2018 VCE Physics examination report

General comments

The table below indicates the percentage of students who chose each option. The correct answer is indicated by shading.

Question	% A	% B	% C	% D	Comments
1	8	89	2	1	$F = BIl$ $F = 4.0 \times 10^{-4} \times 10 \times 0.1$ $F = 4.0 \times 10^{-4}$ N
2	78	14	3	5	Right-hand slap rule. Fingers to the left (N to S), thumb up, palm out of the page.
3	90	5	3	2	Right-hand grip rule. Thumb up, fingers indicate direction of field.
4	8	7	4	81	$E = \frac{kq}{r^2}$ $E = \frac{8.99 \times 10^9 \times 2 \times 10^{-6}}{3^2}$ $E = 2.0 \times 10^3\ V\ m^{-1}$
5	3	6	74	17	$F = \sqrt{(200 - 180)^2 + (240 - 210)^2}$ $F = 36.1\ N$
6	3	20	69	8	$F = m\frac{\Delta v}{\Delta t}$ $F = 1000 \times \frac{20}{2.5}$ $F = 8000\ N = 8\ kN$
7	16	58	9	17	$g \propto \frac{1}{R^2}$ If the radius to the surface of the earth is *R*, then the radius to 2*R* above the surface is 3*R*. Therefore, *g* will be one ninth of 9.76 N kg^{-1}, which is 1.08 N kg^{-1}.

Question	% A	% B	% C	% D	Comments
8	3	7	86	3	$m_1 v_i + m_2 v_i = (m_1 + m_2) v_f$ $10 \times 10^3 \times 6 + 0 = (10 \times 10^3 + 5 \times 10^3) v_f$ $v_f = 4.0 \text{ m s}^{-1}$
9	8	71	6	14	Momentum is conserved in all collisions, but kinetic energy is lost in this collision.
10	17	19	5	59	Sound waves are longitudinal waves, so the medium moves in the same direction as the wave.
11	2	3	7	88	Both options C and D were accepted. The Doppler effect means that the frequency that Alex hears will have increased (option D). As the fire engine approaches, the amplitude of the sound Alex hears will also increase (option C).
12	16	8	55	20	$\Delta x = \frac{\lambda L}{d}$ Only decreasing the slit separation (*d*) will increase the width (Δx).
13	35	4	3	58	At *v* << *c* the Lorentz factor is 1 and it increases exponentially as *v* approaches *c*.
14	12	60	11	16	At *v* << *c* the relativistic E_k is the same as the classical E_k, but as *v* approaches *c* relativistic E_k increases at a greater rate than classical E_k.
15	12	20	18	49	The narrow slit reduces the uncertainty in the particle's position and therefore, the uncertainty in its momentum is increased. This is seen as a change in direction.
16	8	2	84	7	Only transverse waves can be polarised.
17	70	15	8	7	A higher work function means a higher cutoff frequency (x-intercept). The graph must still have the same gradient (Planck's constant).
18	57	8	24	11	Uncertainty is an estimate of the random error associated with a measurement.
19	19	70	4	7	The uncertainty is half a division of the scale.
20	4	82	7	6	The speed of rotation is determined by the experimenter: independent. The peak EMF is the quantity being measured and is dependent on the speed of rotation: dependent. The magnetic field is kept constant throughout the experiment: controlled.

Section B

Question 1a.

Marks	0	1	Average
%	18	82	0.8

$$E = \frac{V}{d}$$

$$E = \frac{10 \times 10^3}{0.2}$$

$$E = 50\ 000 \text{ V m}^{-1}$$

The most common error was to incorrectly convert 10 kV to 10 000 volts.

Question 1b.

Marks	0	1	2	Average
%	36	7	57	1.2

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

$$1.6 \times 10^{-19} \times 10^4 = 0.5 \times 1.7 \times 10^{-27} \times v^2$$

$$v = \sqrt{\frac{1.6 \times 10^{-15}}{8.5 \times 10^{-28}}}$$

$$v = 1.4 \times 10^6 \text{ m s}^{-1}$$

The most common error was to use a different formula (frequently F = *Bqv*).

