2016 VCE Physics examination report

General comments

Students and teachers should note the following points in relation to the 2016 Physics examination.

- The answer space given and number of marks allocated to a question should be used a guide 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 that 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.
- There is no need to restate the question in an answer. When responding to questions that require an explanation, students should ensure that their answers are concise and focus on addressing the question. Many students gave extended responses that contained significant amounts of incorrect or irrelevant material.
- 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 some 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 will not be awarded full marks if they change 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 to the question.
- Students need to be familiar with the operation of the scientific calculator they will use in the examination. Calculators 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 calculations should be done only at the end, not progressively after each step.
- Answers should be simplified to decimal form – that is, no surds or extraneous decimals.
- 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:

- resultant forces on free bodies
- the vector nature of momentum
- converting to and from scientific notation
- energy relationships in springs
- energy considerations in projectile motion
- current flow in series and parallel circuits
- the function of diodes in circuits
- modulation
- the function of DC motors, including application of forces, the role of the commutator and the factors affecting efficiency
- the process of electromagnetic induction
- transformers and line loss
- graphing data and interpreting graphical data
- wave properties of matter particles.

Specific comments

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 resulting in a total more or less than 100 per cent.

Area of Study – Motion in one and two dimensions

Question 1a.

Marks	0	1	2	Average
%	11	4	85	1.8

Students were expected to use a simple kinematics approach.

$v^2 = u^2 + 2ax$

$v^2 = 0^2 + 2 \times 0.10 \times 20 = 4$

$v = \sqrt{4} = 2\text{m s}^{-1}$

The most common mathematical error was to forget to take the square root.

Question 1b.

Marks	0	1	2	Average
%	52	1	46	1

Students were expected to use a net force approach.

$$\sum F = ma$$

$$T - friction = ma$$

$$T - 2000 = 10 \times 10^3 \times 0.10$$

$$T = 3000 \text{ N}$$

Many students struggled with this question. The most common errors were to add the friction to the tension or to omit the friction altogether. It appeared that students could not visualise the forces involved. The use of free-body diagrams is recommended to help visualisation.

Question 1c.

Marks	0	1	2	Average
%	12	1	87	1.8

This question required a conservation of momentum approach.

$$m_1 v_i + m_2 v_i = (m_1 + m_2) v_f$$

$$(20\ 000 \times 3.0) + 0 = 30\ \ 000 \times v_f$$

$$v_f = 2 \text{m s}^{-1}$$

The most common error was to try to use a conservation of kinetic energy approach. It is recommended that students review conservation of momentum in collisions.

Question 1d.

Marks	0	1	2	Average
%	20	7	74	1.6

This question required students to compare the kinetic energies before and after the collision.

$$E_K = \frac{1}{2} m v^2$$

$$E_{K\ initial} = \frac{1}{2} \times 20\ 000 \times 3^2 = 90\ \ 000 \text{ J}$$

$$E_{K\ final} = \frac{1}{2} \times 30\ 000 \times 2^2 = 60\ 000 \text{ J}$$

The drop in kinetic energy shows the collision to be inelastic.

Some students made errors when converting to scientific notation or when answering the question using momentum rather than energy.

Question 1e.

Marks	0	1	2	3	Average
%	11	11	10	67	**2.4**

This question required a conservation of momentum approach.

$$m_1 v_i = m_1 v_f + m_2 v_f$$

$$(20\ 000 \times 2) = (20\ \ 000 \times v_f) + (10\ 000 \times 2)$$

$$40\ 000 = 20\ 000 v_f + 20\ 000$$

$$\Rightarrow v_f = 1.0\ m\ s^{-1}$$

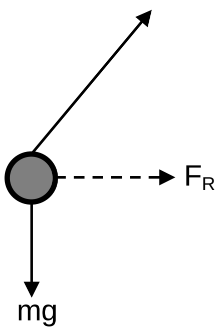
The fact that the result is positive indicates the direction is to the **right**.

The most common errors involved incorrect signs, suggesting that students do not fully understand the vector nature of momentum. It is important that students are familiar with recoil as well as sticky collisions.

Question 2a.

Marks	0	1	2	Average
%	24	23	53	**1.3**

There are only two forces on the ball: tension and the gravitational weight force. As a result of the direction of the application of the tension there is an unbalanced force horizontally inwards – the resultant force.



The most common errors were to mislabel the forces or misrepresent the resultant force as a force that would exist without the other two. Many students also added extra arrows incorrectly.

Question 2b.

Marks	0	1	2	3	Average
%	33	21	1	45	**1.6**

There were two commonly used approaches to solving this problem.

The first was to recognise that the angle between the string and the vertical was 30°, then use the *sin* trigonometry identity:

$$sin30 = \frac{O}{H} = \frac{mv^2/r}{T}$$

$$\therefore T = \frac{2 \times 1.7^2 / 0.5}{0.5}$$

$$T = 23N$$

The second was to use Pythagoras' theorem:

$$T = \sqrt{\left(\frac{mv^2}{r}\right)^2 + (mg)^2}$$

$$T = \sqrt{\left(\frac{2 \times 1.7^2}{0.5}\right)^2 + (2 \times 10)^2}$$

$$T = 23 \text{ N}$$

The most common errors were to treat the motion as vertical circular motion. Other errors were mathematical.

