2013 Physics GA 3: Examination

GENERAL COMMENTS

The 2013 Physics examination was the first under the new examination and study design structure, and consisted of one two-and-a-half hour exam covering Units 3 and 4. Students were required to answer questions from the four core Areas of Study and one Detailed Study.

Students and teachers should note the following points in relation to the 2013 Physics examination.

- Attempting a question a number of different ways will not be awarded any marks unless all methods are correct. It is expected that students will make it clear which working is intended by crossing out the rest. Students are advised to neatly cross out the working that they do not want marked.
- Students should be encouraged to set out their work clearly, so assessors can follow what they have done.
- 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 A3 sheet of notes. Some students included irrelevant, contradictory or incorrect material and could not be awarded full marks.
- Many students responded to questions that required an explanation by answering in dot-point format. This may help to ensure good, concise answers. In particular, 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.
- 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'.
- 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 A3 sheet of notes.
- Derived formulas from the student's A3 sheet 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. In particular, they must ensure that it is in scientific mode and that it does not truncate answers after one or two decimal places.
- Rounding-off 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.
- 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 of concern from this exam included

- application of vectors in Newton's second law and the constant acceleration formulas
- connected bodies
- energy conversion and conservation
- the conversion of units; for example, from nanometre to metre
- more complex projectile motion
- understanding of series circuits
- confusion between Faraday's law and Lenz's law
- understanding of flux and EMF
- understanding of the photoelectric effect
- applying the concept of path difference in interference patterns
- the distinction between matter and electromagnetic radiation, and which formulas can be applied to each, as well as which value of Planck's constant to use.

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%.

Area of Study – Motion in one and two dimensions

Question 1a.

Marks	0	1	2	Average
%	24	2	75	**1.5**

There were two methods of approaching this question. One involved using the constant acceleration formula $x = ut + 1/2at^2$. Alternatively, because the there was no friction, the net force on the trolley was the component of the weight down the plane (5 sin10). Substituting this into Newton's second law (5 sin10 = 0.5 × *a*) gave an acceleration of 1.74 m s^{-2}.

A common error was to determine the average speed (3.5/2 = 1.75), incorrectly assume this was the final speed at the bottom of the ramp and calculate the acceleration from $v = u + at$.

Question 1b.

Marks	0	1	2	3	Average
%	48	16	4	32	**1.2**

This was a two-stage problem. Students first needed to determine the acceleration using $x = ut + 1/2at^2$. This gave 0.19 m s^{-2}. Using this in Newton's second law, $5\sin 10 - F_r = 0.5 \times 0.19$ resulted in a frictional force of 0.77 N.

Some students obtained the correct acceleration but were unable to apply the concept of net force in Newton's second law. Other students assumed that the acceleration would be the same as in Question 1a., where there was no friction.

A far less common alternative method involved determining the final speed of 1.17 m s^{-1} from the constant acceleration formula $x = (u + v)t/2$. Then using
Work done = ΔKE ➔ $(mg\sin\theta - F_r) \times \text{dist} = 1/2mv^2$ ➔ $(5\sin 10 - F_r)\ 3.5 = ½\ 0.5 \times 1.17^2$, which gave a frictional force of 0.77 N.

Another approach was to first find the acceleration of the block with friction and compare it with the acceleration in the previous question where there was no friction. By getting the difference and multiplying by the mass, as in Newton's second law, students found the frictional force.

Question 2a.

Marks	0	1	Average
%	34	66	**0.7**

The gravitational force on the 2 kg mass was 20 N.

A few students omitted the unit and some decided to calculate the gravitational potential energy instead of the force.

Question 2b.

Marks	0	1	2	3	Average
%	70	3	3	24	**0.8**

The first step was to determine the acceleration of the masses. Since there was no friction, the only force acting was the 20 N determined in Question 2a. So applying Newton's second law, $a = F_{net}/m = 20/(6 + 2) = 2.5$ m s^{-2}. Then applying this to the 6 kg mass, $T = m_2 a = 6 \times 2.5 = 15$ N. Some students set up the equation of motion for each of the masses and then solved them as simultaneous equations.

When calculating the acceleration, some students only considered the 2 kg mass and so got an acceleration of 10 m s^{-2}. There seemed to be some confusion about which masses to include when determining the tension.

Question 3a.

Marks	0	1	Average
%	23	77	**0.8**

The momentum after impact was the same as before impact. This was 12 kg m s^{-1}.