Question 1c.

Marks	0	1	2	Average
%	30	5	65	1.4

$$Bqv = \frac{mv^2}{r}$$

$$r = \frac{1.7 \times 10^{-27} \times 1.0 \times 10^6}{2 \times 10^{-2} \times 1.6 \times 10^{-19}}$$

$$r = 0.53 \text{ m}$$

While many students used the correct formula, they subsequently made substitution errors, including using the mass of an electron rather than the proton or having the wrong indices for the values such as 1.6×10^{-16} instead of 1.6×10^{-19}.

The question stated that students were to show their working, so the small number of students who did not show sufficient working could be awarded only partial marks.

Question 2a.

Marks	0	1	2	3	Average
%	10	13	5	72	2.4

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$$

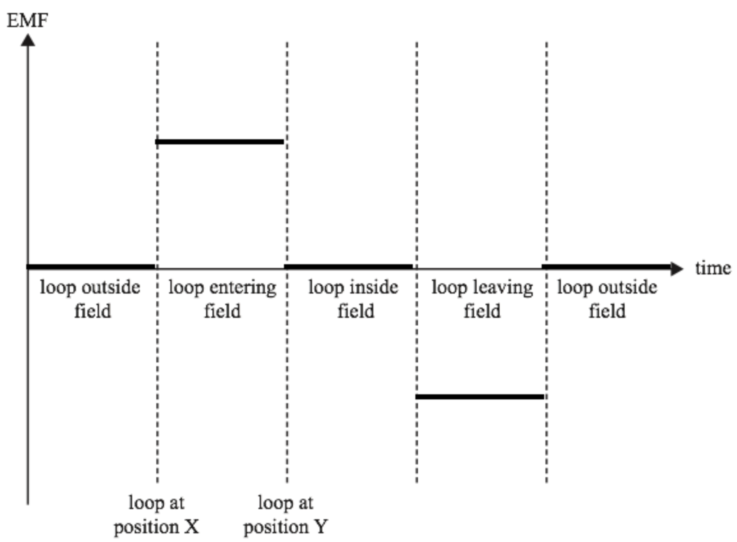
$$\varepsilon = 10 \times \frac{2 \times 10^{-2} \times 1.6 \times 10^{-3}}{0.5}$$

$$\varepsilon = 6.4 \times 10^{-4}\ \text{V}$$

The most common error was to calculate the correct change in flux over time but not to multiply by 10, the number of loops.

Question 2b.

Marks	0	1	2	3	Average
%	47	7	4	42	1.4



An inverted version of the graph was acceptable.

This question was not answered well, with the most common error being to draw a flux graph. Other responses included sine waves and a range of biphasic waveforms, which suggested that few students have an adequate understanding of Faraday's law and how to apply it to find EMF.

Question 3a.

Marks	0	1	2	3	Average
%	15	20	18	47	2

Clockwise

Students were required to explain how they determined the direction. They were required to identify the direction of the current in the loop as H to G or similar, then relate this to the direction of rotation. The most appropriate way to do this was to refer to the right-hand rule or similar.

The most common error was not linking all three aspects: the current direction, the rule that relates current to force and the subsequent direction of rotation. Many students stated that because the current flows from H to G the side HG is forced down, without giving any reference to a link between current and force. Alternatively they would state that due to the right-hand rule, the side HG is forced down, without referencing current.

Students need to practise identifying and linking concepts within their responses rather than leaping from assertion to conclusion.

Question 3b.

Marks	0	1	2	Average
%	57	19	23	0.7

Students were required to identify that the motor would no longer function. Further, they were required to point out that the loop would rotate by one-quarter of a revolution to the vertical position but would not rotate further.

The most common errors were to provide statements regarding the purpose of slip rings and/or split ring commutators, or to describe how the motor would no longer work as a generator.

A number of students stated that the loop would rotate 180 degrees before stopping, and a few who stated that the loop would oscillate between the horizontal and vertical positions.

Question 4a.