The possibility that students were not told of the change of velocity from 1.5 to 1.7 m s^{-1} was taken into consideration. Students who used a value of 1.5 correctly were awarded full marks.

Question 3a.

Marks	0	1	2	Average
%	37	6	57	1.2

Students had to convert the data to the appropriate units and solve:

$$k = \frac{F}{x}$$

$$k = \frac{1.5}{0.75} = 2.0 \text{ N m}^{-1}$$

Common errors involved incorrectly calculating the weight force from the mass and/or incorrectly converting from centimetres to metres. Students are expected to be able to convert between units; for example, centimetres to metres.

Question 3b.

Marks	0	1	2	Average
%	29	24	48	1.2

Students had to first identify graph B as the correct graph then justify their choice by identifying the key aspects of the graph. These were:

- that the speed was minimal (zero) at the top and bottom
- that the speed was maximum in the middle.

The question stem and the graphs themselves identified speed as the variable to be discussed. Many students wrote about kinetic energy but if they did not explicitly link kinetic energy to speed then they were not addressing the question.

Question 4a.

Marks	0	1	2	Average
%	25	6	69	1.5

The question called for the calculation of the energy stored in a spring and two methods were common:

$$E_s = area\ under\ graph = \frac{1}{2}bh$$

$$E_s = \frac{1}{2} \times 0.5 \times 72$$

$$E_s = 18\ \mathrm{J}$$

Alternatively:

$$k = \frac{F}{x} = \frac{72}{0.5} = 144$$

$$E_s = \frac{1}{2}kx^2$$

$$E_s = 0.5 \times 144 \times 0.5^2 = 18\ \mathrm{J}$$

The most common errors were mathematical, involving failure to square the x. Others used $base \times height$ for the area of the triangle.

Question 4b.

Marks	0	1	2	Average
%	25	2	73	1.5

This question required students to equate kinetic energy to the energy stored in the spring, which was calculated in Question 4a.

$$E_k = \frac{1}{2}mv^2$$

$$18 = 0.5 \times 4.0 \times v^2$$

$$v^2 = 9$$

$$\therefore v = 3\ \mathrm{m\ s^{-1}}$$

The most common error was not to take the square root at the end.

Question 4c.

Marks	0	1	2	Average
%	22	25	52	**1.3**

The correct approach was to identify that the impulse given by the spring is the change in momentum of the car.

$I = m\Delta v$

$I = 4.0 \times 2.0 = 8 \text{ kg m s}^{-1}$

The correct unit of kg m s^{-1} or N s was accepted.

The most common error was to incorrectly quote the unit either as kg/m s^{-1} or N/s.

Question 4d.

Marks	0	1	2	3	Average
%	41	5	2	51	**1.7**

Two common approaches were used for this question. The first found the acceleration then used kinematics:

$a = \frac{F}{m} = \frac{2.0}{4.0} = 0.50 \text{ m s}^{-2}$

$u = 2, v = 0, a = -0.5, x = ?$

$v^2 = u^2 + 2ax$

$0^2 = 2^2 - 2 \times 0.50 \times x$

$x = 4.0 \text{ m}$

The alternative was to use a work approach:

$\frac{1}{2}mv^2 = Fd$

$0.5 \times 4.0 \times 2.0^2 = 2 \times d$

$d = \frac{8}{2} = 4.0 \text{ m}$

The most common errors for students who were able to make a start on a solution were mathematical.

Question 5a.

Marks	0	1	2	3	Average
%	23	8	8	61	**2.1**

This projectile motion question required a two-step solution:

$u = 40sin30 = 20, a = -10, x = 0, t = ?$

$x = ut + \frac{1}{2}at^2$

$0 = 20t - 5t^2$

$t^2 - 4t = 0$

$t = 4\ sec$

then,

$d = vt$

$d = 40cos30 \times 4$

$d = 139$ m

A number of students used the range equation incorrectly. As has been advised in previous examination reports, students who wish to use derived formulas must ensure that they are used correctly.

Other students used $v = u + at$ to find the time of flight, but many students who used this approach forgot to double the time.

It is recommended that students do not use the strategy of finding the time to the top of flight and doubling it as the students who did so, frequently forget to double the result.

Question 5b.

Marks	0	1	2	Average
%	49	16	35	0.9

Students were first required to identify the correct graph of kinetic energy, which in this case was graph A. They were then required to justify their choice by identifying the key aspects of the graph which were:

- that the kinetic energy is maximal at the beginning and end of the flight
- the kinetic energy is minimal **but not zero** at the top of the flight/at the midpoint.

This question was not answered well. Many students incorrectly stated that the kinetic energy was zero at the top of the flight path. Others discussed the speed of the ball; however, as the question stem and graphs clearly identified kinetic energy as the variable to be discussed, students who discussed speed were not addressing the question.

Question 6a.

