) Many candidates deduced that the wavelength of the trace was 4.0 cm, but few were able to go any further and use the timebase setting of 2.0 ms / cm to deduce that the time for one revolution of the coil was 8.0 ms.

(iv) Many candidates attempted to use the equation $f = 1/T$ and their answer to **(iii)** to deduce the frequency of the output of the generator and scored partial credit. The fact that T was in milliseconds was missed by almost all candidates and most answers were a factor of 10^3 out.

Question 8

(a) Most candidates correctly stated the difference between a neutral atom of U-235 and a neutral atom of U-238 in terms of the number of neutrons in the nucleus of these atoms.

(b) (i) Many candidates were able to explain what happens to the nucleus of an atom during fission. Other candidates confused fission with radioactive decay.

(ii) Few candidates knew the sequence of events explaining how fission can lead to a chain reaction in the reactor in a power station. The idea that fission neutrons are absorbed by other U-235 nuclei, which themselves split and release further neutrons, was rarely seen.

(iii) Only the strongest candidates gave a correct response stating the purpose of the moderator in the reactor.

(iv) In this question, stronger candidates stated correctly that the control rods slow down/stop the chain reaction.

Question 9

(a) Stronger candidates were able to calculate the orbital period of Venus about the Sun. The most common error was to divide the distance of Venus from the Sun by its orbital speed, instead of the circumference of the orbit of Venus by the orbital speed.

(b) Most candidates gave a correct explanation as to why speed is a scalar quantity.

(c) (i) Only stronger candidates were able to explain that the velocity of Venus as it orbits the Sun changes because its direction of motion is continually changing.

(ii) Most candidates knew that a resultant force needs to act on Venus as it orbits the Sun so that it can stay in a circular orbit/stop it moving off along a tangent.

(iii) Few candidates were able to add an arrow to the diagram, pointing in the correct direction, showing the resultant force on Venus. Most arrows were along a tangent to the orbit or away from the centre of the Sun, instead of towards it. In many cases, the arrow did not have an arrowhead, so the direction of the arrow was not indicated.

(iv) Candidates had to state both that Venus was in a gravitational field / effected by gravitational attraction **and** that the gravitational attraction / field was of 'the Sun' to be credited both marks.

(d) (i) Most candidates named the planet Mercury as the planet closer to the Sun than Venus. A common incorrect answer was the Earth.

(ii) Most candidates stated that the time for mercury to orbit the Sun would be less than that of Venus but were unable to continue to explain this. Only stronger candidates stated that the circumference of the orbit of Mercury is less, and its orbital speed is greater than that of Venus.

PHYSICS

Paper 5054/22
Theory

Key messages

Where candidates need to use a value for *g*, candidates are reminded that they should use the value for $9.8\ \text{m/s}^2$ for the acceleration of free fall on Earth specified on the front cover of the examination paper unless another value of *g* is specified in the question.

It is important for candidates to answer the question that is asked . Some candidates started to write an answer and then continued with what they had learnt and did not check their answer was fully focused on the question asked in the paper. This was especially the case in **Question 9** but there were other places where it occurred.

General comments

On a paper such as this, questions assess all the major learning objectives and a significant proportion of the less prominent ones. Candidates should ensure they are fully familiar with the syllabus in its entirety. Candidates need to ensure that essential facts are not only learnt and memorised but are also understood. This was highlighted in **Question 3** where some candidates quoted the definition of moment in terms of a perpendicular distance but did not identify which of the distances supplied in the question was the perpendicular one.

Various mathematical techniques are needed to answer questions in this paper and candidates were not always successful in rearranging an equation that is primarily known in one format so that another variable is the subject.

Candidates need to be proficient with the use of calculators. When numbers were expressed in standard form, sometimes the answer supplied included the correct significant figures with an incorrect exponent.

Comments on specific questions

Question 1

(a) This was answered well and many candidates were clear about the difference between a vector quantity and a scalar quantity.

(b) Most candidates were able to identify the two vector quantities in the list and identified their choice clearly. There were candidates who had correctly recalled the distinction asked for in **(a)** but were unable to apply it in this question. Temperature was quite commonly selected and momentum was often omitted.

(c) A few candidates omitted this question completely. Many other candidates answered it well and many candidates gained either partial or full credit. Candidates should have noticed that they were asked to show how the answer was obtained and candidates who used a calculator and simply wrote the correct answer down were not awarded full credit.

Question 2

(a) Some candidates were not fully familiar with the topic of momentum but this question, which was a straightforward calculation using the defining equation for momentum, was very often well answered. The numbers in the question were large and some candidates lost track of the figure displayed on the calculator and supplied too many or too few zeros.

(b) (i) This question proved more challenging and, although some candidates used a very clear approach and reached the correct final answer quite simply, there were other who were confused. One incorrect approach was to set the whole momentum of the spacecraft calculated in part **(a)** equal to the momentum of the rear part after the explosion.

(ii) Only stronger candidates answered this correctly. The use of the word 'fuel' was a clue to the source of the energy that was transferred.

(iii) The answer to this question could have been determined several ways.

Question 3

(a) (i) There were many good answers to this question but a small number of candidates misunderstood what was required and wrote about forces acting on the lamina that were neither its weight nor a force that acted downwards.

(ii) Many candidates were able to answer this question and calculated a correct value for the weight. A common error was to use the mass in grams rather than in kilograms. This led to an answer that was a thousand times too large. Even so, the working out sometimes allowed partial credit to be awarded.