Marks	0	1	2	Average
%	44	1	55	1.1

$$V_{DC} = \frac{V_p}{\sqrt{2}}$$

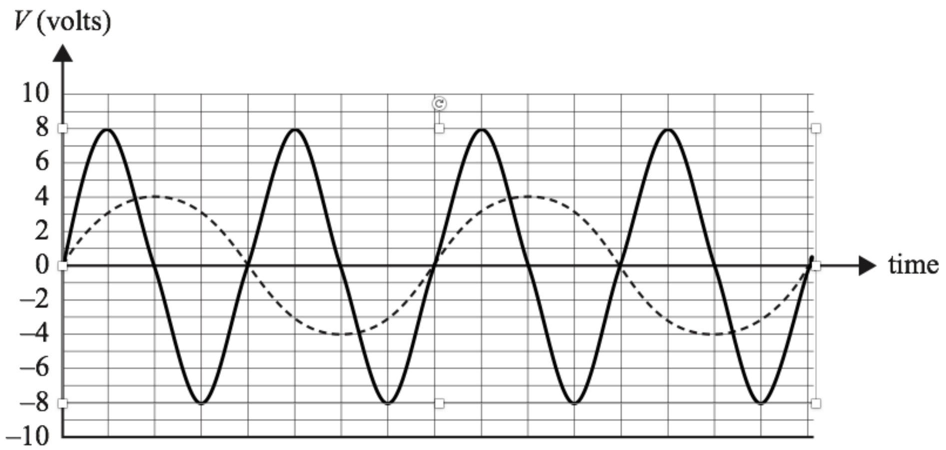
$$V_{DC} = \frac{4}{\sqrt{2}}$$

$$V_{DC} = 2.8 \text{ V}$$

The two most common errors were to multiply the peak voltage by $\sqrt{2}$ or to simply state the peak voltage, 4V.

Question 4b.

Marks	0	1	2	Average
%	19	43	38	1.2



The most common error was to double the period but not the amplitude.

Question 5a.

Marks	0	1	2	Average
%	53	3	44	0.9

As the transformer ratio is 4:1 and the current in the transmission lines is 3A, this means that the current through the globe is $3 \times 4 = 12\text{ A}$.

$P = VI = 4.0 \times 12$

$P = 48\text{ W}$

The most common error was to calculate the power using the current in the transmission lines as the current through the globe. Another common error was to calculate the current through the globe as one-quarter of the transmission line current rather than four times the transmission line current.

Further improvement is needed on basic transformer behaviour.

Question 5b.

Marks	0	1	2	3	Average
%	32	35	2	31	1.4

The voltage drop across the transmission lines is:

$V = RI = 8 \times 3$

$V = 24\text{ V}$

The input voltage to the transformer is four times the globe voltage or 16V.

The output voltage of the power supply must be the sum of these two voltages:

$24 + 16 = 40\text{ V}$

A number of students used an alternative method. In this case they used the 48 W dissipated in the globe and found the total power lost in the transmission lines:

$P_{loss} = I^2 R$

$P_{loss} = 3^2 \times 8 = 72\text{ W}$

This gave a total power supplied by the supply of 120 W.

Now, $P = VI$.

$120 = V \times 3$

$V = 40\text{ V}$

The most common error was to use 4 Ω for the resistance of the lines rather than 8 Ω. Other common errors were to find either the voltage drop across the lines or the voltage at the primary of the transformer and assume that this was the answer.

Question 5c.

Marks	0	1	2	Average
%	23	2	75	1.5

$P_{loss} = I^2R$

$P_{loss} = 3^2 \times 8$

$P_{loss} = 72\ \text{W}$

Students who knew to use the correct formula generally substituted an erroneous current.

Question 5d.

Marks	0	1	2	3	Average
%	72	6	1	21	0.7

The stem stated that 'the light globe operates correctly, with 4.0 V_{RMS} across it'. From this it can be determined that the current through the globe is still 12A.

As the transformer ratio is now 8:1, the line current is one-eighth of this:

$I_{line} = \frac{12}{8} = 1.5\text{A}$

The power loss can now be calculated:

$P_{loss} = I^2R$

$P_{loss} = 1.5^2 \times 8$

$P_{loss} = 18\ \text{W}$

This question was not answered well. Many students struggled with how to apply the new 8:1 ratio.

