**2014**
**Examination**
**Report**

# 2014 Physics GA 3: Examination

## GENERAL COMMENTS

Students and teachers should note the following points in relation to the 2014 Physics examination paper.

- The answer space given and the number of marks allocated to a question should be used a guide as to the amount of detail required in an answer.
- Attempting a question a number of different ways will not be awarded any marks unless all methods are correct. Students are advised to neatly cross out any working they do not want assessed.
- Students should be encouraged to set out their work clearly so assessors can follow what they have done. In questions that involve a number of steps, it is helpful if the student explains all their working.
- In questions that require explanations, students should carefully consider what the question is asking and answer accordingly. They should not simply copy information from their sheet(s) of notes, as this can result in the inclusion of irrelevant, contradictory or incorrect material.
- When responding to questions that required an explanation, many students answered in dot-point format. This may help to ensure good, concise answers. There is no need to restate the question in an answer.
- The use of equations or diagrams in questions that require an explanation can sometimes assist. It is important that diagrams are sufficiently large and clearly labelled. Graphs and sketches should be drawn with care.
- Students' attention should be drawn to the instructions for Section A, 'In questions worth more than 1 mark, appropriate working should be shown'. Full marks may not be awarded where only the answer is shown, and some credit can often be given for working even if the final answer is incorrect.
- Students are also reminded of the instruction for Section A, 'Where an answer box has a unit printed in it, give your answer in that unit'. Students should be discouraged from the practice of changing the unit.
- It is important that students show the numbers substituted into formulas/equations. The formula alone is generally not worth any marks.
- It is expected that formulas be copied accurately from the formula sheet provided with the examination or from the student's sheet(s) of notes. Derived formulas from the student's sheet(s) of notes may be used. However, they must be correct and appropriate for the question.
- Students need to be familiar with the operation of the scientific calculator they will use in the exam. Calculations involving powers of ten sometimes caused difficulties for students. Students must ensure that the calculator is in scientific mode and that it does not truncate answers after one or two decimal places.
- The rounding-off of calculations should be done only at the end, not progressively after each step.
- Answers should be simplified to decimal form.
- Where values of constants are provided in the stem of the question or on the formula sheet, students are expected to use the number of significant figures given.
- Care needs to be taken when reading the scales on the axes of graphs.
- Arrows representing vector quantities should be drawn so that they originate from the point of application. Where appropriate, the length of the arrows should indicate the relative magnitudes.
- Students should ensure that their answers are realistic. Illogical answers should prompt students to check their working.

Areas requiring improvement included:

- connected bodies
- energy conversion and conservation in springs
- complex projectile motion
- apparent weightlessness
- modulation
- explaining direction of induced current using Lenz's law
- operation of transformers and how they work in a power transmission system
- understanding of series circuits
- explaining aspects of the photoelectric effect
- applying the concept of path difference in interference patterns
- explaining electron and X-ray diffraction patterns
- electron energy level diagrams and associated emissions and absorptions
- how the wave nature of matter can explain the electron energy levels.

## SPECIFIC INFORMATION

This report provides sample answers or an indication of what answers may have included. Unless otherwise stated, these are not intended to be exemplary or complete responses.

The statistics in this report may be subject to rounding errors resulting in a total less than 100 per cent.

## Area of study – Motion in one and two dimensions

**Question 1a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 16 | 3 | 82 | 1.7 |

This question was about constant acceleration. Using $x = ut + ½ at^2$, the distance travelled was 2.5 m.

A common error was not squaring the time.

**Question 1b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 50 | 1 | 49 | 1.0 |

The tension in the coupling was the only force accelerating the two trucks. Students needed to apply Newton's second law $F = ma = 20\ 000 \times 0.2 = 4000$ N. It was also possible to apply Newton's law to the engine by first determining the driving force of the engine, $F = ma = 60\ 000 \times 0.2 = 12\ 000$, then $F_{net} = 12\ 000 - \mathrm{T} = 40\ 000 \times 0.2$, giving T = 4000 N.

Using the mass of the engine (40 000 kg) was very common. This assumed that the only force acting on the engine was the tension in the coupling and neglected the driving force of the engine.

**Question 1c.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 19 | 3 | 78 | 1.6 |

Using the conservation of momentum, the speed was 2.0 m $s^{-1}$.

Some students confused the masses, while others assumed it was an elastic collision and used conservation of kinetic energy.

**Question 1d.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 24 | 6 | 8 | 63 | 2.1 |

Students were required to determine the kinetic energy before (320 000 J) and after (160 000 J) the collision. Since kinetic energy had been lost, it was an inelastic collision.

Some students evaluated the momentum before and after the collision, while others did not square the velocity when calculating the kinetic energy.

**Question 2a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 38 | 1 | 61 | 1.2 |

Any of the three sets of data could have been used. With three 50 g masses the stretching force was 1.5 N, so the spring constant was $k = F/x = 1.5/0.3 = 5.0$ N $m^{-1}$.

