Physics marking guide and solution

Sample external assessment 2020

Maths/Science (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 | Queensland Curriculum & Assessment Authority

For all Queensland schools

Introduction

The Queensland Curriculum and Assessment Authority (QCAA) has developed mock external assessments for each General senior syllabus subject to support the introduction of external assessment in Queensland.

An external assessment marking guide (EAMG) has been created specifically for each mock external assessment.

The mock external assessments and their marking guides were:

- developed in close consultation with subject matter experts drawn from schools, subject associations and universities
- aligned to the external assessment conditions and specifications in General senior syllabuses
- developed under secure conditions.

Purpose

This document consists of an EAMG and an annotated response.

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.

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

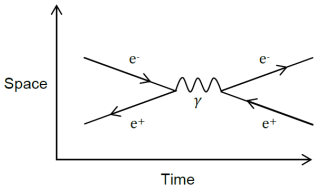
External assessment marking guide

Paper 1: Multiple-choice

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

Paper 1: Short response

Question	Sample response	The response
21	A baryon is a composite subatomic particle made up of 3 quarks.	• defines a baryon [1 mark]
22	$u_y = u \sin\theta$ $u_y = 12 \sin 35^o$ Velocity: 6.9 m s^{-1} (to 1 decimal place)	• identifies the geometry of the scenario [1 mark] • shows substitution correctly performed [1 mark] • provides 6.9 m s^{-1} as the velocity [1 mark]
23	$F_{net} = \frac{mv^2}{r}$ $\therefore r = \frac{mv^2}{F_{net}}$ $r = \frac{5 \times 8^2}{80}$ Radius: 4 m (to the nearest whole number)	• shows correct transposition [1 mark] • shows substitution correctly performed [1 mark] • provides 4 m as the radius [1 mark]

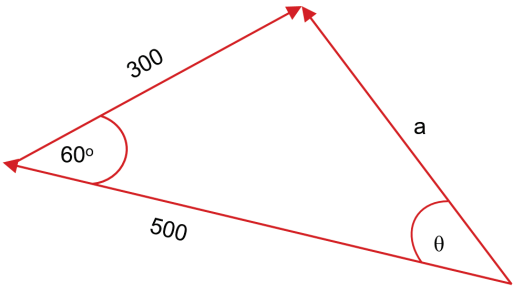
Question	Sample response	The response
24	An electron and positron annihilate to produce a photon and then pair produce another electron and positron.  	• identifies the first step of the interaction [1 mark] • identifies the final step of the interaction [1 mark] • provides the correct corresponding Feynman diagram [1 mark]
25	$F_{net} = qvB\sin\theta$ $\frac{mv^2}{r} = qvB\sin\theta$ $m = \frac{qBr\sin\theta}{v}$ $m = \frac{(4.8\times10^{-19})(0.02)(1\times10^{-4})\sin 90^o}{30}$ Mass: 3.2 x 10^{-26} kg (to 1 decimal place)	• indicates that the magnetic force is equal to the centripetal force [1 mark] • shows correct transposition [1 mark] • shows substitution correctly performed [1 mark] • provides 3.2 x 10^{-26} kg as the mass [1 mark]

Question	Sample response	The response
26	One piece of evidence is the bright and dark bands. This shows that there is interference which is a property of waves.	• identifies one piece of evidence [1 mark] • identifies that this is a characteristic of wave behaviour [1 mark]
27	$\cos\theta = \frac{u_x}{u}$ $= \frac{4}{17}$ Angle: 76° (to the nearest degree)	• identifies cos as the relevant trigonometric ratio [1 mark] • shows substitution correctly performed [1 mark] • provides 76° as the angle [1 mark]

Question	Sample response	The response
28	$\mathrm{m} = \frac{F_g}{g} = \frac{45}{9.8}$ $\mathrm{m} = 4.6\ \mathrm{kg}$	• provides 4.6 as the mass [1 mark]
	$\mathrm{F_{parallel}} = F_g\ \sin\theta$ $\mathrm{F_{parallel}} = -45\ \sin 30^o$ $\mathrm{F_{parallel}} = 22.5\ N$	• provides 22.5 as $\mathrm{F_{parallel}}$ [1 mark]
	$\mathrm{F_{net}} = \mathrm{F_{parallel}} - F_a$ $\mathrm{F_{net}} = 22.5 - 12.5$ $\mathrm{F_{net}} = 10\ N$	• determines net force [1 mark]
	$\mathrm{a_{parallel}} = \frac{\mathrm{F_{parallel_{net}}}}{m}$ $\mathrm{a_{parallel}} = \frac{10}{4.6}$ $a = 2.17\ \mathrm{m\ s^{-2}}$	• determines acceleration [1 mark]
	$s = ut + \frac{1}{2}at^2$ $10 = \frac{1}{2} \times 2.17 \times t^2$	• shows substitution correctly performed [1 mark]
	Time: 3 s (to the nearest whole number)	• determines time [1 mark]

