Physics marking guide and solution

External assessment

Combination response (81 marks)

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

1. describe and explain gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model
2. apply understanding of gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model
3. analyse evidence about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model to identify trends, patterns, relationships, limitations or uncertainty
4. interpret evidence about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model to draw conclusions based on analysis.

Note: Objectives 5, 6 and 7 are not assessed in this instrument.

Queensland Government
Queensland Curriculum & Assessment Authority

Purpose

This document consists of an EAMG.

The EAMG:

- provides a tool for calibrating external assessment markers to ensure reliability of results
- indicates the correlation, for each question, between mark allocation and qualities at each level of the mark range
- informs schools and students about how marks are matched to qualities in student responses.

Mark allocation

Where a response does not meet any of the descriptors for a question or a criterion, a mark of ‘0’ will be recorded.

Allow FT error — refers to ‘follow through’, where an error in the prior section of working is used later in the response, a mark (or marks) for the rest of the response can be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

Where no response to a question has been made, a mark of ‘N’ will be recorded.

External assessment marking guide

Paper 1: Multiple choice

Question	Response
1	B
2	B
3	A
4	B
5	C
6	C
7	A
8	A
9	C
10	B
11	D
12	B
13	B
14	C
15	B
16	C
17	D
18	C
19	A
20	D

Paper 1: Short response

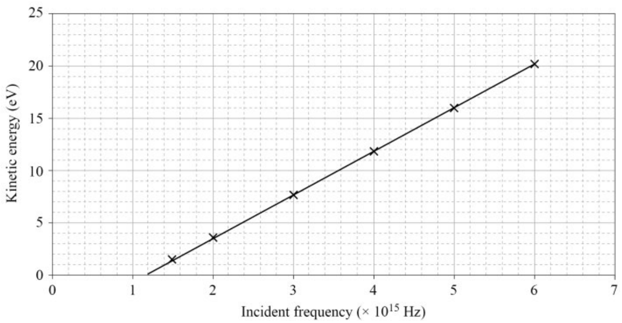
Q	Sample response	The response:	Notes
21	$F = \frac{GMm}{r^2}$ $m = \frac{Fr^2}{GM}$ $m = \frac{2.84 \times 10^3 \times (7.12 \times 10^6)^2}{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}$ Mass = 362 kg	• indicates an understanding of the physical scenario in relation to Newton's law of universal gravitation or other relevant physical concept/s **[1 mark]** • provides pertinent mathematical operation/s correctly performed **[1 mark]** • determines the mass **[1 mark]**	Accept answers inclusive between 361.5 kg and 362 kg. Allow FT error for the mass.
22	1. Electron 2. Electron neutrino 3. Tau 4. Tau neutrino 5. Muon 6. Muon neutrino	• identifies the six leptons **[1 mark]**	Listing the respective antiparticles is permitted but only in addition to, not in place of, the leptons listed in the sample response. Listing the symbols (e, ν_e, ν_μ, μ, ν_τ, τ) in addition to, or in place of, lepton names is permitted. If both are provided then the symbol must match the name. Misspelling of lepton names is permitted as long as the error does not impede meaning.

Q	Sample response	The response:	M	Notes
23	The theory of special relativity states that there is no absolute time. Instead, the measurement of time is relative to the frame of reference in which it is measured. The time measured by a stationary clock is greater than the time measured by a moving clock. From the perspective of either twin, the *other* twin will be younger.	• provides an explanation of why the twins will no longer be the same age • supports the explanation using the theory of special relativity • provides a conclusion about the respective ages of the twins that indicates an understanding of the twin paradox	2	Support using the theory of special relativity may include: – the concept of time dilation/length contraction – relevant calculations.
		• provides an explanation of why the twins will no longer be the same age • supports the explanation using the theory of special relativity **OR** • provides an explanation of why the twins will no longer be the same age • provides a conclusion about the respective ages of the twins that indicates an understanding of special relativity	1	

<table>
<tr><th>Q</th><th>Sample response</th><th>The response:</th><th>Notes</th></tr>
<tr><td>24</td><td>$t = \dfrac{t_o}{\sqrt{1 - \frac{v^2}{c^2}}}$
$4.0 = \dfrac{t_o}{\sqrt{1 - \frac{(0.90c)^2}{c^2}}}$
t_o = 1.7 years
Time = 1.7 years (to 1 decimal place)</td><td>• indicates an understanding of the physical scenario in relation to time dilation, or other relevant physical concept/s [1 mark]
• indicates an understanding that the time provided in the question represents relativistic time [1 mark]
• provides pertinent mathematical operation/s correctly performed [1 mark]
• determines the time [1 mark]</td><td>Only two marks can be awarded if the response confuses proper time and relativistic time.

