Physics marking guide and response

External assessment 2023

Combination response (90 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
QCAA Queensland Curriculum & Assessment Authority

Purpose

This document consists of a marking guide and a sample response.

The marking guide:

- 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.

The sample response demonstrates the qualities of a high-level response.

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.

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

Allow FT mark/s — 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 still be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

Marking guide

Multiple choice

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

Paper 1: Short response

Q	Sample response	The response:
21	The Rutherford model provided evidence for the presence of electrons around the nucleus of an atom, while the Bohr atomic model described how electrons orbit the nucleus. However, Rutherford's model was limited, because it couldn't account for the stability of atoms, as electrons orbiting the nucleus would gradually lose energy and spiral into the nucleus. The Bohr model addressed this by explaining the quantised nature of these orbits and how electrons within the same orbit possess the same discrete quantity of energy.	• describes Rutherford's atomic model **[1 mark]** • describes Bohr's atomic model **[1 mark]** • describes a limitation of Rutherford's atomic model **[1 mark]** • describes significance of quantised energy levels **[1 mark]**

Q	Sample response	The response:
22	$C = 2\pi r = 2 \times \pi \times 35 \approx 219.91\ m$ $f = \frac{1}{T}$ $\therefore v = \frac{2\pi r}{T} = 219.91 \times 1.3 \times 10^6 = 2.86 \times 10^8\ m\ s^{-1}$ Average speed = 2.9×10^8 m s^{-1} (to two significant figures)	• recognises the scenario relates to average speed of objects in uniform circular motion **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the average speed of the particles **[1 mark]**

Q	Sample response	The response:
23	Weak nuclear force Electromagnetic force Gravitational force	• identifies the forces **[1 mark]**

Q	Sample response	The response:
24	$\boldsymbol{n = \frac{1240}{0.4} = 3100\ m^{-1}}$ $B = \mu_0 nI$ $= 4\pi \times 10^{-7} \times 3100 \times 0.5$ $= 0.0019\ \text{T}$ Magnitude = 0.0019 T (to two significant figures) Direction = to the left	• recognises the scenario relates to a magnetic field inside a solenoid **[1 mark]** • calculates the number of turns per metre **[1 mark]** • calculates the magnitude of the magnetic field **[1 mark]** • identifies the direction of the magnetic field **[1 mark]**

Q	Sample response	The response:
25	$L = L_0\sqrt{1-\frac{v^2}{c^2}}$ $18 = L_0\sqrt{1-\frac{(2.0\times10^8)^2}{(3.0\times10^8)^2}}$ $L_0 = 24\text{ m}$ Length = 24 m (to two significant figures)	• recognises the scenario relates to an object experiencing length contraction **[1 mark]** • correctly substitutes for relativistic length **[1 mark]** • calculates the length of the spaceship **[1 mark]**

Q	Sample response	The response:
26	$f = \frac{c}{\lambda}$ $= \frac{3 \times 10^8}{405 \times 10^{-9}}$ $= 7.41 \times 10^{14}$ Hz $E = hf$ $= 6.626 \times 10^{-34} \times 7.41 \times 10^{14}$ $= 4.91 \times 10^{-19}$ J $= 3.07$ eV Energy = 3.07 eV (to three significant figures)	• recognises the scenario relates to conversion of wavelength to frequency **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the energy of photon **[1 mark]** • converts energy into eV **[1 mark]**

Q	Sample response	The response:
27	$\frac{T^2}{r^3}=\frac{4\pi^2}{GM}$ $\frac{T^2}{(3390\times10^3+5000\times10^3)^3}=\frac{4\pi^2}{6.67\times10^{-11}\times6.42\times10^{23}}$ $T=\sqrt{\frac{4\pi^2\times5.91\times10^{20}}{6.67\times10^{-11}\times6.42\times10^{23}}}$ $=2.33\times10^4\ \text{s}$ $v=\frac{2\pi r}{T}$ $=\frac{2\pi\times8.39\times10^6}{2.33\times10^4}$ $=2.3\times10^3\ \text{m s}^{-1}$ Speed = 2.3×10^3 m s^{-1} (to two significant figures)	• recognises the scenario relates to – orbital mechanics **[1 mark]** – circular motion **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • demonstrates correct substitution **[1 mark]** • calculates the speed **[1 mark]**