Question 3b.

Marks	0	1	2	Average
%	32	12	56	**1.3**

The first step was to use conservation of momentum to determine the common speed after the collision to be 2 m s^{-1}. Then calculating the total kinetic energy before to be 36 J and the kinetic energy after to be 12 J, it was concluded that the collision was inelastic. Simply stating that sticky collisions are inelastic was insufficient, as the question asked students to use calculations.

Some students were unable to correctly determine the kinetic energies because they forgot to square the velocity. Others calculated momentum instead of kinetic energy.

Question 3c.

Marks	0	1	2	Average
%	29	30	41	**1.1**

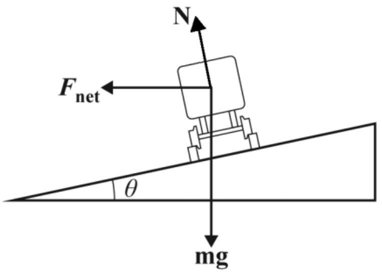
To determine the impulse on m_1 it was necessary to find the change in momentum of m_1. This was 4 – 12 = –8, taking to the right as positive. So the impulse was 8 N s to the left. Since the magnitude of the impulse on m_1 was the same as that on m_2, students could equally well determine the impulse on m_2, as long as they got the direction.

Students knew that impulse was the change in momentum, but were often unable to cope with the vector nature of momentum. Some students used compass directions instead of left/right.

Question 4a.

Marks	0	1	2	Average
%	26	32	42	**1.2**

The expected arrows are shown on the diagram below. It was important for the weight force to be vertical and the normal reaction to be perpendicular to the slope. The weight and normal did not have to be labelled.



Common errors were having the normal force vertical and the net force parallel to the slope.

Question 4b.

Marks	0	1	2	Average
%	45	3	52	1.1

The answer was 7.1°.

Most students used the derived formula, some used a triangle of forces and a few used resolution of forces to get the result. A common mistake was to use the component of the weight force parallel to the plane as the net force. This gave a formula with sin θ instead of tan θ. This gave approximately the same answer, as sin and tan are nearly equal for small values of θ. However, no marks were awarded for this.

Question 5a.

Marks	0	1	Average
%	32	68	0.7

Since the object was moving in a circle at a constant speed, the net force had to be toward the centre of the circle. Therefore, **D** was the correct direction.

Question 5b.

Marks	0	1	2	3	Average
%	53	5	3	40	1.3

There were two forces acting on the mass, tension in the rod up and weight force down. Together these provided the necessary centripetal force. $T - mg = \frac{mv^2}{r}$ Substituting into this gave the tension as 118 N.

While students realised that the net force had to be mv^2/r = 98 N, many did not properly apply the vector nature of the tension and weight.

Question 6a.

Marks	0	1	Average
%	19	81	0.8

At the lowest point the kinetic energy would be zero, and from the graph the gravitational potential energy was zero and the spring potential energy was 20 J. So the total energy was 20 J.

Question 6b.

Marks	0	1	2	Average
%	55	3	42	0.9

The essential principle that needed to be applied was the conservation of energy. From the graph, at point Y there was 10 J of gravitational potential energy and 5 J of spring potential energy. From the previous question the total energy of the system was 20 J. Therefore, there was 5 J of kinetic energy. Using $E_K = ½ mv^2$ the speed was 3.2 m s^{-1}.

The main problem seemed to be that students did not identify that there were three different forms of energy involved at all stages of the motion. They did not subtract both the gravitational potential energy (GPE) and spring potential energy (SPE) from the total energy. Some just subtracted the GPE, while others only subtracted the SPE. Many simply added the GPE and SPE, assuming this would give the kinetic energy.

Question 6c.

Marks	0	1	2	3	Average
%	75	12	6	7	0.5

There were a number of ways in which students could obtain marks for this question. The students had assumed the spring potential energy was zero at point Q. It should have been calculated from the unstretched length as SPE is proportional to Δx^2. It is not linear. Students could also do calculations to show how the energy should have been correctly determined.

Many students thought that the zero of spring potential energy should have been taken at point Y, the centre of the oscillation. Others thought the mass was still moving at points P and Q. Some believed that the problem arose because the gravitational potential energy should have been measured from point P.

Question 7a.

Marks	0	1	Average
%	59	41	**0.4**

The period of the satellite must be the same as that of the Earth, 24 × 60 × 60 = 86400 s.