Question 5e.

Marks	0	1	2	Average
%	24	19	57	1.4

A number of responses were accepted, including, but not limited to, reducing the transmission current, reducing the power lost in the lines or reducing the size or cost of the wires.

A common error was to state one of the factors above and explain that action in detail. While the response was often correct, the question required two reasons.

A significant number of students did not seem to have any knowledge of why high voltages are used.

Question 6a.

Marks	0	1	2	3	Average
%	46	5	4	45	1.5

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

$$2.0 \times 9.8 \times 2.5 = 0.5 \times k \times 0.5^2$$

$$49 = 0.125\text{ k}$$

$$k = \frac{49}{0.125} = 392\text{ N m}^{-1}$$

The most common error was to use 2.0 m rather than 2.5 m for the change in height of the ball.

A number of students tried to use Hooke's law ($mg = kx$) without success.

A small number of students did not show adequate working. In questions such as this, especially where the question states that working is required, the minimal working required is the formula (indicating the conservation of energy) followed by a full substitution. Students are reminded that, as per the instructions for Section B of the examination, where a question is worth more than one mark, appropriate working must be shown.

Question 6b.

Marks	0	1	2	Average
%	80	14	6	0.3

When the ball reaches its maximum velocity the acceleration will be zero. This will occur when the net force on the ball is zero or when $mg = kx$.

The most common error was to state that the maximum acceleration was 9.8 m s^{-2} as the ball hit the spring, but as the gravitational weight force is still acting the ball will not have reached its maximum velocity.

This question was not answered well. This suggests that students' understanding of forces and the relationship between unbalanced forces and acceleration requires improvement.

Question 6c.

Marks	0	1	2	Average
%	86	1	13	0.3

$$mg = kx$$

$$2.0 \times 9.8 = 392 \times x$$

$$x = \frac{19.6}{392} = 0.05\text{ m}$$

This question was not answered well, with most students unable to make a meaningful start. There were a number of attempts to use conservation of gravitational and kinetic energy, with no success.

As with Question 6b., many students had little understanding of situations involving balancing of forces.

Question 7a.

Marks	0	1	Average
%	21	79	0.8

$d = vt$

$d = 3.0 \times 0.4$

$d = 1.2 \text{ m}$

This question was generally answered well.

Question 7b.

Marks	0	1	2	Average
%	33	2	66	1.4

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

$x = 0.5 \times 10 \times 0.4^2$

$x = 0.8 \text{ m}$

The most common error was to use the initial horizontal velocity as the initial vertical velocity.

Question 7c.

Marks	0	1	2	3	Average
%	34	23	1	41	1.5

The speed at which the ball hits the floor is the vector sum of the horizontal and vertical velocities.

$v_{vert} = at$

$v = 10 \times 0.4 = 4 \text{ m s}^{-1}$

Given that the initial horizontal velocity was 3.0 m s^{-1}, the final speed required the use of Pythagoras formula.

$v = \sqrt{a^2 + b^2}$

$v = \sqrt{9 + 16} = \sqrt{25}$

$v = 5 \text{ m s}^{-1}$

It was also possible to solve this using a conservation of energy approach.

$\frac{1}{2}mv_i^2 + mgh = \frac{1}{2}mv_f^2$

$0.5 \times 0.2 \times 3^2 + 0.2 \times 10 \times 0.8 = 0.5 \times 0.2 \times v_f^2$

$0.9 + 1.6 = 0.1v_f^2$

$$v_f = \sqrt{\frac{2.5}{0.1}}$$

$$v_f = 5 \text{ m s}^{-1}$$

The most common error was to simply find the vertical component.

Question 8a.

Marks	0	1	2	Average
%	56	17	27	0.7

The acceleration of the system is:

$$F = ma$$

$$40 = (4 + 1)a$$

$$a = \frac{40}{5} = 8 \text{ m s}^{-2}$$

The force of block A on block B is then:

$$F = ma$$

$$F = 1 \times 8 = 8 \text{ N}$$

The most common error was to apply $F = ma$ but only to the 4 kg block, which gave an acceleration of 10 m s^{-2}.