(b) (i) Many candidates realised that a moment is calculated from a force and a distance but in determining the answer in this case, only a minority of candidates chose the correct distance. Three distances were given on the diagram and each was chosen by candidates with a similar frequency. Candidates using the incorrect distance could be awarded partial credit for the equation.

(ii) The answers to this question varied hugely, with some candidates describing the motion of the lamina both thoroughly and carefully. There were some candidates who described what would have happened if the lamina had been dropped rather than released.

Question 4

(a) (i) The answers given to this question varied widely. Many candidates used the correct equation to deduce the pressure due to the liquid but not all of these candidates then added on the atmospheric pressure.

(ii) Although there were some candidates who did not know what to do here, many others realised that the defining equation for pressure was involved. The form of the equation required here was $F = pA$ which comes from rearranging the equation that is given in the syllabus. The rearrangement was not always conducted successfully and the incorrect $F = p / A$ was often seen.

(b) (i) Many candidates gave answers that suggested that the inverted tube was empty and described the flow of the liquid into the tube. Only stronger candidates answered this correctly.

(ii) Only the strongest candidates were able to describe how the height of a liquid column may be used to determine the atmospheric pressure.

Question 5

(a) (i) This was not well answered. Only a small number of candidates could explain how evaporation causes cooling.

(ii) This question could be answered in terms of particles or by using a macroscopic explanation using the latent heat of vaporisation. The question referred to the energy needed and so an answer in terms of energy or of work done was required.

(b) Many candidates correctly stated two differences between evaporation and boiling. Some candidates gave more than two differences and in some cases this led to errors.

Question 6

(a) A small number of candidates defined wavelength or discussed amplitude. Most candidates gave answers that related to frequency and so gained some credit. However, many answers did not gain full credit as the statements relating to time were too vague. The answer should have referred to **unit** time or *per* unit time or to rate. Candidates need to know that phrases such as “in a certain time” or “in a given time” are not equivalent to references to unit time. Additionally, some candidates did not refer to the **division** by time that produces a rate. When candidates referred to, for example, the number of wavelengths over the time that passes, it was not always clear if ‘over’ was referring to a division or if it was being used in a more general sense. It is best to be precise when a division is being referred to.

(b) The command word on this part was ‘explain’ and so more than a statement about the audibility of the sound was needed. Most candidates were aware that this sound was audible, but a correct explanation was not always offered. Candidates who quoted the frequency range given in the syllabus very often gained credit but answers such as “up to 20 000 Hz” were not the same as “between 20 Hz and 20 000 Hz”.

(c) Candidates often referred to the vibration of the cone or to the production of compressions and rarefactions but there were few explanations of how this led to the production of sound that travelled in the air.

(d) This question was often answered well with many candidates stating that sound does not travel in a vacuum and that there is a vacuum between Earth and the Sun.

Question 7

(a) There were many candidates who did not give the correct symbol for a thermistor or who omitted this part completely.

(b) (i) This question was answered well with full credit very frequently awarded. Occasionally an incorrect expression such as $I = VR$ or $I = R/V$ was used.

(ii) This question was also well answered and again, many candidates scored full credit.

(c) In this question some candidates misremembered the effect of an increase in temperature on a thermistor. Those that recalled this effect correctly did not always use it in a carful explanation of the effect on the current. The mark allocation for this part gave an indication of the detail required in the answer.

Question 8

(a) Many candidates made reference to ‘iron or steel’ but only steel was correct as iron is used to make temporary magnets.

(i) Many candidates found this question challenging but were aware that electromagnetic induction is the cause of the current being produced. The question asked for an explanation and so the term ‘electromagnetic induction’ was required.

(ii) Some candidates showed an understanding of the application of the Lenz law but many others were not aware of what was happening or the requirements here. Answers that used an explanation that involved the attraction of the magnet and the solenoid were more common that the correct explanation.

(c) Many answers gained partial credit for a current that changed in size or a current that changed in direction but answers that described exactly what was happening were rarer. A reference to an alternating current would have been awarded full credit.

Question 9

(a) This question related to the part of a star’s life cycle between the original cloud of dust and gas and the formation of the protostar. There were some good answers and many candidates gained partial credit. Many candidates gave explanations that went far beyond the demands of the question and other candidates only gave explanations that referred to other parts of the stellar life cycle.

(b) (i) This question was a matter of factual recall and was often answered well.

(ii) This was challenging for the candidates with only a few commenting on the fact that an atom of hydrogen-3 contained fewer nucleons than an alpha particle.

(iii) Some candidates answered this correctly but most found it challenging. Balancing an equation for beta particle emission is harder than balancing an alpha-particle equation. The significance of the –1 subscript in the beta-particle symbol was not always understood.

(iv) There were a few good answers but there was also some confusion about the requirements in this question. Many candidates gave answers that involved various parts of the life cycle of stars and fully focussed answers were rare.

(c) The expected answer here was the 'supernova explosion stage' but the simple answer 'supernova' also gained the credit. Only a minority of candidates supplied this answer and some of those who did, also supplied other answers which in many cases were incorrect.

Question 10

(a) (i) The correct path was very commonly indicated and this question was answered well. Some of the gamma symbols were placed in ambiguous positions on the diagram and could not be credited.

(ii) The fact that the other radiation emitted was beta radiation was only occasionally given and an explanation in terms of an appropriate rule or observation was rarely seen.

(iii) Many candidates correctly stated what happened to one of the types of radiation but fewer candidates gave the correct behaviour for both types.