Some students attempted long calculations. Others simply did not realise the significance of the term ‘geostationary’.

Question 7b.

Marks	0	1	2	Average
%	59	9	32	**0.8**

Using the fact that the centripetal force was provided by the gravitational attraction $GMm/R^2 = 4\pi^2 mR/T^2$ and substituting the appropriate values, the radius was 4.2×10^7 m.

Some students assumed that the gravitational field at the satellite was 10 N kg^{-1}. Others mixed up the equation when transposing. Of those with the correct equation some did not substitute into it correctly, either by forgetting the square on the period or using the mass of the satellite instead of Earth. It was evident in responses that some students had difficulty using their calculators. Of those who did manage to determine the correct radius, some then subtracted (or even added) Earth’s radius. In some cases this gave a negative number

Question 7c.

Marks	0	1	2	3	Average
%	38	21	22	19	**1.2**

- Weight means there is a gravitational force acting on her. Therefore, she has weight.
- Weightlessness occurs when the gravitational force is zero, when the gravitational field strength is zero. This does not apply.
- Apparent weightlessness occurs when the reaction force is zero. This does apply as she was in freefall; her acceleration was equal to the acceleration caused by the gravitational field.

Many students explained what the terms meant but did not say whether or not they referred to the astronaut’s particular situation. Some referred to apparent weightlessness as experiencing a small gravitational field. Some believed that space is a vacuum and therefore there is no gravity. Others mixed up the terms ‘weight’ and ‘mass’. There were many long responses that demonstrated considerable confusion.

Question 8a.

Marks	0	1	2	3	Average
%	40	14	4	42	**1.5**

To determine the time of flight, consider the vertical components of the motion and use the constant acceleration formulas. It can be done in one stage using $x = ut + ½at^2 \Rightarrow -15 = 10t - 5t^2$, which, by solving the quadratic equation, gives the answer 3.0 s. Other possibilities include first determining the final speed at the bottom using $v^2 = u^2 + 2ax$ to get $v = 20$, then using $v = u + at$ to get the time of 3.0 s. Another way was to find the time to reach the top, using $v = u + at$, then the distance to the top using $v^2 = u^2 + 2ax$. By adding this distance to the original height students could then use $x = ut + ½at^2$ to get the time for this section and add it to the time for the upward journey. Although the second and third approaches were more involved, they did not involve solving a quadratic equation.

Some students attempted to apply derived formulas to this situation, generally usuccessfully. However, the major problem students encountered was getting the signs correct for up and down when substituting into the constant acceleration equations.

Question 8b.

Marks	0	1	2	3	Average
%	51	9	14	27	**1.2**

On landing, the horizontal component of the velocity was 20 × cos30 = 17.3 m s^{-1} and the vertical component was 20 m s^{-1}, found from $v^2 = u^2 + 2ax$. By applying Pythagoras's theorem, the velocity was $\sqrt{(20^2 + 17.3^2)}$ = 26.4 m s^{-1}. An alternative method would be to use energy conservation. The gravitational potential energy plus kinetic energy at the top would equal the kinetic energy at the bottom. The angle was $\theta = \tan^{-1}(20/17.3)$ = 49°.

The main difficulty was that students could not correctly determine the vertical component of the final velocity.

Area of Study 2 – Electronics and photonics

Question 9

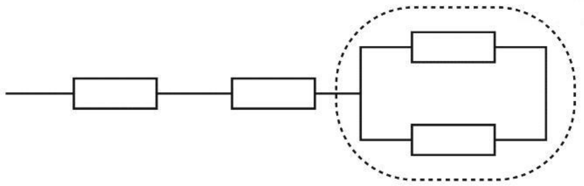
Marks	0	1	2	3	Average
%	22	8	3	67	**2.2**

The largest value of the output voltage was 15 V. With the variable resistor set at 0 kΩ, it used no voltage. So, the whole voltage of the battery was across the output. When the variable resistor was 10 kΩ, it used two thirds of the supply voltage and the voltage across the output was one third or 5 V. So the range of the out voltage was 5 V – 15 V.

Instead of using the voltage divider approach, some students looked at the amount of current flowing at the two extremes and how this would affect the output voltage.

Question 10

Marks	0	1	2	Average
%	15	8	78	**1.7**



There was confusion when attempting to draw the parallel component.

Question 11a.

Marks	0	1	2	Average
%	13	3	84	**1.7**

Applying Ohm's law, R = V/I = 2.5/0.005, the resistance was 500 Ω.