This question was not answered well. Students are advised to spend time ensuring that basic concepts such as these are well practiced and understood.

Question 8b.

Marks	0	1	2	Average
%	14	25	61	1.5

The correct response was 8 N to the LEFT.

This was an application of Newton's third law. Students who scored only one mark generally had the direction correct but not the magnitude. Many students responded with a different value for the force than the one they calculated in Question 8a. This suggests that there are a number of students who are not aware of how to apply Newton's third law.

Question 9a.

Marks	0	1	2	Average
%	35	7	57	1.2

From the graph, the gravitational field strength at 2.0×10^8 m is 3 N kg^{-1}. Since *Juno* has a mass of 1500 kg, the force on *Juno* is $1500 \times 3 = 4500 \text{ N or } 4.5 \times 10^3$.

Many students calculated the force using Newton's law of gravitation. Students who did this found the value to be 4752 N.

While both results were considered correct, the second method was mathematically more complex and errors in this method constituted the most common error for the question.

Question 9b.

Marks	0	1	2	3	Average
%	40	21	6	33	1.3

The area under the graph between 2.0×10^8 m and 1.0×10^8 m is estimated at 14 squares.

Each square is equal to $(1.0 \text{ N kg}^{-1}) \times (0.5 \times 10^8 \text{ m}) = 0.5 \times 10^8 \text{ J kg}^{-1}$.

Therefore, the change in gravitational potential energy is given by:

$$\Delta GPE = 14 \times 0.5 \times 10^8 \times 1500$$

$$\Delta GPE = 1.05 \times 10^{12} \text{ J}$$

Allowances were made for students estimating a different number of squares.

Some students also used a difference in *GPE* approach using the formula $\Delta GPE = mg_f h_f - mg_i h_i$ and substituting the different *g* values and *h* values. This also led to the correct answer.

A number of students approximated the area under the graph as a trapezium. These students were not awarded full marks as a trapezium is an overestimation of the area.

Question 9c.

Marks	0	1	2	3	Average
%	23	16	10	51	1.9

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$

$$T = \sqrt{\frac{4\pi^2 \times (6.70 \times 10^8)^3}{(6.67 \times 10^{-11})(1.90 \times 10^{27})}}$$

$$T = 3.06 \times 10^5 \text{ sec}$$

While most students realised that this question required a combination of Newton's law of gravitation and circular motion, many could not demonstrate a suitable formula and substitution. Forgetting to cube the radius was the most common mathematical error.

Question 10a.

Marks	0	1	2	Average
%	35	2	63	1.3

$$r = \frac{v^2}{g}$$

$$r = \frac{180^2}{9.8}$$

$$r = 3306\, m$$

$$r = 3.3 \times 10^3 \text{ m}$$

The most common errors were mathematical as most students who made an attempt knew the problem involved circular motion.

Question 10b.

Marks	0	1	2	Average
%	24	34	42	1.2

Students were required to state that the force of gravity is **not** zero at the top of the flight and that the 'zero gravity experience' is due to the lack of a contact or normal reaction force.

Many students stated that the force of gravity was zero at the top and then struggled to explain how that might occur. Others stated that if the gravitational force was still present it would be very small, which was also incorrect.

A number of students made reference to 'apparent weightlessness'. It should be pointed out that 'apparent weightlessness' is no longer part of the study design.

Question 11a.

Marks	0	1	Average
%	8	92	0.9

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{340}{340} = 1 \text{ m}$$

Question 11b.

Marks	0	1	2	3	Average
%	56	35	4	5	0.6

Students were required to identify that at the centre there will be a region of relative loudness. They were not required to articulate why this would be so, but many correctly referred to the path difference being zero or another correct aspect of physics.

The first node or quiet region will be one-quarter wavelength from this position (0.25 m) and the second node or quiet region will be one-half wavelength further on (0.50 m). Thus, the total distance from the centre to the second quiet region will be 0.75 m.