(b) This question was almost always approached in the correct way and full credit was often awarded. The manipulation of the difficult powers of ten in a division was a frequent source of error. Some candidates struggled to enter numbers in standard form into a calculator and answers that were incorrect power-of-ten multiples of the correct answer were very common.

PHYSICS

Paper 5054/31
Practical

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.

Measurements and final answers should be rounded to an appropriate number of significant figures with readings from analogue instruments such as ammeters and voltmeters recorded to the precision of the instrument being used. Units should be given if not already given on the answer line of the question paper.

Candidates are advised to check all their 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 find values for points along the graph are valuable skills for candidates to develop.

When candidates take a second set of readings and decided to amend the value they use, they should check through the whole question to find where the amendment must be followed through. Many otherwise good responses showed evidence that this did not happen.

For the planning question, candidates should ensure the experiment they describe will actually refer to the exact investigation featured in the question and then focus on giving details addressing the bullet points.

General comments

Stronger candidates demonstrated that they were able to read and understand the questions and performed the required tasks by following the instructions closely, making accurate, careful observations and measurements and recording them to the correct precision. They were able to construct tables of results with appropriate headings for each column, with the names of the quantities and their units given in the headers.

Attention is drawn to the advice on plotting graphs issued by Cambridge. Some responses to questions involving the plotting of graphs included impractical scales, which led candidates to make errors in plotting and interpreting their graphs.

The plotted points on graphs should be marked with small, fine and 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 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

Section A

Question 1

(a) This question required candidates to explain how to use a dropping pipette. The correct technique should have outlined the steps used and in the correct sequence.

(b) (i) A wave was created by letting a drop of water fall into the centre of a plate of still water. Repeat measurements were taken of the time taken for the wave to travel out to the rim of the plate and back. The average time was then calculated and should have been in the range of 0.75s to 1.25s.

(ii) The plate's diameter should have been measured accurately using a ruler (and should have been in the range of 20 – 25 cm as specified in the Confidential Instructions) and the speed of the wave calculated, remembering that the wave travelled from the centre to edge and back.

(c) (i) Candidates were asked to identify two sources of uncertainty, where errors in measurement could arise. This was an example of a situation where errors can occur even if the experiment is carried out carefully and with attention to good technique.

In this experiment, for example, it was difficult to place one droplet into the exact centre of the plate or to hold a ruler steadily over the plate. The wave travelled quickly, so it was difficult to time it accurately and, because times were short, there would be a large effect due to the reaction time error (i.e. a large percentage error due to reaction time). A source of error not due to measurement could have been that the plate may not have had a perfectly uniform base, so the depth of the water may have varied and this would affect the speed of travel of the wave.

(ii) Suggestions gaining credit included improvements to the experiment described to give more accurate measurement. Weaker candidates suggested a substantially different experiment.

Using a plate with a larger diameter, or one with uniform depth were accepted responses as the use of the larger plate would have reduced the effect of the reaction time error.

The use of technology such as video recording was also accepted, providing that details were given about how it would be used to create an improvement.

Question 2

(a) The potential difference was measured across a 10 Ohm resistor when five different lengths of the resistance wire were attached in series.

Candidates recorded the values obtained from the calculations in **Table 2.1**. Headers for the table should have been completed. In good responses, the symbol for the quantity and the unit were separated by an acceptable separator, such as a forward slash line or brackets around the unit symbol. The values for the current should have increased with decreasing length and the reciprocal of the current should have decreased with an increase of the voltage measurement. Columns of data for each quantity should have been recorded to a consistent number of decimal places down that particular column.

(b) (i) A graph of 1/current, I against length, *L* should have been plotted with $1/I$ on the y-axis. The graph should have started at the origin, as instructed. The scale used should have made best use of the grid but retained a convenient scale.

In stronger responses, points were plotted with an accuracy within half a small grid square.

(ii) Some weaker responses showed a poor placing of the best-fit straight line.

The best-fit line is rarely the straight line passing from the first plot to the last and may not necessarily pass through any of the plotted points but it should be the straight line for which most, if not all, the points lie closest to.

A point which is an anomaly and lies well out of the trend shown by the other plotted points should be ringed or annotated in some way, and then ignored when considering where to place the best straight line.

(iii) The gradient should have been calculated in the usual way. The strongest candidates drew a large gradient triangle with two points on the best-fit line separated by a distance of at least half the distance between the first and last plotted point. Weaker candidates calculated the gradient using co-ordinates from the table that did not lie on the line.

The intercept should have been taken from the point where the best straight line crossed the $x = 0$ axis. A very close estimate from a graph with a scale which meant that the intercept was just above the grid was accepted, but for other cases where the intercept could not be read from the best straight line, a correct calculation using data from the graph was accepted. Candidates should be aware that the intercept cannot be read directly from a graph using a false origin.

(c) The values for the gradient and intercept were substituted into the formula to calculate the resistance of the wire and stronger candidates obtained a value of between 9 and 17 Ohms.

Question 3

(a) (i) Stronger candidates recognised that the rule should be flat on the bench, with the adhesive putty used to prevent it slipping and the masses placed on their rims so that the flat faces are in contact with the glass ball and the curved rims touching the rule so that the flat faces are perpendicular to the scale of the rule when checked using the set square. Weaker candidates thought that the glass sphere should be stuck onto the adhesive putty and the rule placed on top or at the side.

(ii) The diameter recorded should have been very close to 15 mm (1.5 cm).