Accept answers between 1.7 years and 1.8 years inclusive.</td></tr>
<tr><td>25</td><td>$\dfrac{{T_{\text{Mars}}}^2}{r_{\text{Mars}}^3} = \dfrac{4\pi^2}{Gm}$
$T = \sqrt{\dfrac{4\pi^2}{Gm} r^3}$
$T_{\text{Mars}} = \sqrt{\dfrac{4\pi^2}{Gm}(1.5 \times r_{\text{Earth}})^3}$
Therefore $T_{\text{Mars}} = \sqrt{1.5^3} T_{\text{Earth}}$
T_{Mars} = 1.8371 × 365 days
T_{Mars} = 670.5 days
Time = 671 days</td><td>• indicates an understanding of the physical scenario in relation to Kepler's Law or other relevant physical concept/s [1 mark]
• provides pertinent mathematical operation/s correctly performed [1 mark]
• determines the time [1 mark]</td><td>Accept answers between:
• 1.83 and 1.84 years inclusive
• 670 days and 671 days inclusive
• 16 080 and 16 107 hours inclusive
• 57 888 000 seconds and 57 974 400 seconds inclusive.

Allow FT error for the time.</td></tr>
</table>

<table>
<tr><th>Q</th><th>Sample response</th><th>The response:</th><th>Notes</th></tr>
<tr>
<td>26</td>
<td>

x-intercept = 1.13 x 10^{15} Hz
$W_o = hf_o = 6.626 \times 10^{-34} \times 1.13 \times 10^{15}/1.6 \times 10^{-19}$
$= 4.7$ eV
Unknown metal = copper</td>
<td>• identifies a relevant value or feature of the graph [1 mark]
• provides pertinent mathematical operation/s correctly performed or sound mathematical reasoning [1 mark]
• identifies the unknown metal [1 mark]</td>
<td>Relevant values/features of the graph may include:
– x-intercept
– y-intercept
– …

Students may deduce the unknown metal by approximating the y-intercept and using it to estimate the work function. Full marks should be awarded if this occurs.

Students may annotate graph, but this is not essential to marking.</td>
</tr>
<tr>
<td>27</td>
<td>The possible wavelengths of light emitted by Element A are as follows:
<table>
<tr><th>Energy transition</th><th>Difference in energy (eV)</th><th>Difference in energy (J)</th><th>Associated wavelength (nm)</th></tr>
<tr><td>$E_n \rightarrow E_i$</td><td>$E_n - E_i = E_d$</td><td>$E_d \times 1.60 \times 10^{-19}$</td><td>$\lambda = \frac{hc}{E_d}$</td></tr>
<tr><td>1.45–1.47</td><td>–0.02</td><td>–3.2 x 10^{-21}</td><td>62 100</td></tr>
<tr><td>1.45–3.54</td><td>–2.09</td><td>–3.344 x 10^{-19}</td><td>594</td></tr>
<tr><td>1.45–5.74</td><td>–4.29</td><td>–6.864 x 10^{-19}</td><td>290</td></tr>
<tr><td>1.47–3.54</td><td>–2.07</td><td>–3.312 x 10^{-19}</td><td>600</td></tr>
<tr><td>1.47–5.74</td><td>–4.28</td><td>–6.848 x 10^{-19}</td><td>290</td></tr>
<tr><td>3.54–5.74</td><td>–2.2</td><td>–3.52 x 10^{-19}</td><td>565</td></tr>
</table>
It is possible that Element A is one of the gases comprising the gas mixture.</td>
<td>• provides pertinent mathematical operation/s correctly performed to determine the differences between the energy levels in the energy level diagram [1 mark]
• provides pertinent mathematical operation/s to convert eV to joules [1 mark]
• indicates wavelengths produced by Element A that are also included in the emission spectra [1 mark]
• provides an answer that indicates the possibility that Element A is one of the gases comprising the gas mixture [1 mark]</td>
<td>Allow FT error for the final answer.</td>
</tr>
</table>