Marks	0	1	2	3	Average
%	42	40	16	2	0.8

Students were required to identify the following three points:

- that the orbit must be over the equator
- that the orbital period must be 24 hours
- that the mechanics of the orbit can be described using formulas such as $\frac{mv^2}{r} = \frac{GMm}{r^2}$.

This proved to be a difficult question, with few students awarded full marks.

The most common error was to restate the question stem and state that 'a geosynchronous orbit was one where the satellite remains stationary over a fixed point'.

Question 6b.

Marks	0	1	2	3	Average
%	12	20	32	36	1.9

Students were required to identify three points:

- that Emily is incorrect
- that apparent weightlessness can occur in regions where a gravitational field exists
- that the apparent weightlessness is the result of the normal or reaction force equalling zero.

The most common errors involved answers such as ‘Emily is both correct and incorrect’ or ‘Emily is partially correct’, or contradiction, where the student would initially state that Emily was incorrect and later in the response state that she was correct.

Area of study – Electronics and photonics

Question 7a.

Marks	0	1	2	Average
%	33	5	62	1.3

This was a voltage divider problem.

$$V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)$$

$$V_{out} = 12\left(\frac{2}{4 + 2}\right)$$

$$V_{out} = 4\text{ V}$$

An alternative approach used by many students was to find the circuit current and apply Ohm’s law.

$$R_{total} = 6\ \Omega$$

$$\Rightarrow I = 2\text{ A}$$

$$V = RI = 2 \times 2 = 4\text{ V}$$

The most common errors were to either incorrectly solve for the resistance of the parallel resistors or to incorrectly apply the voltage divider equation.

Question 7b.

Marks	0	1	2	Average
%	36	3	60	1.3

In finding the current, two approaches were seen.

$V = 4\text{ V}$ from Question 7a. and $R = 4\ \Omega$ from the question stem.

$$I = \frac{V}{R} = \frac{4}{4} = 1\text{ A}$$

Alternatively:

$I_{supply} = 2\text{ A}$

$I_{R2} = \frac{I_{supply}}{2} = 1\text{ A}$

The most common error was to give the supply current (2A) rather than the branch current.

Question 7c.

Marks	0	1	2	Average
%	60	1	39	0.8

The first step in solving this problem was to realise that the diode would act as a clamp, resulting in the voltage across R_2 being 5 V. The second step was applying Ohm's law.

$I = \frac{V}{R} = \frac{5}{4} = 1.25\text{ A}$

This question was not answered well. The most common error was an inability to identify the voltage across R_2 as 5 V.

Question 8a.

Marks	0	1	2	3	Average
%	49	11	4	37	1.3

This question required a careful analysis of the circuit. The steps for solving were:

- As each LED drops 3 V that means that 9 V will be dropped across the LED network.
- Therefore, 3 V will be dropped across the resistor, giving a supply current of 2 A.
- The supply current will split 50/50 so each LED arm will carry 1 A.
- $P = VI = 3 \times 1 = 3W$ per LED.
- 6 LED's at 3 W each gives 18 W.

This question was not answered well, but there was no single common error. A range of illogical responses was given.

Question 8b.

Marks	0	1	2	Average
%	48	31	21	0.8

Students were required to articulate the following points:

- The current in the arm containing the failed LED will fall to zero.
- The current in the other LED arm will double.
- The supply current will remain unchanged.

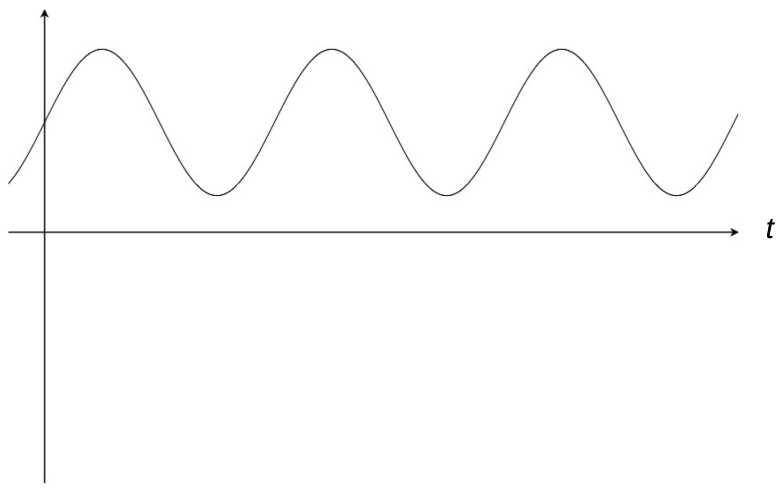
Many students struggled with this question. Many students stated that 'if one LED fails the rest in that arm would fail', which is neither a valid assertion nor a response to the question. Students also made statements such as 'all the voltage would be dropped across the other LEDs', which also did not address the question.

Students should ensure that their responses address the question that is asked.

Question 9

Marks	0	1	2	Average
%	73	13	14	0.4

Students were required to indicate the magnitude of the light intensity in the fibre-optic cable as the input signal varied. An appropriate response was:



Graphs that touched the *x*-axis were also accepted. Graphs that went below the *x*-axis and suggested a negative intensity were not accepted.