(b) (i) Stronger candidates obtained imprints with diameters slightly less than the diameter of the sphere. Other responses, with values larger than the diameter, indicated that some movement had taken place while the load was being placed or that the candidate had pressed the apparatus at some time.

(ii) The area of the circular imprint was calculated using the given formula and the measured diameter (in millimetres) of the imprint.

(c) (i) Due to an issue with this question, careful consideration was given to its treatment in the marking of this part and, in order to ensure that no candidates were disadvantaged, the mark for this part of the question has been awarded to all candidates. A careful examination of all scripts indicated that all candidates provided values of x and y to be used in later parts of the question.

In a similar manner to the method in **(b)(i)** an imprint was made on some modelling clay but this time the 3.0N load was attached near the end of the wooden strip and the distances x and y of the centre of the sphere and the centre of the load from the clamping point were measured to the nearest millimetre.

(ii) The force applied on the modelling clay, F_2, was calculated using the given formula and the candidate's measurement for length x and y from **(i)**.

(iii) The diameter and area of the imprint were calculated.

(d) (i) In stronger responses, the two values for the area of the imprints were used to calculate the constant k and then the two values for the force applied were used to calculate k to 2 or 3 sig figs.

(ii) Candidates were expected to compare their values of k and decide whether they could be considered equal to each other, based on the usual limit of 10 per cent experimental error. Stronger candidates supported their decision with calculations to show that the difference between the two values was either within or outside the limits of experimental error.

(e) Stronger candidates stated two substantially different variables to control in order to ensure similar values for the area of the imprint could be produced in another laboratory.

Question 4

Stronger candidates used the bullet points listed in the question to guide the detail that they included in their plans.

The question specified the planned experiment should investigate one variable affecting the bend angle. Candidates needed to decide on one important variable and stronger candidates restricted their response to discussing just that one variable.

Repetition of details given in the question, such as a copy of the diagram or a list of apparatus shown on the diagram, could not gain credit. Additional annotations made on the diagram given or on a copy of the diagram could be awarded credit if they presented extra, relevant information. Similarly, lists of apparatus additional to that shown in the diagram or mentioned in the question could be given credit.

Some responses included long paragraphs about safety precautions but safety details were not asked for in this question.

The method for the experiment should have involved either measuring the bend angle when various weights were suspended from the centre of the metal strip and keeping the distance between the supports constant, or measuring the bend angle when the distance between the supports was changed and the suspended weight kept constant.

Marking point 2 was awarded if the response mentioned either that the separation between the supports, D, was changed and the bend angle measured for each value of D, or the weight suspended from the strip, W, was varied and the bend angle measured for each value of W.

Marking point 3 was awarded when it was shown that more than two different values of the chosen variable were used.

Ideally five or more different sets of data should have been collected so that there would be enough points to plot a graph.

Marking point 5 was awarded for a table drawn with columns and their headers for the selected variable, D (distance or separation) or W (weight or load) and the bend angle θ. The headers in the table needed to include appropriate units. Many candidates omitted at least one unit from the header.

Marking point 6 was awarded for stating **how** a conclusion to the experiment could be made.

The strongest responses described how a graph of the chosen variable against the bend angle could be plotted and the line produced used to decide the relationship between the two quantities.

Weaker responses were predictions of the relationship that would be found between the two variables investigated instead of being descriptions of **how** to find the relationship between the two variables.

PHYSICS

Paper 5054/32
Practical

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.

Measurements and final answers should be rounded to an appropriate number of significant figures with readings from analogue instruments such as ammeters and voltmeters recorded to the precision of the instrument being used. Units should be given if not already given on the answer line of the question paper.

Candidates are advised to check all their 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 find values for points along the graph are valuable skills for candidates to develop.

When candidates take a second set of readings and decided to amend the value they use, they should check through the whole question to find where the amendment must be followed through. Many otherwise good responses showed evidence that this did not happen.

For the planning question, candidates should ensure the experiment they describe will actually refer to the exact investigation featured in the question and then focus on giving details addressing the bullet points.

General comments

Stronger candidates demonstrated that they were able to read and understand the questions and performed the required tasks by following the instructions closely, making accurate, careful observations and measurements and recording them to the correct precision. They were able to construct tables of results with appropriate headings for each column, with the names of the quantities and their units given in the headers.

Attention is drawn to the advice on plotting graphs issued by Cambridge. Some responses to questions involving the plotting of graphs included impractical scales, which led candidates to make errors in plotting and interpreting their graphs.

The plotted points on graphs should be marked with small, fine and 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 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) (i) The length of the unstretched spring was recorded. There is some variation in the length of the springs supplied by centres, so a sensible value between 1.0 and 10.0 cm measured to the nearest 0.1 cm was accepted for credit.

(ii) The stretched length and the correctly calculated extension should have been written in the correct places.

(iii) The spring constant was calculated using the formula provided. A few candidates noticed that the unit for the spring constant was N/m but the measurements of the lengths were in centimetres and then converted the value for their extension into metres before substituting it. The formula provided already had the conversion incorporated into it and an the additional conversion produced an incorrect value for the constant. However, the mark was awarded in these cases for the correct substitution (of the incorrect value for the extension) into the equation.

(iv) The strongest candidates stated that parallax errors are avoided by ensuring that the readings on the scale of the rule are viewed perpendicularly. Some weaker candidates stated that the scale readings should be taken from eye level and gained credit.

In general, candidates should be encouraged to use a more precise response which refers to the scale reading being viewed perpendicularly or at right angles to it. Vaguer statements such as “viewing in parallel with” or “viewing in line with” were not accepted. A few responses did not answer the question and referred to methods for avoiding other errors.