### Question 2b.

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 71 | 13 | 2 | 14 | 0.6 |

Taking the zero of gravitational potential energy at the lowest point of the oscillation, the gravitational potential energy at the top of the oscillation will equal the spring potential energy at the lowest point. So, $mgh = ½ k x^2$, thus $0.2 \times 10 \times h = 0.5 \times 5.0 \times h^2$, giving h = 0.8 m.

Alternatively, some students knew it would oscillate equally either side of the equilibrium position. They first determined the equilibrium position using $F = kx$, which gave 0.4 m. Since it was released from 0.4 m above this point and would reach 0.4 m below the equilibrium position, the total extension from the unstretched length would be 0.8 m.

Many students worked out the equilibrium position and added on the unstretched length.

### Question 2c.

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 60 | 12 | 27 | 0.7 |

The graphs shown did not include kinetic energy. If this had been included, they would have added to a constant value.

Students often wrote about one graph being linear and the other quadratic as the reason they did not add to a constant value.

### Question 2d.

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 74 | 15 | 3 | 1 | 7 | 0.5 |

As the mass oscillated, the total energy (kinetic, spring and gravitational) remained constant. Take the zero of gravitational potential energy at the lowest point. At the highest point the only energy was gravitational = $mgh$ = 1.6 J. Alternatively, at the lowest point the only energy was spring potential energy = $½ kx^2$ = 1.6 J. The maximum speed occurred at the equilibrium position (centre of oscillation). At that point the total energy (1.6 J) was a combination of kinetic, gravitational and spring, $1.6 = ½ mv^2 + mgh + ½ kx^2 = 0.5 \times 0.2 \times v^2 + 0.2 \times 10 \times 0.4 + 0.5 \times 5.0 \times 0.4^2$, so that the speed was 2.0 m $s^{-1}$.

Very few students were able to progress far with this question. Many assumed that the spring potential energy was equal to the kinetic energy, but did not give an explanation. Others assumed that the kinetic energy was equal to the total energy.

### Question 3a.

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 24 | 3 | 73 | 1.5 |

The vertical component of the initial velocity was 20sin30 = 10 m $s^{-1}$. Then using a constant acceleration formula for the vertical motion $v^2 = u^2 + 2ax$ gave $0 = 100 - 2 \times 10 \times x$ and so $x = 5.0$ m. It was also possible to determine the time to the top of its path and use it to get the height.

Some students neglected the vector nature of the equations and others did not square values substituted into equations.

### Question 3b.

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 41 | 9 | 4 | 46 | 1.6 |

Using the horizontal component of the velocity, the time of flight was determined. $26 = 20t \cos 30$ giving $t = 1.5$ s. This time was then used in a constant acceleration formula for the vertical motion $x = 20\sin 30 \times 1.5 - ½ \times 10 \times 1.5^2 = 3.75$ m. Some students used more steps. They determined the time to reach the top of the flight path, then the total time from the horizontal motion. By subtracting these, they obtained the time from the top to the wall and used this to find the distance down from the top. This was then subtracted from the maximum height to get the required height.

A number of students applied a derived formula for the range, which did not apply to this situation. Others neglected the vector nature of the quantities by omitting negative signs. There were also a number of mathematical errors.

**Question 4a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 27 | 4 | 69 | 1.4 |

To feel weightless there would be no normal reaction force. Therefore, the only force acting (gravity) would be providing the centripetal force. So mg = $mv^2/r$, hence $10 = v^2/20$ and $v = 14(.1)$ m $s^{-1}$.

**Question 4b.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 30 | 31 | 28 | 11 | 1.2 |

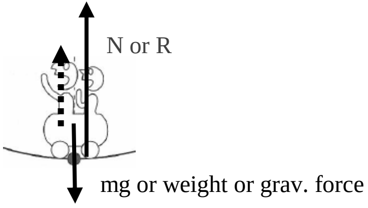
They felt weightless because the normal reaction force was zero. They were in freefall, with their acceleration equal to gravity. They were not actually weightless because the strength of the gravitational field was not zero.

Some students believed that the gravity force down was equal to the normal force up, and therefore they cancelled out or stated that the net force was zero.

**Question 4c.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 17 | 14 | 25 | 44 | 2.0 |

The two forces acting were the gravity force down and the normal force up. Because they were moving in a circular section of the track, the resultant force had to be up.



The quality of some students' diagrams was quite poor. The arrows needed to be drawn clearly so that they could be distinguished. They also needed arrowheads to indicate direction. It was common to see a resultant force and a centripetal force. There were also arrows representing acceleration and velocity.

**Question 5a.**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 26 | 9 | 10 | 12 | 43 | 2.4 |

By transposing $GMm/R^2 = 4\pi^2Rm/T^2$ to give $M = 4\pi^2R^3/GT^2$ and substituting the appropriate values, the mass of the star was calculated to be $1.1 \times 10^{31}$ kg.