This question was not answered well and students had great difficulty explaining the physics of the situation. Many tried to apply a form of mathematical analysis but were unable to find a way to do this.

Question 12a.

Marks	0	1	Average
%	28	72	0.7

$$f = \frac{v}{\lambda}$$

$$f = \frac{3 \times 10^{8}}{565 \times 10^{-9}}$$

$f = 5.3 \times 10^{14}$ Hz

Question 12b.

Marks	0	1	2	Average
%	26	3	71	1.5

$n_{co} sin\theta_c = n_{cl} \sin 90$

$1.67 sin\theta_c = 1.45 \sin 90$

$\theta_c = sin^{-1}\left(\frac{1.45}{1.67}\right)$

$\theta_c = 60.3°$

This question was generally answered well. The most common error was to invert the fraction. A significant number of substitutions showed a value of 1.65 rather than 1.67. Students must ensure that they transpose data correctly.

Question 12c.

Marks	0	1	2	Average
%	39	25	35	1

$n_{air} v_{air} = n_{co} v_{co}$

$1.00 \times (3.00 \times 10^8) = 1.67 \times v_{co}$

$v_{co} = 1.80 \times 10^8 \text{ m s}^{-1}$

The most common errors were to use the refractive index of the cladding rather than the core or not to give the answer to the correct number of significant figures, which was three in this case.

Question 13a.

Marks	0	1	2	3	Average
%	63	4	2	31	1

The energy per photon is:

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

$$E = \frac{6.63 \times 10^{34} \times 3 \times 10^8}{610 \times 10^{-9}}$$

$$E = 3.26 \times 10^{-19} \text{ J}$$

The total number of photons is given by:

$$n = \frac{5.03 \times 10^{-3}}{3.26 \times 10^{-19}}$$

$$n = 1.54 \times 10^{16}$$

The range of incorrect or inappropriate workings given in responses to this question suggested that students had little understanding of how to approach the problem.

Of particular concern was the number of students who found the wavelength of a photon with the laser energy then divided the wavelength of the laser photon by this value. This suggested that students believe that big photons are made up of lots of little photons. When students complete a mathematical solution they need to consider the underlying physics their maths implies.

Question 13b.

Marks	0	1	2	Average
%	26	42	32	1.1

Students were required to identify that the path difference to the point C is zero, and this results in constructive interference at C.

While most students were able to identify constructive interference as the mechanism for the bright reason, they then went on to explain interference in detail. Simply identifying constructive interference explains all bright regions and not the specific region. Students need to remember to focus on responding to the question asked.

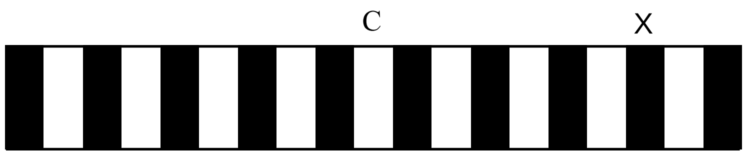
Question 13c.

Marks	0	1	2	Average
%	46	9	45	1

The path difference in terms of lambda is:

$$\frac{2.14 \times 10^{-6}}{610 \times 10^{-9}} = 3.5\lambda$$

3.5λ will place the X above the fourth dark band from the centre as shown.



Some students who did not receive any marks showed no understanding of how to solve the problem.

Question 14

Marks	0	1	2	Average
%	79	16	5	0.3

Students were required to identify that constant speed is not the same as constant velocity, and that the ship in question could be travelling in a circular path or it could be in orbit and still be traveling at a constant speed. Therefore, the spaceship may not be in an inertial frame of reference.

This question was not answered well, and it appears that further improvement is required in the area of special relativity. Many students made statements such as ‘Jani is in an inertial frame but the spaceship is not’.

Question 15

Marks	0	1	2	3	Average
%	46	16	3	36	1.3

$\gamma = 8$, from the phrase '…runs eight times slower…'

$E = (\gamma - 1)mc^2$

$E = (8 - 1)(10\ 000)(3 \times 10^8)^2$

$E = 6.3 \times 10^{21}$ J

The most common errors were to calculate gamma as 1/8 rather than 8 or to forget to square *c* in the substitution.