(b) (i) The spring constant was determined using a different method, based on timing oscillations of the mass suspended from the spring. The time for 20 oscillations should have been about 14 seconds. The second measurement should have been within 1 second of the first time and both times should have been recorded to at least one decimal place. There were many good responses. Some weaker responses showed that half oscillations had been counted and some candidates appeared to have misread the stopwatch.

(ii) The mean time of the two measurements for twenty oscillations, *t*, should have been correctly calculated and written in the space in the table.

(iii) Candidates were then asked to calculate the mean period T of the oscillation and then T^2, the square of the mean period for one oscillation. Stronger candidates divided the mean time by 20 to find T and then found the square of that value. Some weaker candidates multiplied the value of T by 2 instead of finding its square.

(iv) For the final part of **(b),** a formula was used to calculate the spring constant. This was treated as a check on the overall quality of practical work, reflecting correct timing measurements and calculations. Stronger candidates gave values of 20 – 25 N/m.

(c) Stronger candidates explained that the reaction time error for a single oscillation is reduced when the time for 20 oscillations is measured and the time for a single oscillation obtained from this measurement. Weaker candidates who referred only to human error or that a single oscillations is ‘just too fast’ were not awarded credit.

Question 2

(a) (i) The thermometer was placed in the upper region of the hot water and left for 30 seconds and then the measured temperature was recorded in the table to the nearest 0.5 degree. Some weaker candidates wrote the value to the nearest whole number or to more than one decimal place.

(ii) After waiting 3 minutes, the temperature was measured again and the new value, which should have been lower, was written in the table in the space underneath the space for the first reading. All the temperatures should have been written to the same level of precision. There were many accurate responses. Some candidates obtained results showing the second temperature to be higher than the first, possibly because they had not waited long enough before taking the first reading.

(iii) The strongest candidates explained that the 30 second delay was to allow the liquid in the thermometer to reach its maximum value. Weaker candidates stated that the temperature reading should become constant and were not awarded credit as the thermometer was in water that was actually cooling.

(b) The temperature change within a fresh supply of water was again measured but this time the thermometer should have been placed much lower in the liquid. The two temperature measurements should have been written in the right-hand column of the table.

(c) (i) The rate should have been given to more than one significant figure and the correct appropriate unit written beside the value. The cooling rate could have been calculated in °C / minute or °C / second. Some candidates gave their answer as a fraction and were not awarded credit.

(ii) The cooling rates were calculated for the lower part of the liquid using the second column of results. The rate should have been given to more than one significant figure and the correct appropriate unit written beside the value. The cooling rate could have been calculated in °C / minute or °C / second.

(d) (i) Stronger candidates used their different cooling rates to explain that thorough stirring would result in the cooling rate being exactly the same throughout the hot water or that the temperature would have been exactly the same throughout the water. Some candidates referred to the movement of heat molecules and could not be awarded credit.

(ii) Candidates were given credit for noting that the arrangement held the thermometer steady at one point in the liquid or that the thermometer was held so that the scale was outwards and visible or that the thermometer was clamped so that the scale was not obscured. There were few correct responses to this part question.

(e) Stronger candidates named just one variable to remain constant and the majority of these candidates correctly stated the room temperature or the volume of the water used. Weaker candidates gave vague answers such as the time, similar beaker, the beaker, or the temperature.

Question 3

(a) Accurate responses had a positive value close to 3.5 V (1.5 to 3.5 V were allowed) written to at least one decimal place. The majority of responses gained credit here.

(b) The voltage should have been a positive value lower than the measurement in **(a)**and the current should have been recorded to at least 2 decimal places.

(c) The readings from **(b)** should have been entered into the table, and four further sets of measurements taken and recorded. The headers at the top of each column should have been completed with the units and a forward slash or a pair of brackets written as a separator between the quantity and the unit. Values in each column should have been written to consistent numbers of decimal places.

(d) A graph of V (y-axis) against I (x-axis) should have been plotted and the instruction to start both axes from the origin should have been followed. Candidates' measurements often meant that starting from zero resulted in a graph occupying less than half the grid; the origin was necessary for a later question asking for the y-axis intercept (when $x = 0$) and so candidates were not expected to produce graphs occupying more than half the grid in this case. There were many good responses where candidates were awarded credit for the demonstration of the plotting skills outlined in an earlier section of this report.

(e) (i) Stronger candidates drew a large gradient triangle and used it to obtain two sets of coordinates for calculating the gradient. Two distinct marks on the best-fit straight line, identifying the exact ends of the hypotenuse of the gradient triangle**,** were sufficient to gain credit, but the presence of a triangle made it clear to the examiner that these were the points being used. In many responses, the selected points were not far enough apart.

(ii) For responses in which the graph had been plotted according to the instructions given in the question, the value of V_0 was simply taken as value of V at the intercept on the y-axis. For other responses, where the true y-axis (vertical grid line where $x = 0$) was off the grid then it became necessary to make the best estimate of the value or to calculate the value using the formula for a straight line ($y = mx + c$). Many weaker candidates did not realise that if a false origin had been used or the graph had not started from the origin, then the y-axis drawn was not the true y-axis and so would not give the correct value for V_0. Some weaker candidates used more than one scale on an axis and this was not accepted.

(f) Stronger candidates answered this correctly but weaker candidates still misunderstand how to carry out this type of comparison.