Common errors included not converting the period to seconds, forgetting to square or cube values, incorrect transposing of the equation, copying from notes and an inability to use the calculator correctly.

**Question 5b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 37 | 48 | 16 | 0.8 |

It was not possible to determine the mass of the planet from the data provided because its mass appears on both sides of the equation and thus cancels out of the equation.

## Area of study – Electronics and photonics

**Question 6a.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 7 | 93 | 1.0 |

The voltmeter would read 0 V because there is no difference in electrical potential between the terminals of the meter.

**Question 6b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 26 | 6 | 69 | **1.5** |

The voltmeter was now measuring the potential difference across the 300 Ω resistor. Treating it as a voltage divider would give [300/1200] × 8 = 2.0 V. Alternatively, students could have determined the current in the circuit = V/R = 8/1200 = 0.00666 and then use Ohm's law to determine the voltage across the 300 Ω = IR = 0.00666 × 300 = 2.0 V.

Although they realised it could be treated as a voltage divider, some students got the incorrect ratio. Of those who first calculated the current, some rounded off this value before using it in the Ohm's law calculation. Students should be encouraged to carry the value in the calculator register.

**Question 7a.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 24 | 12 | 7 | 57 | **2.0** |

From the graph, the voltage across the LED was 2 V. By knowing the power of the LED, the current through it was calculated with $P = VI$, $0.3 = 2 \times I$ hence $I = 0.15$ A. The voltage across the resistor was 9 V, and the current through it was 0.15 A, so using Ohm's law the resistance was 60 Ω.

Some students applied the power formula $P = VI$ to the resistor, perhaps believing that the 300 W referred to it instead of the LED.

**Question 7b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 32 | 5 | 63 | **1.3** |

Since the voltage across the LED was 3 V, the voltage across the resistor was 9 V. So the power dissipated by the resistor was $P = VI = 9 \times 0.5 = 4.5$ W.

Some students seemed to assume that the LED was the same LED as in part a., and thus determined that the voltage across the resistor was 10 V.

**Question 8a.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 12 | 88 | **0.9** |

Reading from the graph, when the potential difference was zero, the current was 3.6 mA.

**Question 8b.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 36 | 64 | **0.7** |

With the switch open, the current was zero. Reading from the graph, the potential difference across the photodiode was 1.3 V.

**Question 8c.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 10 | 21 | 12 | 57 | **2.2** |

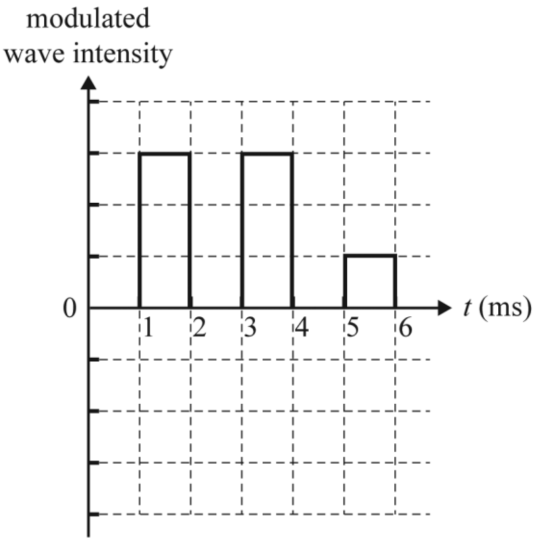
From the graph, operating the photodiode at 1 V meant a current of 1.6 mA. Therefore, the voltage across the resistor and the current through it were also 1 V and 1.6 mA respectively. Thus, using Ohm's law, the resistance was 625 Ω.

Some students neglected to convert or incorrectly converted the current to ampere when substituting into Ohm's law. Others assumed that the voltage across the resistor was the maximum that the photodiode could provide (1.3) minus the voltage at which it was now operating (1.0).

**Question 9**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 66 | 9 | 25 | **0.6** |

The modulated signal was:

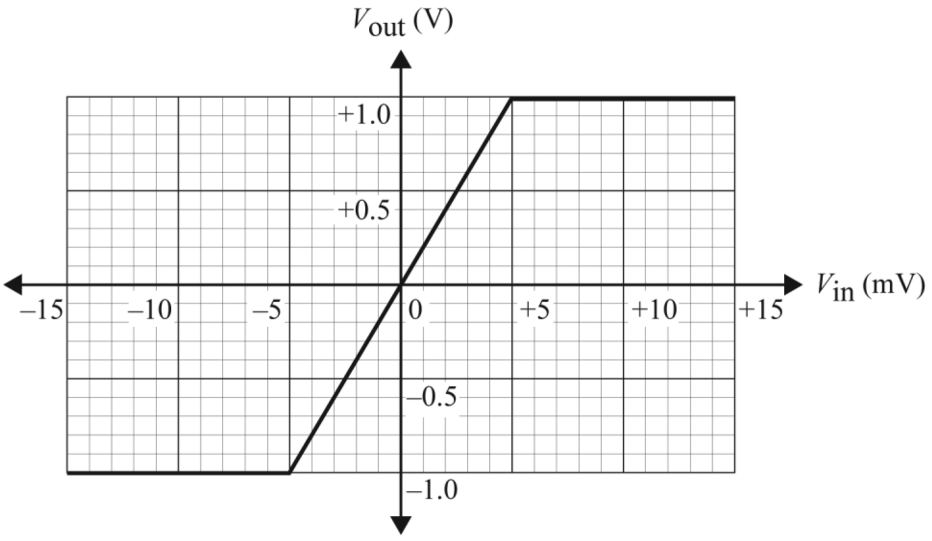


Some students drew the correct general shape but did not have the correct ratio of the amplitudes. Others included a sine wave within the rectangular blocks. Many mirrored the signal under the time axis.

**Question 10a.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 19 | 10 | 18 | 53 | **2.1** |

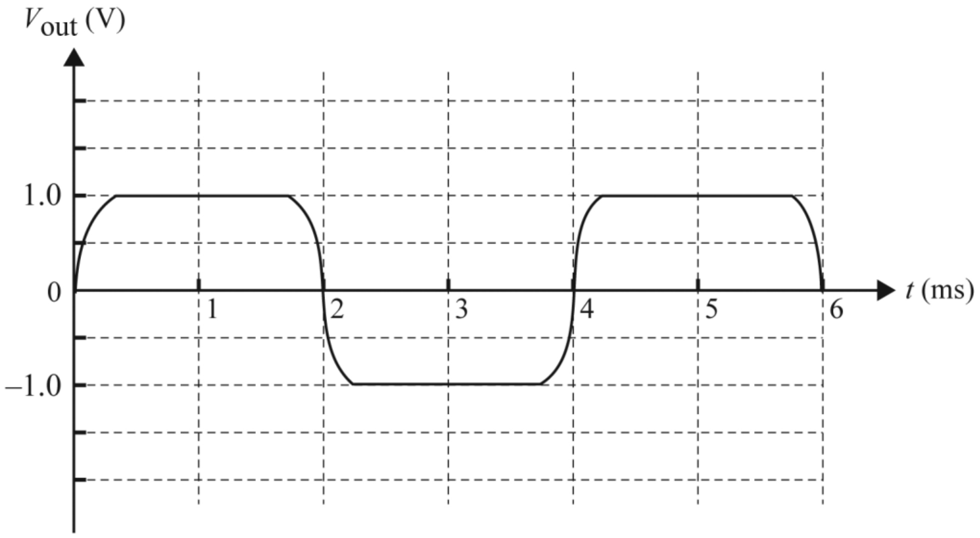
The expected graph is shown below; however, graphs with biasing shown were also acceptable. Common errors included drawing the characteristics for an inverting amplifier, not showing scales on the axes, and having clipping commencing at the wrong point or not shown at all. Some students gave the incorrect amplification.



**Question 10b.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 19 | 18 | 7 | 55 | 2.0 |

The output signal is shown below. If the student showed biasing on the characteristics in part a., other possibilities were acceptable. The main errors were inverting the signal or not showing clipping. Some students' sketches did not show the same period as the original.



**Question 11**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 17 | 15 | 12 | 4 | 53 | 2.6 |

At 300 lux the resistance of the LDR was 500 Ω. The control unit switched when $V_C$ was 4 V. Using the voltage divider relationship $V_C = R_V/(R_{LDR} + R_V) \times 9 \Rightarrow 4 = R_V/(500 + R_V) \times 9 \Rightarrow R_V = 400\ \Omega$. Alternatively, knowing that the resistance of the LDR was 500 Ω and that the voltage across it would have to be 5 V, students could determine the current through it to be 0.01 A using Ohm's law. Then applying this to the resistor with a voltage of 4 V and the current 0.01 A, the resistance was 400 Ω. Another method was to use the fact that the ratio of the voltages would be the same as the ratio of the resistances.

Students commonly determined the resistance of the LDR as 500 Ω but had the wrong voltage divider ratio or the voltage required by the control unit.

## Area of study – Electric power

**Question 12a.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 49 | 51 | 0.5 |

The current was going up the front of the coil and down the back, so the magnetic field resulting went from right to left. At X it was pointing to the left, so option **A.** was correct.

**Question 12b.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 34 | 66 | 0.7 |

At point X the magnetic field was to the left, the current was up the page, so the force applied was out of the page (option **E.**).

**Question 13a.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 67 | 33 | 0.4 |

The desired effect required a change in flux through the loop. This could be achieved by moving it to the right so that it moves out of the magnetic field or by rotating it. So the correct answer was **C.** (moving the loop sideways [to the right] so that it moves out of the magnetic field) and **D.** (rotating the loop about a horizontal axis).