Q	Sample response	The response:	Notes
28	$B_1 = \frac{\mu_0 I_1}{2\pi r_1}$ = 1.6 x 10^{-6} T $B_2 = \frac{\mu_0 I_2}{2\pi r_2}$ = 4 x 10^{-7} T The magnetic fields are going in different directions, so working out the difference gives an overall magnetic field of B = 1.2 x 10^{-6} T The force on a moving charge in a magnetic field is given by $F = qvBsin\ \theta$ The velocity is at right angles to the direction of the magnetic field so sin 90 = 1. *F* = 2 x 10^{-9} x 3.33 x 10^{5} x 1.2 x 10^{-6} Magnetic force = 7.99 x 10^{-10} N	• indicates an understanding of the physical scenario in relation to the magnetic field generated by a wire or other relevant physical concept/s **[1 mark]** • provides pertinent mathematical operation/s correctly performed to determine net magnetic field strength **[1 mark]** • provides pertinent mathematical operation/s correctly performed **[1 mark]** • determines the force on the charge **[1 mark]**	Accept values inclusive between 7.99 x 10^{-10} N and 8 x 10^{-10} N. Allow FT error for the magnetic field strength.

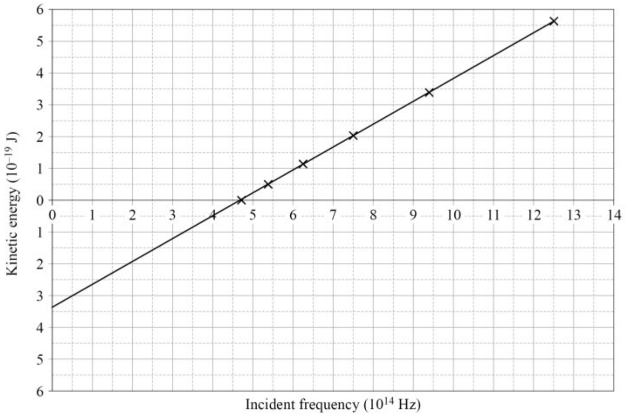
Paper 2: Short response

Q	Sample response	The response:	Notes
1	An object with mass cannot travel at the speed of light because as its velocity approaches 1*c*, its momentum approaches infinity.	• states that as velocity approaches the speed of light (or equivalent), the object's momentum approaches infinity **[1 mark]** **OR** • states that as velocity approaches the speed of light (or equivalent), the energy required to accelerate the object approaches infinity **[1 mark]**	Equivalent statements may include: – as velocity approaches *c* – … No mark is to be awarded if the response only indicates that the object's mass increases to infinity. Equivalent mathematical explanations are acceptable, e.g. $E_r = \sqrt{(m_o c^2)^2 + (pc)^2}$
2a	$c = 0$ $m = \frac{2000 - 0}{0.0278 - 0} = 72\ 000$ $E = 72\ 000(\frac{1}{r^2})$	• provides a correct value for the *y*-intercept **[1 mark]** • provides a correct value for the gradient of the graph **[1 mark]** • provides the equation **[1 mark]**	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done so in the sample response. In this case: Accept values for the *y*-intercept between 50 NC^{-1} and –50 NC^{-1} inclusive. Accept values for the gradient between 70 000 and 72 500 inclusive. Allow FT error for the equation.
2b	$(E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2})$ equate the gradient to k*q*. $q = 72\ 000 / 9 \times 10^9$ C = 8×10^{-6} C Charge = 8.0×10^{-6} C	• indicates an understanding of the physical scenario in relation to the gradient being used to find the charge **[1 mark]** • provides pertinent mathematical operations correctly performed **[1 mark]** • determines the charge **[1 mark]**	Allow FT error from part a). Allow FT error for the charge.