This question was not answered well. Many students drew generic diagrams of modulation, but these were inappropriate as the question stem clearly asked for the intensity of the light.

Question 10a.

Marks	0	1	Average
%	1	99	1

From the graph the correct value was 1000 Ω.

Question 10b.

Marks	0	1	2	Average
%	34	2	64	1.3

This question required a voltage divider approach.

The first step was to find the thermistor resistance at –2 °C from the graph, which was 4000 Ω.

$$V_{out} = V_{in}\left(\frac{R_1}{R_1+R_2}\right)$$

$$2 = 6\left(\frac{R_1}{R_1+4000}\right)$$

Note the formula has been modified to find V_{out} over R_1 rather than R_2.

$$\Rightarrow \frac{R}{R+4000} = \frac{1}{3}$$

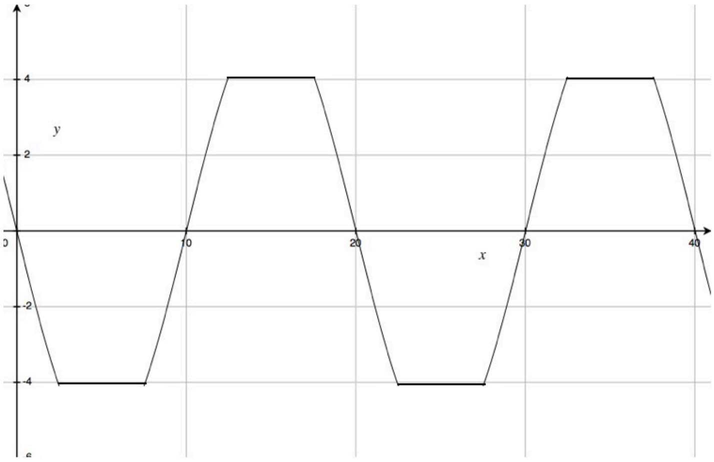
$\Rightarrow R = 2000\ \Omega$

The most common error was to incorrectly set up the voltage divider equation.

Question 11a.

Marks	0	1	2	Average
%	14	25	61	1.5

Most students were able to draw an inverted, clipped sine wave.



Square waves were not accepted as it is not possible to assess the clipping voltage.

Question 11b.

Marks	0	1	2	Average
%	19	36	45	1.3

Students needed to clearly identify what clipping was and how it was caused.

- Clipping is a distortion of the output waveform where the tops and/or bottoms get cut off.
- It is caused by the amplifier operating outside its linear region and the peak of the amplified signal exceeds the maximum (or supply) voltage of the amplifier.

Many students stated that clipping occurs when the input signal exceeds the maximum output voltage of the amplifier. However, clipping in this case occurs when the input signal exceeds 100 mV, which is significantly below the 4 V maximum output.

Area of study – Electric power

Question 12

Marks	0	1	2	3	Average
%	10	14	28	48	2.2

At least four field lines for each situation were required.

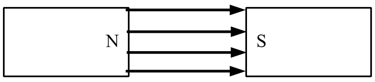


Figure 17a

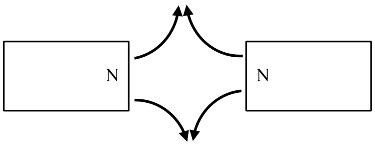


Figure 17b

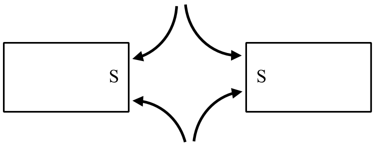


Figure 17c

The most common errors were not to draw the lines for Figure 17a. parallel to each other and to give incorrect directions for Figures 17b. and 17c.

Question 13a.

Marks	0	1	2	Average
%	15	6	80	1.7

Students were asked to find the force on a current-carrying wire.

$F = BIl$

$0.32 = B \times 2000 \times 3$

$\therefore B = 5.3 \times 10^{-5}\ \mathrm{T}$

The most common errors were arithmetic.

Question 13b.

Marks	0	1	2	Average
%	37	22	41	1.1

Students were first required to identify **C (east)** as the correct direction then support this with a statement. The most appropriate approach was to identify the right-hand slap rule (or similar) with the fingers pointing north and the thumb pointing down. This resulted in the palm facing east.

Many students ignored the information in the stem and tried to explain their own understanding of the flow of current in a lightning strike. Students are reminded to carefully read the question stem.

Question 14a.

Marks	0	1	Average
%	60	40	0.4

A and B

Question 14b.

Marks	0	1	2	Average
%	56	27	18	0.6

Students were required to identify **horizontal** as the correct starting position, then justify this decision with a statement such as, 'In this position the force is maximal' or 'In this position the torque is maximal'.

Many students struggled with this question and were not able to identify horizontal as the correct position. Some students who were able to identify horizontal as the correct position were often unable to clearly articulate why.

Question 14c.

Marks	0	1	2	Average
%	44	22	34	0.9

Students were required, firstly, to identify the two improvements that would increase the speed of the motor. These were **A** and **B**. Secondly, they were asked to explain their choices. Correct explanations were: 'Increasing the battery voltage leads to an increase in loop current, which leads to an increase in force: $F = nBIl$.' or 'Increasing the number of turns leads to an increase in force due to $F = nBIl$.'