This question required students to select **one or more** options. Therefore, it was important to check all possibilities.

**Question 13b.**

| **Marks** | **0** | **1** | **2** | **3** | **Average** |
|---|---|---|---|---|---|
| **%** | 33 | 10 | 7 | 50 | **1.8** |

The EMF generated in the loop was determined using Faraday's law $\varepsilon = -n\Delta\phi_B/\Delta t = (0.08 \times 0.050)/0.010 = 0.4$ V. This value was then substituted into Ohm's law with the current to determine the resistance as 20 Ω.

A common error involved students converting the time from milliseconds to seconds. Others neglected the area of the loop all together.

**Question 13c.**

| **Marks** | **0** | **1** | **2** | **3** | **Average** |
|---|---|---|---|---|---|
| **%** | 43 | 24 | 13 | 21 | **1.1** |

Initially the flux was downwards and decreasing. According to Lenz's law, the induced current would oppose the change in flux. Therefore, the current induced in the loop would be clockwise.

Students needed to refer to the change in flux, not the change in magnetic field. Some wrote about opposing the change, but it was unclear what change this referred to. It was important to explain the initial conditions and how they were changing. Some students appeared not to realise that the loop in Figure 25 was the same as that shown in Figure 24.

**Question 14a.**

| **Marks** | **0** | **1** | **Average** |
|---|---|---|---|
| **%** | 70 | 30 | **0.3** |

Since the input to the transformer was DC, there would be no output voltage. Transformers require a changing flux, thus a changing input current.

Many students simply applied the turns ratio to obtain an output of 480 V, perhaps assuming it was AC.

**Question 14b.**

| **Marks** | **0** | **1** | **2** | **Average** |
|---|---|---|---|---|
| **%** | 16 | 31 | 53 | **1.4** |

This question referred to an AC input. The output was 400 V, so the input would be 400 × (130/5200) = 10 V. This was the RMS value, so the peak value was $10\sqrt{2} = 14.1$ V. Students could also first get the peak value of the output then apply the turns ratio to get the peak input.

The most common error was to simply determine the peak value of the output and go no further. Other students inverted the turns ratio.

**Question 15a.**

| **Marks** | **0** | **1** | **Average** |
|---|---|---|---|
| **%** | 26 | 74 | **0.8** |

Since the 13 V was supplied and the light globe had 3 V, 10 V was lost in the lines.

**Question 15b.**

| **Marks** | **0** | **1** | **Average** |
|---|---|---|---|
| **%** | 35 | 65 | **0.7** |

Using $P = V^2/R = 3^2/1.5 = 6.0$ W. This answer could have been achieved by first calculating the current in the circuit.

**Question 15c.**

| **Marks** | **0** | **1** | **Average** |
|---|---|---|---|
| **%** | 41 | 59 | **0.6** |

The current could be determined from the wires I = V/R = 10/5 = 2.0 A, or by applying the same formula to the globe or to the whole circuit. Alternatively, a power formula ($P = VI$) could have been applied to the globe and and the power determined in part b. could have been used.

**Question 15d.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 49 | 6 | 5 | 40 | **1.4** |

For the globe to operate at maximum allowed voltage of 6.0, applying Ohm's law $I = 6.0/1.5 = 4.0$ A. Therefore the voltage loss in the wires was $V = IR = 4.0 \times 5.0 = 20$ V. So, the total voltage in the circuit was 6 + 20 = 26 V. Another slightly more complicated method involved the use of power. It could also be treated as a voltage divider.

Some students gave the correct answer but gave incorrect working or did not give any working. Students are reminded to show all working.

**Question 16**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 30 | 15 | 24 | 23 | 8 | **1.7** |

Since the amount of power to be transmitted was fixed, a step-up transformer could be used to increase the voltage and thereby decrease the current. Less current meant less power loss in the lines ($P = I^2R$). A step-down transformer would be used to reduce the voltage to something more appropriate for the end user.

Some students did not mention that there was a fixed amount of power that had to be transmitted. Others neglected to explain the use of the step-down transformer at the consumer end of the transmission system. In explaining the step-up transformer students commonly quoted Ohm's law, $V = IR$ and that by increasing the voltage the current would decrease. Some students misinterpreted the question as requiring an explanation of how a transformer works. Others thought that by changing the voltage and current it changed the resistance in the lines.

**Question 17a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 16 | 17 | 67 | **1.5** |

The forces on the sides were WX: down, XY: no force, YZ: up, ZW: no force.

**Question 17b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 24 | 8 | 68 | **1.5** |

The force was determined from the formula $F = nIlB = 75 \times 2.0 \times 0.40 \times 0.020 = 1.2$ N.

Common errors included omitting the number of turns, not converting the length to metres correctly and giving the strength of the magnetic field as 0.2 instead of 0.020.