Some students neglected to convert mA to A, or performed an incorrect conversion.

Question 11b.

Marks	0	1	2	Average
%	11	2	87	**1.8**

Using Ohm's law, the resistance of the thermistor was 200 Ω. Then, reading from the graph, this equated to a temperature of 20 °C.

The most common errors involved the conversion of mA to A or an inability to use the calculator correctly.

Question 11c.

Marks	0	1	2	Average
%	12	2	86	**1.8**

Ohm's law gave the resistance as 2000 Ω and then, reading from the graph, the light intensity was 15 lux.

Once again, the most common errors involved unit conversions and use of the calculator.

Question 11d.

Marks	0	1	2	3	4	Average
%	29	4	16	7	45	2.4

From the graph, raising the temperature of the room would increase the resistance of the thermistor. Hence, the voltage across the thermistor would increase and there would be lower voltage across the resistor, so the buzzer would turn off.

From the light-dependent resistor (LDR) graph, reducing the light intensity would increase the resistance of the LDR. Hence, the voltage across it would increase and there would be lower voltage across the resistor, so the buzzer would turn off.

Some students argued that switching off the buzzer would cause the light to be less bright and the temperature to increase. They had reversed the cause and effect. This showed little understanding of the context of the question. Others correctly stated that increasing the temperature or decreasing the light intensity would increase the respective resistances, but did not adequately relate this to the effect it would have on the voltage across the resistor. Some attempted calculations related to the buzzer voltage but generally did not appreciate that the current would change from the original 5 mA. A small number of students suggested that increasing the resistance of the thermistor or LDR would block the voltage from getting through to the buzzer. Others suggested that reducing the resistance of the thermistor or LDR would turn off the buzzer by somehow reducing the total voltage of the circuit.

Question 12a.

Marks	0	1	2	3	Average
%	12	13	4	71	2.4

The voltage of the battery was the sum of the voltages of the light-emitting diode (LED) and the resistor. From the graph, when the current was 10 mA the voltage across the LED was 2.0 V. Using Ohm’s law the voltage across the resistor was 4.5 V. So the battery voltage was 6.5 V.

Question 12b.

Marks	0	1	2	Average
%	50	16	35	0.9

In the LED, electrical energy was converted to light energy, while in the resistor electrical energy was converted to thermal energy.

Some students explained the functions of an LED and resistor instead of describing the energy transfers involved.

Question 13a.

Marks	0	1	2	Average
%	38	14	47	1.1

The gain of the amplifier was the gradient of the linear section of the graph. This was 400.

When determining the gradient it was common for students to take points that were not on the linear section. Others did not convert the input from mV to V and so got answers for the amplification of less than 1. Students should have realised this was not an appropriate answer and checked where they had made the error.

Question 13b.

Marks	0	1	2	Average
%	22	42	36	1.2

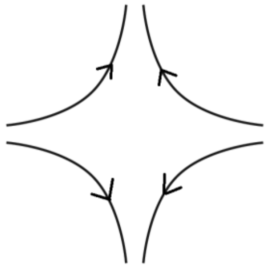
It was an inverting amplifier because an increase in the input voltage produced a decrease in the output voltage. Alternatively, students could have drawn diagrams showing the input and output voltages inverted.

Some students wrote that a positive input gave a negative output. This was insufficient for full marks. Simply stating that the gradient was negative was an indication that it was an inverter but did not describe why it was called an inverter. For two marks, more was required.

Area of Study – Electric power

Question 14

Marks	0	1	2	Average
%	32	22	46	1.2



The question specifically asked for field lines in the dashed box between the solenoids. Many students drew separate patterns for each solenoid without showing how these interacted in the dashed box.

Question 15a.

Marks	0	1	Average
%	23	77	0.8

The number of turns on the secondary coil was six times that on the primary coil, so the voltage across the secondary coil was also six times that of the primary coil. Thus, the answer was 18 V.

Some students either multiplied or divided by $\sqrt{2}$.

Question 15b.

Marks	0	1	Average
%	24	76	0.8

The peak voltage was the RMS value multiplied by $\sqrt{2}$, giving an answer of 25.5 V.

Question 15c.

Marks	0	1	2	Average
%	26	16	58	1.3

Using $P = V^2/R = (18)^2/1200$, the power dissipated was 0.27 W.

A common error was to use the peak voltage.

Question 15d.