Q	Sample response	The response:
28	The law of conservation requires the baryon and lepton numbers to be conserved during a particle interaction. The electron antineutrino is required to maintain symmetry for this interaction. The law of conservation also requires mass to be conserved so an antineutrino is required to ensure this.	• identifies conservation of lepton number / symmetry of the interaction **[1 mark]** • describes conservation of mass **[1 mark]**

Paper 2: Short response

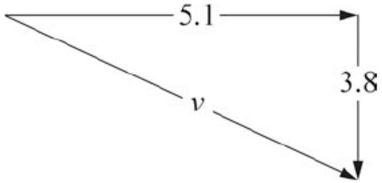
Q	Sample response	The response:
1	An object travelling near the speed of light will experience an increase in mass, resulting in increased momentum. It will also experience time slower compared to an observer in another, non-relativistic frame of reference. Finally, an object moving at relativistic speeds would be observed to decrease in length in the direction of its travel.	• describes the effect of – time dilation **[1 mark]** – length contraction **[1 mark]** – relativistic momentum **[1 mark]**
2	For object A to remain stationary, $F_{g,parallel} = F_T$ and $F_T = F_c$ $F_{g,parallel} = 7 \times 9.8 \times \sin 30 = 34.3 = F_c$ $F = \frac{mv^2}{r}$ $34.3 = \frac{7.0 \times v^2}{0.26}$ $v = \sqrt{\frac{34.3 \times 0.26}{3.0}}$ $= 1.7 \text{ m s}^{-1}$ Speed = 1.7 m s^{-1} (to two significant figures)	• identifies the equivalence of the parallel component of force due to gravity and centripetal force **[1 mark]** • calculates the parallel component of force due to gravity **[1 mark]** • recognises the scenario relates to centripetal force acting on an object **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the speed of object B **[1 mark]**

Q	Sample response	The response:
3a)	$E = \frac{F}{q}$ $= \frac{2.8}{5 \times 10^{-6}}$ $= 5.6 \times 10^{5}$ N C^{-1} Electric field strength = 5.6×10^{5} N C^{-1} (to two significant figures)	• recognises the scenario relates to force acting on a point within an electric field **[1 mark]** • calculates the electric field strength at T **[1 mark]**

Q	Sample response	The response:
3b)	Using force Force between charges *S* and *T*: $F_{ST} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ $= 9\times10^9 \times \frac{5\times10^{-6}\times5\times10^{-6}}{r^2}$ $= \frac{0.225}{r^2}$	• recognises the scenario relates to forces between charges **[1 mark]**
	Force between charges *T* and *U*: $F_{TU} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ $= 9\times10^9 \times \frac{5\times10^{-6}\times40\times10^{-6}}{(2r)^2}$ $= \frac{1.8}{4r^2}$ $= \frac{0.45}{r^2}$	• identifies the relationship between force and distance for – charges *S* and *T* **[1 mark]** – charges *T* and *U* **[1 mark]**
	Equating the forces: $\lvert F_{net}\rvert = \lvert F_{ST} - F_{TU}\rvert$ $\lvert 2.8\rvert = \left\lvert\frac{0.225}{r^2} - \frac{0.45}{r^2}\right\rvert$ $r^2 = \left\lvert\frac{-0.225}{2.8}\right\rvert$ $r = 0.28\ \text{m}$ r = 0.28 m (to two significant figures)	• identifies the vector relationship between forces **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates the value of *r* **[1 mark]**

Q	Sample response	The response:
4	Force on object A $= mg = 79 \times 1.6 = 126.4\text{ N} \approx 130\text{ N down}$ Force on object B $= mg = 32 \times 3.7 = 118\text{ N} \approx 120\text{ N down}$ Object A experiences the greatest force.	• recognises the scenario relates to relationship between the force due to gravity and mass **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • identifies the object experiencing the greatest force acting on it **[1 mark]**