The most common errors were not to identify both improvements.

Question 15a.

Marks	0	1	2	Average
%	14	27	59	1.5

Students were required to find flux.

$\Phi = BA$

$\Phi = 0.0050 \times 0.0060$

$\Phi = 3.0 \times 10^{-5}\ \text{Wb}$

The most common errors were to give the incorrect unit or make arithmetical errors.

Question 15b.

Marks	0	1	2	3	Average
%	41	28	11	19	1.1

Students were asked to identify the direction of current through the resistor, which was **left**. They were then asked to explain their answer. Students were required to demonstrate their understanding by articulating the following points:

- The initial flux is to the left and decreasing.
- The induced flux will be to the left and increasing.
- The right-hand grip rule/right-hand solenoid rule indicates current to the left in the resistor.

This question proved difficult for most students. A number of students simply stated Lenz's law, which was not specific enough in this context. While many students were able to articulate one, or even two, of these points, very few were able to create a coherent narrative from the initial change in flux to the final induced current.

It is recommended that students practise responding to this type of question with a series of connected statements.

Question 16a.

Marks	0	1	2	Average
%	41	1	59	1.2

The most appropriate approach was to use a power equation:

$$P = \frac{V^2}{R}$$

$$P = \frac{18^2}{9}$$

$$P = 36\ \text{W}$$

Most errors were arithmetic, with students forgetting to square the numerator.

Question 16b.

Marks	0	1	2	Average
%	69	1	30	0.6

There were two common approaches to solving this question. The first was to find the circuit current and use this to find the voltage drop across the lines.

$$R_{total} = 12\ \Omega$$

$$I = \frac{V}{R} = \frac{18}{12} = 1.5\ \text{A}$$

$$V_{drop} = RI = 3 \times 1.5 = 4.5\ \text{V}$$

Alternatively, some students used a voltage divider approach using the 3 ohms of the line (R_2) and the 9 ohms of the globe (R_1).

$V_{out} = V_{in}\left(\frac{R_2}{R_1+R_2}\right)$

$V_{out} = 18\left(\frac{3}{12}\right)$

$V_{out} = 4.5\text{ V}$

This question was not answered well. The range of responses indicated that students struggled to model this. Many students simply added all the resistances in the circuit. It is recommended that students spend more time learning to analyse line loss.

Question 16c.

Marks	0	1	2	3	Average
%	64	4	1	31	1

A two-step solution was required to solve this question. The first step was to identify the voltage across the globe as the supply voltage minus the line loss calculated in Question 16b.

$V_{globe} = V_{supply} - V_{loss}$

$V_{globe} = 18 - 4.5 = 13.5\text{ V}$

The second step was to solve for the power dissipated by the globe.

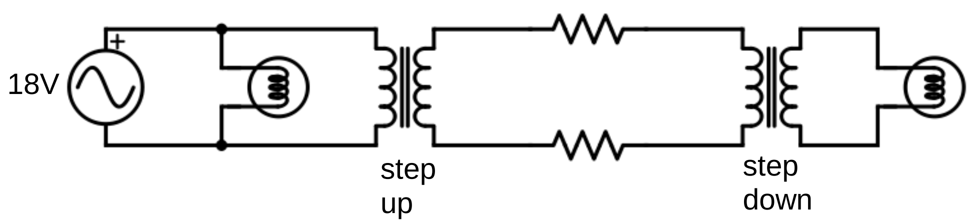
$P = \frac{V^2}{R} = \frac{13.5^2}{9} = 20\text{ W}$

This question was not answered well. The most common error was not being able to identify the voltage across the globe. There were also a number of arithmetic errors.

Question 16d.

Marks	0	1	2	Average
%	48	39	13	0.7

Students were required to draw a schematic diagram.



This question was not answered well. The most common error was to draw the circuit with a DC supply. Another common error was not knowing how to draw or place transformers in the circuit.

Question 16e.

Marks	0	1	2	3	Average
%	29	14	31	26	1.6

Students were required to identify three points.

- Transformers maintain constant power.
- Transformers allow power to be transmitted at high voltage and low current.
- Reducing current reduces power loss as power loss is proportional to I^2.

While most students were able to articulate one or two of these points, few were able to articulate all three. The most common omission was the concept of fixed or constant power delivery.

It is recommended that students familiarise themselves with the benefits of transformers in power distribution.

Question 17a.

Marks	0	1	2	Average
%	29	4	68	1.4

This question required a simple conversion between period and frequency.

$$f = \frac{1}{T} = \frac{1}{0.040} = 25\ \text{Hz}$$

The most common error was to fail to convert msec to sec.

It is recommended that students ensure they are comfortable with simple skills such as converting between units.

Question 17b.

Marks	0	1	Average
%	17	83	0.9

Students were required to convert peak voltage to RMS voltage.

$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = 2.5\ \text{V}_{RMS}$$

Question 17c.

Marks	0	1	2	Average
%	64	21	15	0.5

Students were required to identify the following:

- The emf is greatest when the loop is horizontal.
- At this point the rate of change of flux is maximal.