Marks	0	1	2	3	Average
%	48	15	21	16	1.1

When the switch was closed there was a sudden change (increase) in the current. This resulted in a change in the flux. By applying Faraday's law this flux change induced a voltage and thus current in the secondary coil. When the switch remained closed there was no further change in the current and thus no change in the flux. This resulted in no more voltage or current in the secondary coil.

Some students referred to the Physics principle involved as Lenz's law instead of Faraday's law. It was important to refer to a change in flux rather than a change in magnetic field. Many students described how a transformer worked with AC, but this did not address the question.

Question 16a.

Marks	0	1	2	Average
%	30	21	50	1.2

The motor rotated anticlockwise. The current was from W to X, the magnetic field was to the right, so according to the right-hand slap rule (or similar) the force was down.

Question 16b.

Marks	0	1	2	Average
%	22	13	66	**1.5**

Applying the formula F = nBIl = 20 × 0.5 × 0.5 × 0.05 the force was 0.25 N.

Some students neglected the number of turns. Others either did not convert the units or converted them incorrectly.

Question 16c.

Marks	0	1	2	Average
%	29	31	40	**1.1**

It would not improve the operation. The coil would stop at 90° because the slip rings would not reverse the current in the armature. Reversing the current every half turn is essential for the motor to operate.

Some students confused the motor with a generator.

Question 17a.

Marks	0	1	2	3	Average
%	37	9	5	49	**1.7**

Firstly, the average EMF needed to be determined. $\varepsilon = -n\,(\Delta\phi)/(\Delta t)) = -1 \times 0.4/0.5 = 0.8$ V. Then, applying Ohm's law gave the current $I = \varepsilon/R = 0.8/0.1 = 8$ A.

A common error was to determine the EMF and assume that was the current.

Question 17b.

Marks	0	1	2	Average
%	51	8	41	**0.9**

The EMF was zero when the flux was not changing; that is, when the gradient of the flux-time graph was zero. This occurred at 0.5, 1.0 and 1.5 seconds.

Question 17c.

Marks	0	1	2	3	4	Average
%	54	17	9	7	13	**1.1**

As the ring descended the flux was up and increasing. Thus, an EMF was induced to oppose the change in flux. This required the induced magnetic flux to be downwards, and therefore a current clockwise when viewed from above.

Many students referred to flux or a change in magnetic field instead of a **change in flux**. Some simply did not give enough detail for a four-mark question. Others determined the direction from the original magnetic field instead of from the induced field.

Question 17d.

Marks	0	1	2	Average
%	74	5	21	**0.5**

At point A: (0), 2.0
At point B: 1.0
At point C: 0.5, 1.5, (2.5)

A common error was for students to include times such as 0.25, 0.75, 1.25, 1.75 and 2.25. It appears they did not fully comprehend what was happening in the situation.

Question 18a.

Marks	0	1	2	Average
%	32	6	62	**1.3**

Students needed to realise this was a simple **series** circuit with the solar cells as the battery, the tool shed as one resistor and the transmission lines as another resistor. The voltage drop across the transmission line resistor was 24 V and the current through it was 6.0 A. By using Ohm's law the resistance of these lines was 4 Ω.

A common error was to assume the current in the lines was 12 A. This indicated a basic misunderstanding of series circuits. Others worked out the resistance to be 4 Ω and then doubled it. They apparently interpreted the statement that the voltage loss in the transmission lines referred to one line only.

Question 18b.

Marks	0	1	2	Average
%	28	3	69	1.4

The power output of the solar cells was 1200 W and the current was 6 A. So using P = VI, the output voltage was 200 V.

Some students worked out the 200 V and then either subtracted or added 24 V. This indicated a fundamental misunderstanding of series circuits. Once again, some students used 12 A as the current instead of 6 A.

Question 18c.

Marks	0	1	2	3	Average
%	31	5	9	55	1.9

The power input was given as 1200 W. The power loss had to be determined by $P_{loss} = VI = 24 \times 6 = 144$. Students could also use V^2/R or I^2R. Hence, the ratio was (144 × 100)/1200 = 12%.

The main errors arose from a misunderstanding of series circuits. Students used the same wrong voltages and currents as they had in the previous parts of the question.

Question 18d.