(g) Stronger candidates referred to a current too large for the ammeter, the overheating of the resistance wire or the fact that mark of 20 cm on the scales was covered by insulating tape and therefore inaccessible for the experiment. Weaker candidates made unrealistic comments, referring to the circuit getting too hot and burning or the ammeter exploding.

Question 4

Candidates were required to plan an experiment to find out how the mass of a trolley affected its average speed (after it had accelerated down an inclined track) as it moved along a flat bench and came to a halt at the end of its stopping distance.

Marking point 1 was awarded if the response mentioned the use of a stopwatch and one other essential piece of equipment; either a device to measure the distance travelled (e.g. a metre rule or measuring tape) or a balance to measure the mass.

Marking point 2 was awarded for stating that the stopping distance and the time taken would be measured. Many weaker candidates described measuring the distance or time incorrectly. The stopping distance and time should not have included the travel down the ramp (inclined track).

Marking point 3 was awarded for describing how the mass of the trolley was changed by fixing masses to it. Weaker responses suggested that trolleys of different mass could be used, but this was not accepted because other variables would be changed (e.g. friction between the trolley wheels and the track).

Marking point 4 was awarded for identifying a key controlled variable that should remain constant throughout the experiment. The key variables to control were to use exactly the same trolley, to release the trolley from the same position each time and to keep the same angle of incline of the ramp. The strongest responses listed more than one of the key variables.

Marking point 5 was awarded for a table drawn with columns and their headers for the selected variable, for mass, (stopping) distance and (stopping) time. Headers to the columns with correct units were necessary in order for credit to be awarded. The strongest responses also had a column for the average speed but this was not required for credit.

Marking point 6 was awarded for stating **how** a conclusion to the experiment could be made. The strongest candidates described how the average speed would be calculated for each mass of the trolley and then that graph of average speed against mass should be plotted or the results compared to find out whether a change in mass affected the average speed.

Weaker candidates gave a prediction as to what the conclusion should be instead of indicating **how** the experimenter should process or analyse the results to find any relationship.

PHYSICS

Paper 5054/41
Alternative to Practical

Key Messages

- Candidates will need to have had a thorough grounding in practical work during the course, including reflection and discussion on the precautions taken to improve reliability, and control of variables.
- Candidates should be reminded to include units when quoting the values of physical quantities when they are not already provided and 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.
- Candidates should 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’. Such comments need to be linked to the practical situation being considered, with specific detail given. 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 a curved line of best fit through all points will often produce a curve that is not smooth.
- Candidates should be aware that this paper tests an understanding of *experimental* work. Explanations need to be based on data from the question and should be based on practical rather than theoretical considerations.
- Numerical answers should be expressed clearly, to the appropriate number of significant figures.

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 candidates was good, but some candidates approached this paper as they would a theory paper and not from a practical perspective. Most candidates attempted all the questions and there was no evidence of candidates suffering from lack of time. Stronger candidates were able to follow instructions, record observations clearly and perform calculations accurately. However, some candidates did not round their numerical answers correctly or give the answers to a sensible number of significant figures.

Comments on specific questions

Question 1

(a) Candidates were expected to describe how to use a dropping pipette to measure 1.0 cm^3 of water. Most candidates gained some of the available credit but answers frequently lacked a logical progression. There were some excellent answers from candidates who put the procedure in the correct order.

(b (i) Candidate were given a diagram showing three different times on a stopwatch and asked to find the average time. This is a commonly asked question and was answered well by many candidates. Others left their answer in stopwatch notation (instead of seconds) or thought the stopwatches were showing times in minutes.

(ii) This question asked candidates to find the speed of the wave and they were given the equation of speed = distance/time. A diagram of the plate was drawn to half size and they were expected to use this to measure the diameter of the plate which would be equal to double the radius (the distance travelled by the wave). Some candidates did not appear to have a ruler as many of the distances given were not correct, even allowing for confusing the radius and diameter.

(c) (i) Candidates were asked to identify two causes of uncertainty in the experiment. Only stronger candidates answered this correctly. Many candidates talked of repeating the experiment, but this had already been done. Candidates needed to describe uncertainties caused by the method and few did this. Some mentioned parallax errors but did not give detail to indicate where the parallax error may have occurred, i.e. in reading a ruler measurement.

(ii) Few candidates were able to suggest an improvement.

Question 2

(a) (i) This question was well answered and candidates read the voltmeter accurately.

(ii) Initial credit was available for calculating the values of I and $1/I$ and this was usually awarded. Some candidates did not round correctly. Further credit was available for consistency in the recording of marks in the table. Only stronger candidates did this successfully. Candidates should know to give all answers in one column to the same number of decimal places. Few candidates were then able to add correct column headings with a unit in the table. This was often ignored or incorrect. Giving the unit for $1/I$ as 1/A caused difficulty.

(b) (i) The graph was generally plotted correctly but axes were not always labelled.

(ii) Lines of best fit were variable. There should have been an even number of points above and below the line.

(iii) Finding the gradient of the line was challenging for some candidates but most gave a correct intercept value.

(c) The calculation was carried out correctly by many candidates.

Question 3

(a) Candidates were shown a selection of apparatus and asked to explain how to find the diameter of a glass ball. There were some excellent diagrams given to explain this by stronger candidates. Candidates seemed to think they had to use all the apparatus, often in illogical ways.

(b) (i) Only a few candidates considered the unit expected in their answers, i.e. mm and not cm.

(ii) Candidates were told that the measurements were to a scale of 1: 5 and then asked to give the actual length in metres. Only a few candidates calculated this correctly.