Question 16

Marks	0	1	2	Average
%	46	2	53	1.1

$t = t_0\gamma$

$t_0 = \frac{20}{1.41}$

$t_0 = 14.2$ hours

The most common error was to confuse proper time with dilated time, which resulted in multiplying 20 by 1.41.

Question 17ai.

Marks	0	1	Average
%	22	78	0.8

Kym

Question 17aii.

Marks	0	1	2	Average
%	56	28	17	0.6

This question assessed students' understanding of the wave model predictions of the photoelectric effect. Many students identified that Sai was referring to the wave model, though they were not required to do so.

Students were required to identify that increasing the brightness would increase the amplitude/energy of the light, and that by combining this with a longer exposure time would increase the total energy delivered to the metal. If more energy was delivered then the electrons may be able to accumulate enough energy to be ejected.

Students who received only one mark were able to state that the energy delivered would be increased but could not relate this to both the change in brightness and the increase in time.

Students who did not receive any marks generally tried to apply a particle model explanation with no success.

Students need to be familiar with the wave model predictions of the photoelectric effect as well as the particle model explanations.

Question 17b.

Marks	0	1	2	Average
%	39	18	43	1.1

Students were required to identify that Planck's constant can be found from the gradient of the graph. They were not required to rule a line on the diagram on page 17 although many did so.

$$Grad = \frac{rise}{run}$$

$$Grad = \frac{3.3 - 0.2}{6 \times 10^{14}}$$

$$Grad = 5.2 \times 10^{-15} \text{ eV } s$$

Given that students could rule a line of best fit with a range of gradients, the correct response was within the range 5.0×10^{-15} to 6.0×10^{-15} eV s.

A significant number of students used data points to calculate a gradient. While this resulted in a value within the correct range, it was only because the data points lie on, or very close to, the line of best fit. Had the data points been more scattered, the result of using them for a gradient calculation could result in a value that is outside the acceptable range. Students are reminded that when finding the gradient of a line of best fit they should use points on their line, not data points provided.

A small number of students quoted the value of Planck's constant as provided on the formula sheet. It should be pointed out that questions of this type require students to perform calculations rather than identify a value from the formula sheet.

Question 17c.

Marks	0	1	2	Average
%	48	12	40	0.9

When using a graph to find the work function the appropriate method is to find the *y*-intercept. In this case the work function was 3.5 eV with a tolerance of 0.5 eV up or down to allow for where students ruled their line of best fit.

A significant number of students responded by saying that the work function comes from the formula $W = hf_0$. While this was also correct, it increases the difficulty in answering the question as many students who started this way went on to either use the value for Planck's constant from the formula sheet rather than the one they calculated for their graph or they went on to incorrectly estimate f_0. Either of these generally resulted in a work function outside the acceptable range.

Students are advised to become more familiar with interpreting the results of the photoelectric effect experiment.

Question 18a.

Marks	0	1	2	Average
%	40	17	43	1.1

The electron and the X-ray must have the same wavelength if they produce the same diffraction pattern.

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

$$8000 = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{\lambda}$$

$$\lambda = 1.55 \times 10^{-10} m$$

$$\lambda = 0.155 \text{ nm}$$

Many students struggled to begin responding to this question. Of those who did know how to complete the problem, many could not convert to nanometres. Converting between units is an expected skill.

Question 18b.

Marks	0	1	2	3	Average
%	63	5	4	28	1

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

$$1.55 \times 10^{-10} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times v}$$

$$v = 4.7 \times 10^{6} \text{ m s}^{-1}$$

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

$$E = 0.5 \times 9.1 \times 10^{-31} \times (4.7 \times 10^{6})^2$$

$$E = 1.0 \times 10^{-17} \text{ J}$$

The majority of students struggled to begin responding. There was a range of incorrect formulas used as a starting point with no progress beyond.

Question 19a.

Marks	0	1	Average
%	36	64	0.7

Red

Question 19b.