Marks	0	1	2	3	Average
%	43	5	5	47	1.6

This needed to be approached as a simple series circuit. The first step was to determine the current in the circuit by using the voltage loss in the transmission lines and the resistance of these lines. $V_{loss} = IR \Rightarrow 10 = I \times 2$, so I = 5 A. Knowing the power output of the solar cells was 1200 W and the current output was 5 A, $P_{supply} = VI \Rightarrow 1200 = V \times 5$ can be used to give 240 V.

Some students determined the current as 5 A and assumed this was the answer for the voltage. Others neglected the fact that the toolshed was part of the series circuit and had resistance. They treated the question as if the total resistance of the circuit was 2 Ω. Still others determined the voltage correctly to be 240 V, but then subtracted the 10 V lost in the transmission lines, presumably to get the voltage available at the toolshed.

Area of Study 4 – Interactions of light and matter

Question 19a.

Marks	0	1	Average
%	14	86	0.9

The energy was given by $E = hf = (6.63 \times 10^{\times 34})\ (6.7 \times 10^{14}) = 4.4 \times 10^{-19}$ J.

Some students used the wrong Planck's constant. Others used an incorrect formula, E = hc/f.

Question 19b.

Marks	0	1	Average
%	26	74	0.8

Using the wave equation $c = f\lambda$, $3 \times 10^8 = 6.7 \times 10^{14}\ \lambda$. So, $\lambda = 4.5 \times 10^{-7}$ m.

Some had difficulty with the powers of 10 calculations.

Question 20a.

Marks	0	1	2	Average
%	60	5	34	**0.8**

The longest wavelength would correspond to the smallest energy, which would be 1.08 eV. By substituting into the equation $E = hc/\lambda$, $1.08 = (4.14 \times 10^{-15})(3 \times 10^{8})/\lambda \rightarrow \lambda = 1.15 \times 10^{-6}$ m.

A common error was to assume the energy transition was 3.19 eV. Others used the incorrect Planck's constant.

Question 20b.

Marks	0	1	2	3	Average
%	50	2	14	34	**1.3**

Using $E = hc/\lambda$, a spectral line of 588.63 nm equates to an energy of 2.11 eV. This would result from a transition from 2.11 eV to 0 eV with sodium.

Some students referred to a transition from 0 to 2.11 instead of the other way. Simply stating that there was an energy level at 2.11 was inadequate. Some students worked backwards, assuming a transition from 2.11 to 0 and worked out to which wavelength this would correspond.

Question 21a.

Marks	0	1	Average
%	58	42	**0.4**

Since it required a 1.85 V reverse potential to stop the electrons, the electrons must have had 1.85 eV of kinetic energy. To convert this to joules, multiply by 1.6×10^{-19}, which gives 2.96×10^{-19} J.

Many students did not seem to recognise the relationship between the stopping potential and the energy of the photoelectrons. Others did not convert the value to joules.

Question 21b.

Marks	0	1	2	Average
%	64	5	31	**0.7**

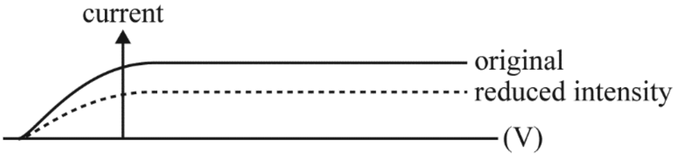
The work function was the difference between the energy of the photon and the energy of the emitted electron.
$W = hf - E_K(\text{max}) = (4.14 \times 10^{-15})(1.00 \times 10^{15}) - 1.85 = 2.29$ eV.

A common error was for students to determine the energy of the photon, but then assume it was the work function. Others used the incorrect Planck's constant.

Question 21c.

Marks	0	1	2	Average
%	34	13	53	**1.2**

Since the same frequency of light was used the energy of the photons was the same. Therefore the energy of the ejected electrons was the same, 1.85 eV. Accordingly, the same stopping voltage was required, 1.85 V. However, since the intensity of the light was reduced, not so many electrons would be ejected. So the graph required needed to look something like the following.



Question 21d.

Marks	0	1	2	Average
%	58	32	10	**0.5**

The frequency of the incident photons was less than the threshold frequency and therefore the photons did not have enough energy to free any electrons. The energy of the photons was less than the work function.

Many students made general statements about the photoelectric effect that did not address the question. There were also students who confused electrons and photons.

Question 22a.

Marks	0	1	2	Average
%	35	37	28	1

The intensity would be bright because the path difference to the centre was zero wavelengths. The question asked about the brightness at the exact centre, so it was important to be specific.