This question was not answered well. The most common error was to state that the emf was greatest when the loop was vertical because the flux/area at this point is greatest. It was clear that many students were not aware of the relationship between flux and emf.

Question 17d.

Marks	0	1	2	3	4	Average
%	5	7	19	33	35	2.9

Suggested change	emf (increases, decreases, no effect)
Increase the number of turns in the rotation coil.	**increases**
Increase the frequency of rotation of the coil.	**increases**
Increase the strength of the permanent magnets.	**increases**
Reduce the resistance of the resistor R.	**no effect**

The most common error was to state that the final change (reducing the resistance) would affect the emf.

Area of study – Interactions of light and matter

Question 18a.

Marks	0	1	2	Average
%	41	2	58	1.2

Students were required to draw on their understanding of interference.

X is the second dark band, which means that the path difference is 1.5 lambda.

$1.5\lambda = 750$

$\lambda = 500 \text{ nm}$

The most common error involved not knowing that the second nodal line was 1.5 wavelengths.

Question 18b.

Marks	0	1	2	Average
%	39	2	59	1.2

Most students were able to find the path difference to the second antinodal line.

Second antinodal line means that the path difference is $2\,\lambda$.

$2 \times 500 = 1000 \text{ nm}$

Question 18c.

Marks	0	1	2	Average
%	35	15	50	1.2

Students were required to identify **response D** as the result of increasing the slit width. To explain their choice, students were required to articulate two points.

- The width of the pattern is proportional to $\frac{\lambda}{w}$.
- As slit width increases the pattern width decreases.

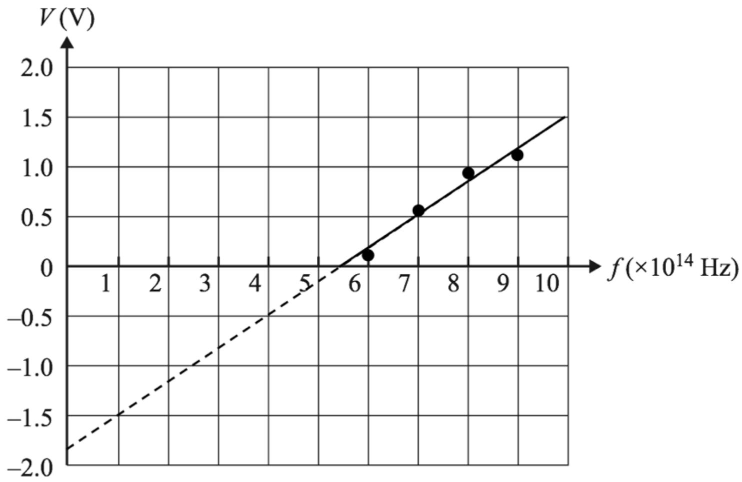
A large number of students referred to Young's double-slit experiment, which was not appropriate. Other students could not refer to factors that affect diffraction.

It is recommended that students familiarise themselves with diffraction as well as interference.

Question 19a.

Marks	0	1	2	Average
%	8	11	81	1.8

Most students were able to correctly plot the points and rule a line of best fit.



A number of students did not continue the line below the *x*-axis, which made it difficult for them to complete Question 19b. Other students simply joined the dots with a jagged line.

Question 19b.

Marks	0	1	2	3	Average
%	27	19	20	34	1.6

Students were required to use the graph they had drawn to derive the answers. As there were allowed variations in the line that was ruled, there were allowed variations in student responses. Examples of correct values derived from the graph in Question 19a. would be:

Planck's constant: 3.5×10^{-15} eV s

Threshold frequency: 5.5×10^{14} Hz

Work function: 1.8 eV

The most common errors were to simply quote Planck's constant from the data sheet or to read the threshold frequency as 5.5 Hz.

Question 19c.

Marks	0	1	2	Average
%	70	16	14	0.5

Students were required to indicate that the voltage measurement provides information about the maximum kinetic energy of the photoelectrons.

It was evident that many students found this question difficult. Some students were able to link the voltage to kinetic energy but did not indicate that it was the maximum kinetic energy.

Many students wrote about other information regarding the photoelectric effect that could be derived from the graph such as the work function of the metal or the threshold frequency. Such responses were not appropriate as the question stem clearly asked about the photoelectrons.

Students are reminded that, while the information on their sheet of notes can act as a reminder, they must understand that copying phrases directly from the sheet without specific reference back to the question will generally not be acceptable.

Question 19d.

Marks	0	1	2	3	Average
%	31	15	18	36	1.6

Students were required to articulate the following:

- The two graphs would be the same.
- The graphs support the particle theory of light.
- The energy of the photons depends on their frequency, not the intensity of the light source.

Most students were able to articulate the first two points but could not articulate the third.

Question 20a.

Marks	0	1	2	Average
%	39	9	51	1.1

By applying the formula for the de Broglie wavelength:

$$\lambda_d = \frac{h}{mv}$$

$$0.36 \times 10^{-9} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times v}$$

$$v = 2.0 \times 10^{6} \text{ m s}^{-1}$$

Common errors included not converting nm to m, using the incorrect Planck's constant or using incorrect versions of the formula.