Q	Sample response	The response:	Notes
3	The shortest wavelength in the visible spectrum will have the largest energy difference. $E = hf$ $= \frac{hc}{\lambda}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{400 \times 10^{-9}}$ $= 4.9695 \times 10^{-19}\ \text{J}$ $E = \frac{4.9695 \times 10^{-19}}{1.60 \times 10^{-19}}$ $\approx 3.106\ \text{eV}$ The largest transition below $3.106\ \text{eV}$ is between $-2.7\ \text{eV}$ and $-5.6\ \text{eV}$. $E = -2.7 - -5.6$ $= 2.9\ \text{eV}$ In joules, $E = 2.9 \times 1.60 \times 10^{-19}$ $= 4.64 \times 10^{-19}\ \text{J}$ $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E}$ $= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{4.64 \times 10^{-19}}$ Wavelength = 428 nm	Solution 1 • indicates an understanding of the physical scenario in relation to the relationship between wavelength of emitted light and the energy level diagram **[1 mark]** • provides pertinent mathematical operation/s correctly performed to move between values for wavelength and energy **[1 mark]** • identifies the largest allowable energy transition for visible light to be emitted (consequentially correct) **[1 mark]** • identifies the consequentially correct transition to produce the shortest wavelength of visible light **[1 mark]** • determines the wavelength of light **[1 mark]** **OR** Solution 2 • indicates an understanding of the physical scenario in relation to the relationship between wavelength of emitted light and the energy level diagram **[1 mark]** • provides pertinent mathematical operation/s correctly performed to calculate all energy differences **[1 mark]** • provides pertinent mathematical operation/s correctly performed to identify all possible wavelengths emitted by the atom **[1 mark]** • identifies the consequentially correct wavelengths within the visible spectrum **[1 mark]** • determines the wavelength of light **[1 mark]**	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept answers inclusive between 428 nm and 432 nm. Allow FT error for the wavelength.

Q	Sample response	The response:		Notes
4	The photoelectric effect experiment demonstrates that the number of electrons ejected from a metal plate is proportional to the intensity of incident light, whereas the kinetic energy of the ejected electrons is proportional to the frequency of incident light. The fact that frequencies lower than a threshold value will not eject an electron suggests that light energy is quantised. As the frequency increases, the kinetic energy of the ejected electrons increases, suggesting that light can be conceived as packets of energy (photons). The fact that a greater intensity of light causes more electrons to be ejected suggests that the greater the intensity, the more photons (or packets of energy) are incident on the metal plate, also confirming the idea of light as a photon.	• describes		Relevant features of the photoelectric effect are: – intensity of light is proportional to number of photoelectrons – no photoelectrons are released below a threshold frequency of light – kinetic energy of photoelectrons increases with frequency of light – photoelectrons are released immediately when light strikes the metal – or other suitable responses consistent with a reasonable understanding.
		– three relevant features of the photoelectric effect – two relevant features of the photoelectric effect	3 marks 2 marks	
		– one relevant feature of the photoelectric effect	1 mark	
		• identifies how		
		– two relevant features provide evidence of quantisation of photons	2 marks	
		– one relevant feature provides evidence of quantisation of photons	1 mark	
5	$F_2 = \frac{1}{4\pi\varepsilon_o}\frac{Q_1 \times q_e}{r_1^2}$ $= 9 \times 10^9 \times \frac{3(1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$ $= 1.3 \times 10^{-8}\text{N}$ $F_1 = \frac{1}{4\pi\varepsilon_o}\frac{Q_2 \times q_e}{r_2^2}$ $= 9 \times 10^9 \times \frac{2(1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$ $= 9.0 \times 10^{-9}\text{N}$ $\lvert F_{net} \rvert = \lvert F_1 \rvert - \lvert F_2 \rvert$ $= 1.4 \times 10^{-8} - 9.1 \times 10^{-9}$ Force = 4.0×10^{-9} N (to 1 decimal place)	• indicates an understanding of the physical scenario in relation to Coulomb's law **[1 mark]** • provides pertinent mathematical operation/s correctly performed **[1 mark]** • determines the forces (or electric field strength) imposed by each nuclei on the electron **[1 mark]** • determines the correct net force **[1 mark]**		An understanding of the physical scenario of Coulomb's law may include: – the electron experiences two forces due to the two charges – … Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done so in the sample response. In this case: Accept values inclusive between: 1.3×10^{-8} N and 1.4×10^{-8} N for F_2 9.0×10^{-9} N and 9.1×10^{-9} N for F_1. Allow FT error for all force calculations.