It was common for students to give generalised statements about constructive interference or the path difference being 0λ, 1λ, 2λ, etc.

Question 22b.

Marks	0	1	Average
%	39	61	0.6

Lower frequency means longer wavelength. Therefore, the pattern would be more spread out. So the correct answer was **D**: move further away from the centre of the pattern.

Question 22c.

Marks	0	1	2	3	Average
%	61	7	7	25	1

The first step was to determine the wavelength. For the second bright band the path difference was 2λ and this was 1.4×10^3 nm or 1.4×10^{-6} m. So λ was 7×10^{-7} m. The path difference to the first dark band was $\lambda/2$, which was 3.5×10^{-7} m.

Some students incorrectly used the wavelength from Question 22a. Others did not handle the unit conversions.

Question 22d.

Marks	0	1	2	3	Average
%	26	13	20	41	1.8

The statement was incorrect. Young's experiment demonstrates interference, which is a wave phenomenon. The particle model does not explain interference. The particle model predicts just two bands on the screen. It should be noted that students were not required to make all of these points to obtain full marks.

It was important to refer to interference because the pattern observed on the screen was an interference effect. Some students gave generalised statements that did not address the question adequately.

Question 23a.

Marks	0	1	2	Average
%	61	9	31	0.7

There were a number of ways of approaching this question. The simplest was to use the derived equation $p = E/c = (80000 \times 1.6 \times 10^{-19})/3 \times 10^8 = 4.3 \times 10^{-23}$ kg m s^{-1}. Alternatively, students could have determined the wavelength using $E = hc/\lambda$, which would give 1.55×10^{-11} m, then use $p = h/\lambda$ to give the answer.

Common errors included not converting the energy to joules or using the incorrect Planck's constant.

Question 23b.

Marks	0	1	2	3	Average
%	49	16	10	26	1.2

Student A was correct. The fringe spacing was determined by the wavelength, which in turn depended directly on the momentum.

Some students argued that both A and B were correct.

Section B – Detailed studies

Detailed Study 1 – Einstein's special relativity

Question	% A	% B	% C	% D	% No Answer	Comments
1	8	10	5	78	1	
2	37	39	16	8	0	The speed of sound from A to B = 30/0.0857 = 350 m s^{-1}, while from B to A is 30/0.0909 = 330 m s^{-1}. Speed of sound with no wind = middle value = 340 m s^{-1}, so wind speed = 10 m s^{-1}.
3	46	21	14	19	1	Work done = $(m - m_0) \times c^2 = (5.1 - 1.7) \times 10^{-27} \times 9 \times 10^{16} = 3.1 \times 10^{-10}$ J
4	2	12	4	81	1	
5	18	16	61	5	1	
6	38	34	18	9	1	$E_{total} = mc^2$. So $m = 2.17 \times 10^{-10}/(9 \times 10^{16}) = 2.41 \times 10^{-27}$. Now relativistic mass $m = m_o\gamma$. So $m_o = 2.41 \times 10^{-27}/10 = 2.41 \times 10^{-28}$ kg.
7	3	33	7	57	0	
8	16	36	24	24	0	
9	76	10	8	6	1	
10	9	50	27	14	1	Time dilation, $t = t_0\gamma = 1 \times (1 + [5 \times 10^{-11}])$
11	8	30	37	24	1	The distance is at right angles to motion, so it is unaffected.

Detailed Study 2 – Materials and their use in structures

Question	% A	% B	% C	% D	% No Answer	Comments
1	4	11	9	76	0	
2	4	11	79	6	0	
3	7	67	12	13	0	
4	9	9	18	64	0	
5	48	15	28	8	1	Stress = $1000 \times 10/(4.0 \times 10^{-2}) = 2.5 \times 10^5$ Pa. Young's modulus = $30 \times 10^6/1.5 \times 10^{-3} = 2 \times 10^{10}$ Pa. So strain = stress/Young's modulus = $2.5 \times 10^5/2 \times 10^{10} = 1.25 \times 10^{-5}$. So, $\Delta l = 20 \times 1.25 \times 10^{-5} = 2.5 \times 10^{-4}$ m = 0.25 mm.
6	9	18	60	13	0	
7	6	41	32	20	1	Taking torques about point P, $200 \times 3 + 100 \times 1.5 = T_{SR} \times 4$ so the tension = 187.5 N.
8	7	17	34	42	1	Taking torques about K, $T_{MN} \times 2.0 = 4000 \times 10 \times 3.0 + 1000 \times 10 \times 6.0$, so T_{MN} = 90 000 N
9	56	20	19	5	0	Top is under tension, concrete is weak under tension, so this is where the steel rods should be.
10	12	53	13	21	1	At point G the weight of truck is down, so forces in FG and HG must be up and so is tension. At F force due to FG is downwards and to the right as FG is in tension, so force in FE must be upwards for balance and is also to the right. So the force in FE is outwards, which means it is under compression. This means that at F the force in FH must be to the left, therefore it is in compression as well.
11	9	74	8	8	1	