**Question 17c.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 43 | 21 | 36 | **1.0** |

The forces on opposite sides of the coil were in opposite directions, so a torque (turning effect) was produced. A simple diagram could also have been used, for example:

Some students did not address the question. They instead explained the operation of a commutator in a DC motor or explained the origin of the force on one side of the coil.

**Question 17d.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 10 | 11 | 7 | 73 | **2.4** |

This question related to how the commutator regulated the current in the coil. Before the vertical the current flowed from W ➔ X, at the vertical there was no current and after the vertical the current flowed from X ➔ W.

**Question 18a.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 36 | 31 | 24 | 8 | 1.1 |

The spinning loop produces an AC signal and since the slip rings provide a constant connection, the output to the oscilloscope will be AC. A split-ring commutator would be needed to provide a DC output.

Many treated this as a motor instead of a generator and so did not address the question. There were also many answers, perhaps copied from student notes, that did not address the question.

**Question 18b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 45 | 5 | 51 | 1.1 |

The time for half a rotation was 25 ms, so the period was 50 ms or 0.05 s. Therefore, the frequency was 1/0.05 = 20 Hz.

Some students neglected to double the time given to get the time for a complete rotation. Others halved the time instead of doubling. Powers of ten also caused difficulty.

**Question 18c.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 30 | 26 | 44 | 1.2 |

Increasing the speed of rotation increased the rate of change of flux and therefore increased the output voltage. Faraday's law could also be used to explain an increase in the output voltage. With a smaller time in the denominator, the voltage would increase.

## Area of study – Interactions of light and matter

**Question 19a.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 40 | 60 | 0.6 |

The path difference to the second bright band out to the right was two wavelengths, which was 840 nm.

Some students did not recognise the relationship between path difference and wavelength.

**Question 19b.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 53 | 1 | 46 | 0.9 |

The path difference to the second dark band from the centre would be one and a half wavelengths. Since its position coincided with point P from part a., the path difference had to be the same, 840 nm. So, 840 = 1.5 $\lambda$ and $\lambda$ = 560 nm.

Some students did not recognise the significance of the dark band being at the same position as that of the bright band in part a. Others tried to use the wavelength from part a.

**Question 20a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 19 | 9 | 72 | 1.5 |

The threshold frequency (from graph $1.8 \times 10^{15}$ Hz) gives the photon with just barely enough energy to eject an electron. This is the work function. $W = h \times f_{threshold} = 6.63 \times 10^{-34} \times 1.8 \times 10^{15} = 1.19 \times 10^{-18}$ J (or $1.2 \times 10^{-18}$ J)

The two most common errors were using the wrong Planck's constant and missing the $\times 10^{15}$ Hz on the horizontal axis scale. Some students appeared to have difficulty using their calculators properly.

**Question 20b.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 51 | 25 | 17 | 7 | 0.8 |

According to the particle model of light, increasing the intensity at the same frequency would only increase the number of photons. It would not change the energy of each photon. Hence, the kinetic energy of the ejected electrons would not change.

Many students gave detailed explanations about why the wave model was inadequate in explaining why the maximum kinetic energy of the ejected electrons was unchanged. However, the question specifically asked for an explanation of why the evidence supports the particle model of light. Another very common error was discussing the energy and number of the electrons without mentioning photons. Less common were references to protons instead of photons.

**Question 21a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 29 | 6 | 65 | 1.4 |

Applying the formula for the energy of a photon and transposing gave $\lambda = hc/E = (4.14 \times 10^{-15}) \times (3 \times 10^{8})/4.1 = 3.0 \times 10^{-7}$ m.

Some students were not clear on which units were being used for energy and so used the incorrect version of Planck's constant.

**Question 21b.**

| Marks | 0 | 1 | Average |
|---|---|---|---|
| % | 45 | 55 | 0.6 |

Increasing the size of the hole would produce less diffraction, and therefore the diameter of the rings would be smaller.

**Question 21c.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 59 | 12 | 29 | 0.7 |

For the same wavelength, the degree of diffraction is inversely proportional to the size of the aperture. Increasing the size of the aperture would decrease the spread. Formulas could be incorporated to assist the explanation.

Students had difficulty giving a clear explanation.

**Question 21d.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 48 | 21 | 22 | 10 | 1.0 |

The diffraction pattern spacing depends on the wavelength. Since the spacing of the two patterns was different, the wavelengths were different. The wavelength was directly related to the momentum (h/p), not to the energy.

Many students did not relate the wavelength to the momentum. Others said electrons and X-rays of the same wavelength have the same diffraction. Although this is true it was irrelevant to the question.

**Question 22a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 50 | 18 | 32 | 0.8 |

An atom in the first excited state could absorb a photon of 1.8 eV and move to the second excited state because the energy gap was 1.8 eV. However, it cannot emit a 1.8 eV photon because there is no energy level at 4.9 – 1.8 = 3.1 eV.