(iii) Stronger candidates were able to do this well.

(c) This question was answered relatively well.

(d) Candidates were given a graph of data and asked to plot two further given points in **(i)** on the grid and then draw a best fit curve in **(ii)**. This was answered well. In **(iii)**, they were asked to take data from the graph and show how this was done on the graph. Credit was available for showing the working lines on the graph but many candidates did not do this.

(e) (i) Many candidates used their data successfully to find two values of the constant *k*.

(ii) The values of these constants were hugely different in most cases and this was intended. However, many candidates stated that the two values were within 10% and the student's claim that they were within the limits of experimental accuracy was correct.

(f) Candidates were asked to identify two variables that should be controlled in this experiment. They did not appear to have a good understanding of what is meant by a control variable. Responses needed to be precise. A significant number of candidates identified mass without stating which mass they wanted to control.

Question 4

A number of candidates repeated the question and redrew the apparatus which did not gain credit.

The diagram explained the experiment, so candidates were expected to state any extra apparatus needed and in this case, they needed a protractor.

They needed to choose the variable they intended to change – the independent variable. There were two alternatives here. The majority chose to change the weight applied on the metal strip and a few chose to change the distance between the stands. Both were acceptable. A small number of candidates opted to change both possible variables at the same time – these plans were not valid.

Candidates were expected to repeat measurements of the dependent variable for at least two values of the independent variable and preferably five values, to get a suitable range of results. Stronger candidates gained credit by suggesting taking results with weights of 1N, 2N, 3N, 4N and 5N or simply giving five different weights (or five distances between the stands if this was their chosen independent variable).

They then needed to state the variables which would be kept constant – the control variables. If they had opted to change the weight applied, then the control variable would be the distance between the stands and vice versa but other options were also allowed, e.g. using the same metal strip.

The results table needed to show two columns – one for the chosen independent variable and one for the bend angle. Units were required and many candidates did not put these in their column headings.

Finally, a conclusion was required. Candidates needed to look to compare the results in the table or possibly to draw a suitable graph of their data stating which variable goes on each axis. A number of weaker candidates just suggested plotting a graph of the data which was not sufficient.

Weaker candidates made predictions as to the conclusions they expected to take rather than explaining **how** their results could be analysed or processed to help them reach a conclusion.

PHYSICS

Paper 5054/42
Alternative to Practical

Key messages

- Candidates will need to have had a thorough grounding in practical work during the course, including reflection and discussion on the precautions taken to improve reliability, and control of variables.
- Candidates should be reminded to include units when quoting the values of physical quantities when they are not already provided and 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.
- Candidates should 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’. Such comments need to be linked to the practical situation being considered, with specific detail given. 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 a curved line of best fit through all points will often produce a curve that is not smooth.
- Candidates should be aware that this paper tests an understanding of *experimental* work. Explanations need to be based on data from the question and should be based on practical rather than theoretical considerations.
- Numerical answers should be expressed clearly, to the appropriate number of significant figures.

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. Only a very small number of candidates did not attempt all sections of each of the questions and there was no evidence of candidates suffering from 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) (i) The unstretched length of the spring was recorded correctly in centimetres to the nearest millimetre by the majority of candidates. Occasionally, an extra zero was added to the recorded dimension.

(ii) The simple subtraction to calculate the extension of the spring was almost always completed correctly.

(iii) The calculation of the spring constant k_1 was usually correct, but some candidates rounded their calculated value incorrectly, and gave answers such as 24.7 or 25.0.

(iv) Most candidates understood the meaning of the term 'parallax error' and were able to explain how such errors can be avoided. Few candidates explained what was meant by a parallax error, and many incorrectly stated that the position of the eye needed to be parallel and not perpendicular to the reading being taken.

(b) (i) Despite the instruction to record the reading on the stop-watch to 1 decimal place, answers of 13.58s were common.

(ii) The majority of candidates were able to calculate the mean value for the time of 20 oscillations of the spring from the two readings of the stop-watch given in the table.

(iii) The period of oscillation of the spring T was usually calculated correctly. However, some candidates divided by 10 instead of 20, despite being told that the timings in the table were for 20 oscillations of the spring. The calculation of T^2 proved to be more challenging, as a significant minority of candidates doubled their value for T instead of squaring it.

(iv) The calculation of a second value k_2 for the spring constant was done well, with most candidates using their value for T^2 and substituting it into the equation. Some candidates squared their value for T^2 again, before substitution.

(c) There were very few correct answers to this more demanding final part of the question. Most candidates realised that the reaction time of the person performing the experiment was involved in the explanation. Almost all of these candidates incorrectly thought that timing 20 oscillations rather than just 1 oscillation would reduce the human reaction timing error, rather than reducing its effect. Acceptable responses seen from candidates who were successful here, were:

1. Timing 10 oscillations reduces the effect of reaction timing errors.
2. Timing 10 oscillations reduces the percentage error/uncertainty.
3. The reaction time error is spread over 20 oscillations/a longer time.

Question 2

(a) (i) The value of the initial temperature of the hot water was almost always read correctly as 85.5 °C from the scale of the thermometer. When the scale was misread, the most common incorrect value given was 80.5 °C.

(ii) Few candidates understood why the student waited for 30 s before reading the initial temperature of the water. Many candidates simply reworded the question or stated that it would improve accuracy without giving detail as to how it would improve accuracy. Candidates needed to recognise that the student waits for the temperature reading on the thermometer to stop increasing, or allows the temperature to reach its maximum value. Many candidates discussed the water reaching a constant temperature, instead of focussing on how this affected the temperature reading.