Detailed Study 3 – Further electronics

Question	% A	% B	% C	% D	% No Answer
1	14	22	60	5	0
2	14	18	50	17	1
3	22	47	24	7	1
4	12	18	17	52	2
5	14	74	6	5	1
6	4	12	35	48	1
7	37	9	50	3	1
8	31	18	35	15	1
9	8	62	22	7	1
10	11	16	31	39	2
11	13	51	18	16	1

Detailed Study 4 – Synchrotron and its applications

Question	% A	% B	% C	% D	% No Answer	Comments
1	65	10	8	16	0	
2	8	50	25	17	0	$W = Vq = 90\ 000 \times 1.6 \times 10^{-19} = 1.44 \times 10^{-14}$ J = $1.44 \times 10^{-14}/1.6 \times 10^{-19}$ = 90000 eV = 90 keV
3	29	51	14	6	0	Section 1 is the electron gun; section 2 is the linac, which takes electrons to 99% of c.
4	9	67	23	2	0	
5	10	1	23	65	0	
6	6	14	15	64	0	
7	8	52	26	13	0	Using $n\lambda = 2d\sin\theta$, $\lambda = 0.4 \times 10^{-9}$ m, $d = 0.3 \times 10^{-9}$. At $\theta = 90^{\circ}$, $\sin\theta = 1$ and $n = 2 \times 0.3 \times 10^{-9} \times 1/(0.4 \times 10^{-9}) = 1.5$. So the number of peaks is 1.
8	38	22	19	20	1	Initial photon energy = $hc/\lambda = (4.14 \times 10^{-15})(3 \times 10^{8})/(6.9 \times 10^{-12})$ = 180 keV. So final photon energy = (180 – 74) keV = 106 keV. Therefore, $\lambda = hc/E = (4.14 \times 10^{-15})(3 \times 10^{8})/(106 \times 10^{3}) = 1.17 \times 10^{-11} = 11.7 \times 10^{-12}$ m.
9	1	5	83	10	0	
10	16	65	10	8	0	This question has been reviewed and both B and D accepted. Information about Synchrotron light sources can be obtained from: http://www.synchrotron.org.au/index.php/about-us/our-facilities/accelerator-physics/development-of-synchrotron-light-sources
11	68	9	14	8	1	

Detailed Study 5 – Photonics

Question	% A	% B	% C	% D	Comments
1	31	58	6	4	
2	7	13	7	72	
3	12	28	7	52	
4	10	7	75	7	
5	7	10	8	74	
6	9	65	24	2	
7	25	30	42	3	From the graph, blue is attenuated more than red. So the light will have a reddish tinge.
8	2	7	25	66	
9	33	14	39	14	
10	22	38	25	15	Light going from medium B to medium A is bending away from the normal, so total internal reflection can occur this way.
11	18	13	26	43	Where the fibre bends, the incident angle at which the light strikes the fibre wall can go below the critical angle, and so light can refract out of the fibre.

Detailed Study 6 – Sound

Question	% A	% B	% C	% D	% No Answer	Comments
1	7	10	1	82	0	
2	8	82	8	2	0	
3	72	11	12	4	0	
4	1	6	84	9	0	
5	4	7	69	20	0	
6	8	20	23	49	0	$L_2 - L_1 = 10\log_{10}(I_2/I_1) = 10\log_{10}(0.005I_1/I_1) = -23$ dB
7	54	6	8	31	0	While dynamic loudspeakers do operate via electromagnetic effects, it is not electromagnetic induction.
8	9	72	7	11	1	
9	2	5	88	4	0	
10	8	17	67	8	0	
11	39	7	50	3	1	Since the distance between two adjacent nodes is ½ λ, therefore the wavelength was $2 \times 0.96 = 1.92$ m. So the speed was $v = f\lambda = 500 \times 1.92 = 960$ m s^{-1}.