While many students could explain the absorption exciting the atom to the next level, the lack of an emitted photon was not explained well.

**Question 22b.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 54 | 6 | 4 | 36 | 1.2 |

The unknown level was 8.9 eV. This allowed for photons to be emitted when atoms transitioned from 8.9 ➔ 6.7 (2.2 eV), 9.8 ➔ 8.9 (0.9 eV) and 10.4 ➔ 8.9 (1.5 eV).

Some students picked a level that worked for two of the emitted photons but not all three.

**Question 23a.**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 26 | 30 | 45 | 1.2 |

The de Broglie wavelength was related to the momentum $\lambda = h/p = 6.63\times10^{-34}/(9.1 \times 10^{-31} \times 2 \times 10^{6}) = 3.6 \times10^{-10}$ m = 0.36 nm.

Errors included using the wrong version of Planck’s constant, calculator errors and converting from metres to nanometres.

**Question 23b.**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 52 | 12 | 16 | 21 | 1.1 |

If the de Broglie wavelength of the electron fits the orbit an integral number of times ($2\pi r = n\lambda$), a standing wave is formed. Only electrons with energies corresponding to these wavelengths exist.

Some students had difficulty giving clear explanations.

## Section B – Detailed studies
## Detailed study 1 – Einstein’s special relativity

| Question | % A | % B | % C | % D | % No Answer | Comments |
|---|---|---|---|---|---|---|
| **1** | 15 | 52 | 31 | 2 | 0 | |
| **2** | 3 | 6 | 7 | 84 | 0 | |
| **3** | 15 | 18 | 40 | 26 | 1 | Substitute into the length contraction formula $L = L_0/\gamma$ to get $1.99 = 2/\gamma$, then solve for $v$ to get $0.10c$ |
| **4** | 24 | 25 | 14 | 37 | 0 | A classical interpretation would have the speed of the radio wave signal travelling at a speed of *c* irrespective of the motion of the transmitter. The wavelength and frequency would vary in the forward and backward directions but the speed would not vary. Therefore, the speed relative to *Hector* would be $c – 0.4c = 0.6c$ |
| **5** | 62 | 11 | 13 | 14 | 0 | |
| **6** | 14 | 7 | 42 | 37 | 0 | To measure proper time the two events need to occur at the same place relative to the observer, and thus can be timed with a single clock located at that place. This is not the case, hence option D was the correct answer. |
| **7** | 32 | 40 | 26 | 2 | 0 | In each situation the observer is at rest relative to the event being measured, so the time is the same in each case. |
| **8** | 5 | 7 | 83 | 5 | 0 | |
| **9** | 28 | 34 | 20 | 18 | 0 | The proper time as observed by someone in the spacecraft was $t_0 = 10/3 \times 10^8 = 3.33 \times 10^{-8}$ s. Therefore, the time as measured by the observer would be $t = t_0 \times \gamma = (3.33\times10^{-8}) \times 1.25 = 4.17 \times 10^{-8}$ s = 42 ns. |
| **10** | 9 | 52 | 30 | 9 | 0 | |
| **11** | 39 | 20 | 14 | 26 | 1 | The rest mass energy of one pion must be $2.25\times10^{-11}$ J (from the data given before Question 10). To increase to $\gamma mc^2 = 3 \times mc^2$ requires an extra energy input of $(\gamma – 1)mc^2 = 4.5 \times 10^{-11}$ J. |

## Detailed study 2 – Materials and their use in structures

| Question | % A | % B | % C | % D | % No Answer | Comments |
|---|---|---|---|---|---|---|
| **1** | 84 | 9 | 4 | 3 | 0 | |
| **2** | 3 | 18 | 71 | 8 | 0 | |
| **3** | 5 | 3 | 90 | 2 | 0 | |
| **4** | 5 | 15 | 12 | 68 | 0 | |
| **5** | 59 | 5 | 3 | 33 | 0 | |
| **6** | 18 | 57 | 14 | 11 | 0 | |
| **7** | 17 | 56 | 19 | 8 | 0 | |
| **8** | 25 | 39 | 22 | 13 | 0 | The sum of the torques about any point on the beam must be zero. Taking torques about point W, the weight of the beam and the tension in the string have no effect because they act through the point about which torque is being evaluated. Therefore, the torque caused by the force of the wall on the beam must also be zero. This will only occur if this force also acts through the point W, which would be directly along the beam. There must be a non-zero force to balance the horizontal component of the tension in WZ. |
| **9** | 8 | 60 | 26 | 6 | 0 | |
| **10** | 27 | 19 | 8 | 46 | 0 | Concrete needs reinforcement where it will be in tension. In arches all the blocks are in compression, so no reinforcement is needed. |
| **11** | 13 | 8 | 15 | 64 | 0 | |