Marks	0	1	2	3	Average
%	61	17	11	11	0.8

Students were required to identify the following ideas/concepts:

- that electrons orbit nuclei in shells with discrete energy levels
- electrons can transition between these shells by absorbing or emitting discrete amounts of energy equal to the difference between the two shells
- since transitioning electrons can only release discrete amounts of energy, only discrete spectral lines will be observed

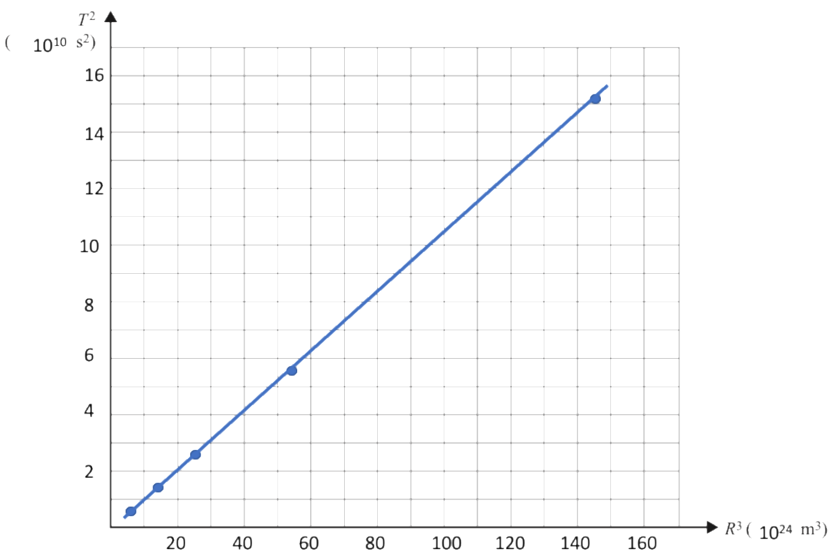
Students who did not score any marks generally spoke of absorption spectra or gave answers that restated the stem such as '…the hydrogen atom emits discrete spectral lines because all of the photons have the same wavelength…'.

Some students responded with information about electron orbits. While this was the basis for the argument they then went on to give detail about the orbits themselves, often referencing the relationship between the circumference and the deBroglie wavelength of the electron, but not describing the origin of the spectral lines. Some students went on to discuss electron shell transitions but did not relate this back to the spectral lines.

Students are reminded that they are required to respond to the question asked and should not attempt to present prepared responses as these will rarely fit the question.

Question 20a.

Marks	0	1	2	3	4	5	Average
%	7	2	2	4	16	68	4.3



This question was generally answered well. The only major concern was the number of students who reversed the axes even though they were labelled.

Question 20b.

Marks	0	1	2	Average
%	23	41	37	1.2

Students were required to find the gradient of their line of best fit. For example:

$$Grad = \frac{rise}{run}$$

$$Grad = \frac{(9.5 - 1) \times 10^{10}}{(90 - 10) \times 10^{24}}$$

$$Grad = 1.06 \times 10^{-15}$$

As there was some variation in how students could place this line, a gradient calculation that gave a value in the range 9.9×10^{-16} and 1.1×10^{-15} was accepted.

While most students realised that a gradient calculation was required, a significant number left out the exponents.

Question 20c.

Marks	0	1	2	3	Average
%	56	7	3	34	1.2

Gradient from graph: 1.06×10^{-15}

$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$ where $\frac{T^2}{r^3}$ is the gradient of the graph and M is the mass of Saturn.

$$1.06 \times 10^{-15} = \frac{4\pi^2}{6.67 \times 10^{-11} \times M_{Saturn}}$$

$$M_{Saturn} = \frac{39.48}{6.67 \times 10^{-11} \times 1.06 \times 10^{-15}}$$

$$M_{Saturn} = 5.6 \times 10^{26} \text{ kg}$$

Many students used a form of Kepler's law as shown above, but rather than use their gradient in place of $\frac{T^2}{r^3}$ as required they simply used one of the data points. While this resulted in the correct answer, it did not demonstrate the required understanding and was not awarded full marks. Students are reminded to read the question carefully and follow the instructions.