Students had to use the formula provided on the formula sheet: $\lambda = {}^{h}/_{p}$

Students should also spend more time learning which Planck's constant to use.

Question 20b.

Marks	0	1	2	3	Average
%	49	5	4	43	1.4

Using the energy formula:

$$E = \frac{hc}{\lambda}$$

$$E = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{0.36 \times 10^{-9}}$$

$$E = 3450 \text{ eV}$$

The most common errors were not converting nm to m, or calculating the energy in J but then either incorrectly converting to eV or not converting at all.

Question 20c.

Marks	0	1	2	Average
%	43	31	26	0.9

Students were required to articulate two points:

- that the amount of diffraction depends on wavelength
- that the similarity of the patterns implies that the wavelengths are the same.

Common errors included stating that similar wavelengths were due to similar energies or velocities.

Question 21a.

Marks	0	1	2	Average
%	35	11	55	1.2

By using the energy formula:

$$E = \frac{hc}{\lambda}$$

$$2.6 = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{\lambda}$$

$$\lambda = 480 \text{ nm}$$

The most common error was to use the wrong Planck's constant. It is recommended that students spend more time learning when to use which version.

Question 21b.

Marks	0	1	2	Average
%	33	3	65	1.3

A single, downwards-pointing arrow from n = 3 to n = 1 was required.

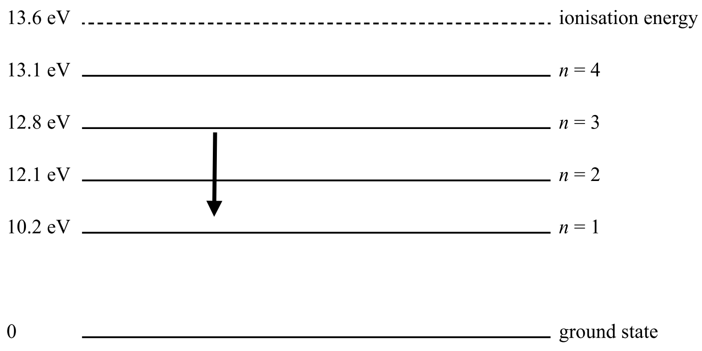


Figure 25
not to scale

The most common errors were to draw an upwards-pointing arrow or to draw a line and fail to give a direction.

A number of students drew subsequent arrows as part of their working for Question 21c., which obscured their response to this question.

Question 21c.

Marks	0	1	2	3	Average
%	23	6	36	36	1.9

Students needed to give six energies:

0.7 eV, 1.9 eV, 2.6 eV, 10.2 eV, 12.1 eV and 12.8 eV

The most common errors were to provide too few energies or too many. Students who gave too many included transitions from n = 4 or from the ionisation energy.

Detailed studies

Detailed study 1 – Einstein's special relativity

Question	% A	% B	% C	% D	% No Answer	Comments
1	28	21	48	3	0	Although both observers are in different inertial frames each will observe time passing at the same rate in their own frames.
2	2	45	49	5	0	Anna sends the two pulses simultaneously from her perspective and both pulses travel at the same speed. The space lab is moving towards her while Barry moves away, so she will see the signal reach the spacelab first as it will travel a shorter distance.
3	6	8	79	7	0	
4	9	75	12	4	0	
5	9	69	11	11	0	
6	16	8	71	5	0	
7	58	20	11	11	1	

Question	% A	% B	% C	% D	% No Answer	Comments
8	9	25	19	47	1	As the particle is accelerating it does not have a constant velocity, so special relativity cannot be applied in this situation.
9	11	61	12	14	1	
10	17	38	32	11	1	By conservation of energy: $(\gamma - 1)m_0c^2 = m_0c^2 + KE_{nucleus}$ $(3 - 1)m_0c^2 = m_0c^2 + KE_{nucleus}$ $2m_0c^2 = m_0c^2 + KE_{nucleus}$ $\therefore KE_{nucleus} = 1.0\ m_0c^2$
11	7	7	49	36	1	As light is an electromagnetic phenomenon, only the electromagnetic properties of a medium will affect its speed, which implies that option **C** is the correct answer. In all other cases the measurement of the speed of light would be constant.

Detailed study 2 – Materials and their use in structures

Question	% A	% B	% C	% D	% No Answer
1	3	1	96	1	0
2	18	12	13	57	0
3	6	75	2	18	0
4	7	9	6	78	0
5	68	8	8	16	0
6	71	11	6	10	0
7	5	13	63	19	0
8	89	2	3	6	0
9	53	21	15	12	0
10	4	16	70	9	1
11	19	64	10	6	1

Detailed study 3 – Further electronics

Question	% A	% B	% C	% D	% No Answer	Comments
1	31	44	16	8	1	The mains wiring with the highest voltage represents the greatest risk.
2	1	88	8	3	0	