Q	Sample response	The response:
5	Light with energy equivalent to *hf* has the ability to produce photoelectrons from a metallic surface. When the frequency of light is below the threshold frequency for the metallic surface, the light will be reflected with no transfer of energy. When the frequency of light is above the threshold frequency for the metallic surface, the energy of the photons will be absorbed and photoelectrons with kinetic energy proportional to the excess energy will be released. The intensity of incident light is proportional to the number of photoelectrons for frequencies greater than the threshold frequency.	• identifies incident light has energy equivalent to *hf* **[1 mark]** • describes transfer of energy when frequency of light is – below the threshold frequency **[1 mark]** – above the threshold frequency **[1 mark]** • identifies relationship between intensity of incident light and resultant photoelectrons **[1 mark]**

Q	Sample response	The response:
6a)	$u_y = 8.0\sin 50 = 6.13\ \text{m s}^{-1}$ $v_y = gt + u_y$ $0 = -9.8t + 6.13$ $t = 0.63\ \text{s}$ Time = 0.63 s (to two significant figures)	• recognises the scenario relates to an object undergoing projectile motion **[1 mark]** • calculates the initial vertical velocity **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • calculates time taken to reach maximum height **[1 mark]**
6b)	Method 1: Vector solution Impact velocity equal to the vector sum of v_x and v_y $v_y^2 = 2gs_y + u_y^2$ $= 2 \times -9.8 \times 1.2 + 6.13^2$ $= 14.1$ $v_y = 3.7\ \text{m s}^{-1}$ $v_x = u_x = 8.0\cos 50 = 5.1\ \text{m s}^{-1}$  $v = \sqrt{5.1^2 + 3.7^2} = 6.3\ \text{m s}^{-1}$ Final velocity = 6.3 m s^{-1} (to two significant figures)	• recognises the scenario relates to the relationship between initial and final velocities – vertically **[1 mark]** – horizontally **[1 mark]** • calculates final – vertical velocity **[1 mark]** – horizontal velocity **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • determines the final velocity **[1 mark]**

Q	Sample response	The response:
6b)	Method 2: Energy solution $\sum E_i = \sum E_f$ $KE_i = KE_f + GPE$ $\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgh$ $\frac{1}{2} \times 8^2 = \frac{1}{2}v^2 + 9.8 \times 1.2$ $v^2 = 40.48$ $v = 6.36 \text{ m s}^{-1}$ Final velocity = 6.4 m s^{-1} (to two significant figures)	• recognises the scenario relates to – conservation of energy **[1 mark]** – kinetic energy **[1 mark]** – gravitational potential energy **[1 mark]** • demonstrates correct substitution **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • determines the final velocity **[1 mark]**

Q	Sample response	The response:
7	Young's double slit experiment and black-body radiation both provide evidence for the behaviour of light. In Young's double slit experiment, the interference patterns formed as light passed between the two slits demonstrates the wave nature of light. In contrast, black-body radiation demonstrates the quantised nature of light as electrons can only absorb or emit energy in discrete amounts. Therefore, light has some wave properties and some particle properties.	• identifies evidence for the nature of light comes from – Young's double slit experiment **[1 mark]** – black-body radiation **[1 mark]** • describes evidence for wave nature of light **[1 mark]** • describes evidence for photons **[1 mark]** • concludes light has the properties of both waves and particles **[1 mark]**

Q	Sample response	The response:
8a)	The induced current is a result of the changing area of the enclosed loop. $\Delta A = \Delta l w = w v \Delta t$ Therefore: $emf = -n\frac{\Delta(BA_{\perp})}{\Delta t}$ $emf = -1 \times \frac{Bwv\Delta t}{\Delta t}$ $23 \times 10^{-6} = -B \times 1.4 \times 40$ $B = \frac{23 \times 10^{-6}}{1.4 \times 40}$ $= 4.1 \times 10^{-7}$ T Magnetic field strength = 4.1×10^{-7} T (to two significant figures)	• recognises the scenario relates to Faraday's law and changing area **[1 mark]** • identifies relationship for the change in area over time **[1 mark]** • provides appropriate mathematical reasoning **[1 mark]** • determines the magnitude of the magnetic field strength **[1 mark]**
8b)	The induced current in the loop moves in an anticlockwise direction. This is because the induced current will oppose any change as described by Lenz's law.	• concludes the direction of the induced current in the loop is anticlockwise **[1 mark]** • justifies the conclusion using Lenz's law **[1 mark]**