Q	Sample response	The response:	Notes
6	Using the right-hand rule and the motion of the particle, it must be a positive particle. The particle moves in a circle due to the magnetic force. $$F_{mag} = F_{circular}$$ $$qvB\sin\theta = \frac{mv^2}{r}$$ Particle enters perpendicularly, therefore $\sin\theta = \sin 90^\circ = 1$ $$qvB = \frac{mv^2}{r}$$ $$m = \frac{qBr}{v}$$ $$m = \frac{(1.60 \times 10^{-19})(0.090)(3.48 \times 10^{-1})}{1.50 \times 10^6}$$ $$m = 3.34 \times 10^{-27}\text{kg}$$ Therefore, Particle Q must be Particle 4.	• indicates an understanding of the physical scenario in relation to the force on a positive charge in a magnetic field, and centripetal force **[1 mark]** • provides pertinent mathematical operations correctly performed **[1 mark]** • determines the mass **[1 mark]** • identifies the correct particle using the mass and the charge of the particle **[1 mark]**	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept answers inclusive between 3.33×10^{-27} kg and 3.35×10^{-27} kg.

Q	Sample response	The response:	Notes
7	 Gradient = $\frac{\Delta E_K}{\Delta f} = \frac{5.6\times10^{-19}-1.5\times10^{-21}}{1.25\times10^{15}-4.68\times10^{14}} = 7.2\times10^{-34}$ Work function = *y*-intercept = 3.3×10^{-19}J $E_K = 7.2\times10^{-34}\times f - 3.3\times10^{-19}$	• provides a correct value for the *y*-intercept **[1 mark]** • provides a correct value for the gradient of the graph **[1 mark]** • provides the equation **[1 mark]**	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept values inclusive between: 7.1×10^{-34} and 7.3×10^{-34} for the gradient. 3.3×10^{-19} and 3.5×10^{-19} for the *y*-intercept. Students may annotate graph, but this is not essential to marking. Allow FT error for the equation.
8	Gradient of the graph = 6 m s^{-2} = acceleration The component of the acceleration due to gravity down the inclined plane is $g\sin\theta$ Therefore $g\sin\theta = 6$ $\theta_i = \sin^{-1}(6/9.8) = 38^\circ$	• arrives at a value for the gradient **[1 mark]** • indicates an understanding of how the acceleration of the object is represented by the gradient of the graph **[1 mark]** • provides pertinent mathematical operation/s correctly performed using the gradient value **[1 mark]** • determines angle **[1 mark]**	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept values inclusive between 37° and 38° for the angle. Allow FT error from the gradient value calculated.

Q	Sample response	The response:	Notes
9	The gradient of the graph can be used to find $\frac{GM}{4\pi^2}$. The gradient of the graph can be found using the following two points: (0,0) and (40 000, 10). First, the *x* values will be converted to seconds^2 (0,0) and (2.985984 x10^{14}, 10 x 10^{32}). The gradient = 3.37 x 10^{18} Let the gradient be represented by the pronumeral *V*. $V = \frac{GM}{4\pi^2}$ $M = \frac{V4\pi^2}{G}$ Mass = 2.0×10^{30} kg (to 1 decimal place)	• indicates an understanding that the gradient represents $\frac{GM}{4\pi^2}$ **[1 mark]** • provides pertinent mathematical operation/s correctly performed to convert days^2 into seconds^2 **[1 mark]** • arrives at a value for the gradient **[1 mark]** • provides pertinent mathematical operation/s correctly performed using the gradient **[1 mark]** • determines the mass **[1 mark]**	Accept any other value if it is the product of acceptable variations to rounding, differences in values read off a graph or chosen from a table, or expressed to a greater precision than done in the sample response. In this case: Accept values for the gradient inclusive between 3.33 x 10^{18} and 3.40 x 10^{18}. Accept values for the mass inclusive between 1.9 x 10^{30} kg and 2.1 x 10^{30} kg. Allow FT error for the mass.