(b) (i) Despite being provided with the equation for the average rate of cooling of the hot water, many candidates confused the temperatures given in the table and inserted the wrong pairs of temperatures into the equation. Other candidates who had correctly calculated the rate of cooling, did not give their answers to 2 significant figures, as requested. Most candidates gave the correct units for the answer, °C / min and a correct conversion to °C / s was also accepted.

(ii) This question involved an identical calculation for the rate of cooling of the water at the bottom of the beaker. The principle of error carried forward was applied here so that candidates who had used an incorrect pair of temperatures in the previous part could obtain full credit here.

(c) (i) The majority of candidates were able to use their answers to **(b)** to explain why a hot liquid should be stirred before measuring its temperature.

(ii) Most candidates were able to look at the arrangement of the apparatus given in the diagrams and suggest a valid way of arranging the apparatus to make it easy to read the thermometer accurately. The most common correct answer was to use a stand/clamp to hold the thermometer steady.

(d) Almost all candidates were able to suggest one variable that should be kept constant in the experiment. Of those candidates who suggested that the initial temperature of the water should be kept constant, many omitted the word ‘initial’.

(e) Only stronger candidates realised that if the hot water was left to cool down for 30 minutes after the experiment ended, then its temperature would have fallen back to room temperature/22.5 °C. Many had forgotten that the value for the room temperature was given to them at the very start of the question.

Question 3

(a) (b) The readings on the scales of the voltmeter and the ammeter were almost always recorded correctly.

(c) The units of the quantities involved were usually entered correctly in the table headings. Some candidates did not understand what was required and wrote distance, voltage and current instead of cm, V, A.

(d) Graph-plotting skills were of a reasonable standard, but many responses failed to score full credit. The most common sources of error were:

- Awkward scales, such as 3 or 7. Choosing such scales makes the points much harder to plot clearly.
- Not starting both axes from (0, 0), as instructed.
- Choosing scales such that the plotted points did not span at least half of the given grid.
- Failure to use linear scales.
- Poor choices for the best-fit straight line.

However, there were many excellent, carefully plotted and drawn, best-fit lines produced.

(e) (i) As expected, candidates who drew a large triangle to determine the gradient of their graphs obtained the most accurate values for the gradient of the line. Credit was available for showing the points selected on the graph. Many candidates gave no clear indication on the graph of the information used to determine the gradient, despite the instruction given to do so.

(ii) Most candidates read the intercept on the V-axis correctly. Candidates who had made an incorrect choice of scale for the V-axis ended up with their y-intercept above the grid. These candidates were awarded credit if they made a sensible estimate of the intercept.

(f) Candidates were asked to state whether their values of V_0 from **(a)** and V_0 in **(e)(ii)** 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 were able to do this.

(g) Few candidates were able to explain why the experiment should not be conducted with lengths of resistance wire less than 20.0 cm. Many candidates thought that the circuit would blow up, the wire would melt, or the person carrying out the experiment might get electrocuted. The most common correct answer was that the wire would get hot. Other acceptable answers that were seen were that the current might exceed the full scale deflection of the ammeter, or that the wire was covered in insulating tape below 20.0 cm, so no current would flow.

(h) The symbol for a variable resistor was not well known. There were many examples of thermistors, fixed resistors and LDRs seen. Even when the symbol was known, some candidates did not ensure that their sketch showed the arrow passing through both of the longer sides of the rectangle. Candidates were more successful in completing the partially-connected circuit diagram.

Question 4

Most candidates understood the brief for this question and described a suitable method.

The first of the three method marks were obtained by many candidates. Candidates were asked to state any additional apparatus required to be able to calculate the average speed of the trolley as it travelled across the bench and came to rest. The majority of candidates mentioned a stop-watch to measure the time taken, but far fewer mentioned a ruler or measuring tape. Most candidates stated that the distance needed to be measured, but did not say what measuring instrument they would use.

The second method mark was awarded far less often. Many candidates did not follow the instructions given in the question, and measured the total distance travelled by the trolley from the point of release on the slope, until it came to rest on the bench. The plan referred to the average speed of the trolley along the bench, so only candidates who measured the distance from the bottom of the slope to the rest position of the trolley on the bench gained credit here.

The third method mark was awarded to the majority of candidates. Most repeated the experiment with extra masses added to the trolley.

The fourth mark, for identifying a key variable to keep constant, presented no difficulty to the majority of candidates. Candidates usually kept the height of the end of the ramp above the bench/the angle of the ramp constant or released the trolley from the same position on the ramp each time.

The fifth mark was for drawing a table to show how to present the results. Drawing the table of results presented problems for many candidates. All that was required was a table containing three columns with headings for mass, distance (travelled) and time with appropriate units. Any extra columns, such as ‘average speed’ were ignored. Many tables just had headings for mass and average speed, and candidates missed out the actual measurements of distance and time that would need to be recorded, before the average speed could be calculated.

The sixth mark was for explaining *how* the results can be used to reach a conclusion. Many candidates instead made predictions based on their knowledge e.g., the greater the mass of the trolley, the greater the stopping distance will be.

The easiest way to address this requirement was to plot a graph of the mass of the trolley against average speed (and to describe the trend indicated by the graph). An equally acceptable method of drawing a conclusion was to use the results table to compare the average speeds with the masses added to the trolley to see if/how changing the mass affects the average speed of the trolley.