Question	% A	% B	% C	% D	% No Answer	Comments
3	11	35	41	13	0	An ideal diode will conduct when there is a forward voltage potential. Because of the capacitor, the voltage at X may well be greater than the voltage at E at any arbitrary time. Thus, the diode will only conduct when the voltage at W is higher than the voltage at X. The most frequent incorrect response was option B, suggesting that students did not know the function the capacitor would play.
4	38	10	42	9	0	The greater the ratio of $\frac{\tau}{T}$, the better the smoothing. The period, *T*, of the 5 kHz input is much less than the *T* of the 50 Hz input. Therefore, the ratio will be lowest using the 50 Hz input and the ripple will be largest. The most frequent incorrect response was option C, which suggested that students were not aware of the ratio described.
5	20	14	23	42	1	$\tau = RC$ $15 \times 10^{-3} = 400 \times C$ $\therefore C = 37.5 \times 10^{-6}$
6	21	23	45	10	0	As the capacitor charges the current into it will fall to zero. Therefore, option A was the correct response.
7	11	10	17	61	0	
8	13	55	19	11	2	
9	19	46	25	10	1	Without the capacitor there will be no smoothing. The Zener diode will limit the output to 5 V.
10	42	19	17	21	2	The current through the load is: $I = \frac{V}{R} = \frac{5}{25} = 0.2\ A$ The current through the regulator is the same (0.2 A) and the voltage dropped is 3 V (8 – 5 = 3). Therefore, the power dissipated by the regulator is: $P = VI = 3 \times 0.2 = 0.6\ W$

Question	% A	% B	% C	% D	% No Answer	Comments
11	17	26	39	17	2	The maximum voltage drop across the regulator is: $P = VI$ $2.7 = V \times 1$ $V = 2.7\ V$ This means that the DC supply voltage cannot exceed 7.7 V (5 + 2.7). Given that the minimum DC supply voltage is 6.2 V, the correct response was option C.

Detailed study 4 – Synchrotron and its applications

Question	% A	% B	% C	% D	% No Answer	Comments
1	81	6	10	3	0	
2	8	13	20	58	1	
3	82	8	3	7	0	
4	6	81	7	7	0	
5	2	3	92	3	0	
6	16	4	68	12	0	
7	20	17	20	43	0	For a crystal of known layer spacing, the Bragg angle is proportional to $\sin\theta$. This allows for a specific wavelength to be selected based on the orientation of the crystal.
8	17	8	64	10	1	
9	3	86	7	4	1	
10	8	38	38	14	1	The angle of 22° will be the first peak of one of the layers. This gives *d* = 0.40 nm. The 26° peak is either the first peak of the other layer or the second peak of the layer just found finding *d* for *n* = 1 and *n* = 2 gives *d* = 0.34 nm or *d* = 0.68 nm. This indicates that it must be the other layer spacing. That means the 48° angle must be the second peak for one of the layers. Using *n* = 2 gives *d* = 0.40 nm. Therefore, the correct response was option C.
11	5	77	11	6	0	

Detailed study 5 – Photonics

Question	% A	% B	% C	% D	% No Answer	Comments
1	29	48	8	13	2	Only option B gave broad spectrum, incoherent light. A star's light is incoherent while the laser and LED are monochromatic. The most frequent incorrect response was option A, which suggested that students thought that a star produces broad spectrum light rather than a range of discrete wavelengths.
2	6	10	65	19	0	
3	17	12	62	10	0	
4	15	13	17	54	0	
5	19	54	13	13	0	
6	60	19	10	12	0	
7	12	13	17	58	0	
8	52	4	17	27	0	
9	8	19	31	42	0	Material dispersion refers to the change in refractive index (and therefore velocity of light) at different wavelengths. To reduce material dispersion the best approach is to reduce the range of wavelengths being transmitted.
10	62	10	17	12	0	
11	12	12	37	40	0	For the light to stay in the fibre, the light must strike the core-cladding interface at an angle greater than the critical angle. If the fibre is bent, the light can strike the curved core-cladding interface at less than the critical angle, and some light will be lost to transmission into the cladding.

Detailed study 6 – Sound

Question	% A	% B	% C	% D	Comments
1	20	3	66	10	
2	3	91	6	0	
3	85	5	6	4	
4	7	73	17	4	
5	12	12	9	68	
6	1	10	87	2	
7	8	20	34	38	In the centre, constructive interference will produce a loud region. Each subsequent loud region will occur half a wavelength (0.5 m) from that position. The first quiet region will be 0.25 m from the centre. The second quiet region will be 0.5 m further on at 0.75 m from the centre. This will place Yasmin 4.25 m from speaker B.
8	68	8	15	9	

Question	% A	% B	% C	% D	Comments
9	6	35	53	5	The question described a pipe, open at one end and closed at the other, and subjected to increasing frequencies. If the pipe can initially support a standing wave at 256 Hz, what would be the second frequency at which a standing wave could be supported? The length of the pipe will be $\lambda/4$ at 256Hz and $3\lambda/4$ at the second frequency, indicating that the second frequency will have a wavelength one third that of the first frequency and therefore the second frequency will be three times the first or 768 Hz (option C). Option B was also accepted as a correct answer as the term 'second harmonic' has a specific meaning and refers to a frequency twice that of the fundamental, or 512 Hz in this case.
10	5	75	6	14	
11	80	6	8	6	