## Detailed study 3 – Further electronics

| Question | % A | % B | % C | % D | % No Answer | Comments |
|---|---|---|---|---|---|---|
| **1** | 12 | 23 | 10 | 55 | 0 | |
| **2** | 11 | 75 | 9 | 5 | 0 | |
| **3** | 12 | 10 | 59 | 19 | 0 | |
| **4** | 59 | 17 | 10 | 14 | 0 | |
| **5** | 3 | 69 | 13 | 14 | 0 | |
| **6** | 75 | 15 | 5 | 5 | 0 | |
| **7** | 17 | 13 | 15 | 55 | 0 | |
| **8** | 4 | 61 | 15 | 20 | 0 | |
| **9** | 15 | 25 | 35 | 25 | 0 | Decreasing the frequency of the supply allows more time for the voltage to drop, and therefore increases the amplitude of the ripple. |
| **10** | 29 | 7 | 16 | 48 | 0 | |
| **11** | 29 | 22 | 29 | 20 | 1 | The voltage from the bridge rectifier would now be half wave rectified. After passing the smoothing circuit it would look something like option D. The Zener diode then regulates it, but cannot maintain the voltage when the supply drops below the stated value. |

## Detailed study 4 – Synchrotron and its applications

| Question | % A | % B | % C | % D | % No Answer | Comments |
|---|---|---|---|---|---|---|
| **1** | 66 | 13 | 17 | 4 | 1 | |
| **2** | 76 | 10 | 6 | 8 | 0 | |
| **3** | 10 | 76 | 12 | 2 | 0 | |
| **4** | 5 | 7 | 7 | 81 | 0 | |
| **5** | 48 | 10 | 32 | 9 | 1 | Device B produces photons with the maximum energy (approximately 200 – 300 keV), and therefore the maximum frequency ($E = hf$). The maximum energy and thus frequency of photons from device A is less than device B. |
| **6** | 2 | 11 | 83 | 4 | 0 | |
| **7** | 16 | 59 | 16 | 8 | 1 | |
| **8** | 4 | 6 | 15 | 75 | 0 | |
| **9** | 6 | 79 | 9 | 6 | 0 | |
| **10** | 4 | 10 | 53 | 33 | 0 | |
| **11** | 6 | 4 | 78 | 12 | 0 | |

## Detailed study 5 – Photonics

| Question | % A | % B | % C | % D | % No Answer | Comments |
|---|---|---|---|---|---|---|
| **1** | 7 | 54 | 21 | 16 | 1 | |
| **2** | 7 | 12 | 37 | 43 | 1 | For the critical angle $\sin\theta_C = n_{Cladding}/1.4$. By decreasing the refractive index of the cladding the overall ratio is lowered and thus $\theta_C$ is reduced. |
| **3** | 23 | 44 | 31 | 1 | 1 | The danger is related to the intensity of light hitting the retina. The laser produces a very narrow, concentrated beam. |
| **4** | 8 | 76 | 9 | 6 | 1 | |
| **5** | 24 | 41 | 19 | 15 | 1 | Photons stimulate other photons to be emitted and moving in the same direction. |
| **6** | 17 | 5 | 63 | 13 | 2 | |
| **7** | 32 | 11 | 46 | 10 | 1 | The light is incoherent as photons are emitted quite randomly from individual atoms. |
| **8** | 14 | 19 | 28 | 38 | 1 | A wide fibre is needed to gather more light and the acceptance angle is given by $\tan\theta = 1/10$, thus $\theta = 5.7^0$ |
| **9** | 19 | 17 | 5 | 57 | 2 | |
| **10** | 41 | 19 | 5 | 33 | 2 | From the graph, absorption was the dominant factor. Since the silica was of very high purity and the least possible non-uniformity, absorption was mainly a result of the silica itself. |
| **11** | 48 | 26 | 12 | 12 | 2 | LEDs produce a range of wavelengths that will cause a spread. |

## Detailed study 6 – Sound

| Question | % A | % B | % C | % D | % No Answer | Comments |
|---|---|---|---|---|---|---|
| **1** | 70 | 3 | 9 | 18 | 0 | |
| **2** | 3 | 8 | 83 | 6 | 0 | |
| **3** | 18 | 11 | 57 | 14 | 0 | |
| **4** | 5 | 4 | 9 | 82 | 0 | |
| **5** | 3 | 20 | 10 | 67 | 0 | |
| **6** | 4 | 9 | 83 | 4 | 0 | |
| **7** | 7 | 67 | 17 | 9 | 0 | |
| **8** | 17 | 22 | 31 | 30 | 0 | A pressure node is where the pressure does not vary. It remains at atmospheric pressure, which on the scale described is zero. |
| **9** | 9 | 61 | 22 | 7 | 0 | |
| **10** | 79 | 11 | 4 | 6 | 0 | |
| **11** | 3 | 79 | 14 | 3 | 0 | |