Paper 2: Short response

Question	Sample response	The response
1a	$\text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{3.5 \times 10^{-18}}{0.008}$ $\text{gradient} = 4.4 \times 10^{-16}\ \text{Nm}^2$	• identifies a correct method to determine the gradient [1 mark] • determines gradient [1 mark]
	$F = 4.4 \times 10^{-16} \times \frac{1}{r^2}$	• identifies relationship between F and r [1 mark]
1b	$\text{gradient} = GMm$ $4.4 \times 10^{-16} = G\,(2.5 \times 10^{-3})^2$ Experimental value for G = 7.0 x 10^{-11} N m^2 kg^{-2} (to one decimal place)	• identifies that the gradient is equivalent to $G \times M \times m$ [1 mark] • determines G [1 mark]
2	$B = \frac{\mu_o I}{2\pi r} = \frac{(4\pi \times 10^{-7})(12)}{2\pi \times 0.06}$ Magnitude = 4 x 10^{-5} T (to the nearest whole number) Direction = into the page	• shows substitution correctly performed [1 mark] • provides 4×10^{-5} T as magnitude and the direction of the magnetic field is into the page [1 mark]
3	**Vector resolution method** $F_{1_y} = 300 \sin 40^o$ = 193 N	• provides 193 as F_{1_y} [1 mark]
	$F_{1_x} = 300 \cos 40^o$ = 230 N	• provides 230 as F_{1_x} [1 mark]
	$F_{2_y} = 500 \sin 20^o$ = 171 N	• provides 171 as F_{2_y} [1 mark]

$F_{2_x} = -F_2 \cos 20^o$ $= -500 \cos 20^o$ = –470 N	• provides –470 as F_{1_x} [1 mark]
$F_{y_{net}} = F_{1_y} + F_{2_y}$ $= 193 + 171$ = 364 N	• determines net vertical force [1 mark]
$F_{x_{net}} = F_{1_x} + F_{2_x}$ $= 230 + -470$ = –240 N	• determines net horizontal force [1 mark]
$F_{net} = \sqrt{(F_{y_{net}})^2 + (F_{x_{net}})^2}$ $= \sqrt{364^2 + 240^2}$ = 436 N	• determines the net force [1 mark]
$\theta = \tan^{-1}\left(\frac{364}{240}\right) = 56.6^o$ 56.6° above $x - axis$ directed to the left	• determines direction [1 mark]
Sine/cosine rule method  	• identifies the geometry of the scenario [1 mark]
$a^2 = b^2 + c^2 - 2bCos\theta$	• states the cosine rule [1 mark]
$a^2 = 500^2 + 300^2 - 2(500)(300)Cos60$	• shows substitution correctly performed [1 mark]
$a = 436$ N	• provides 436 as the net force [1 mark]
$\frac{SinA}{a} = \frac{SinC}{c}$	• states the sine rule [1 mark]
$\frac{Sin60}{436} = \frac{Sin\theta}{300}$	• shows substitution correctly performed [1 mark]
$\theta = 36.6^o$	• provides 36.6° as the angle [1 mark]

	Add θ to 20° to find the angle up from the horizontal. 56.6° above $x - axis$ directed to the left	• determines direction [1 mark]
4a	$\text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{(4.2 - 0) \times 10^{-19}}{(18 - 12) \times 10^{14}}$ $\text{gradient} = 7.0 \times 10^{-34}$ J.s $y\text{-intercept} = -8.0 \times 10^{-19}$ J $\text{Max } E_k = 7.0 \times 10^{-34} f - 8.0 \times 10^{-19}$	• determines gradient [1 mark] • determines y–intercept [1 mark] • identifies the relationship [1 mark]
4b	$W = \frac{8.0 \times 10^{-19} \text{ J}}{1.60 \times 10^{-19} \text{ J/eV}}$ $= 5 \text{ eV}$ The metal is most likely to be copper, which has a work function of 5.1 eV.	• determines work function [1 mark] • identifies metal, with a reason [1 mark]
5	$E_2 - E_1 = \frac{hc}{\lambda}$	• identifies the relationship between difference in energy levels and wavelength of the emitted photon [1 mark]
	Transition from –2.7 eV to –5.7 eV gives 3 eV $\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{(3)(1.60 \times 10^{-19})} = 414 \text{ nm}$	• identifies the energy change corresponding to 413 nm [1 mark]
	Transition from –5.7 eV to –8.2 eV gives 2.5 eV $\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{(2.5)(1.60 \times 10^{-19})} = 497 \text{ nm}$	• identifies the energy change corresponding to 496 nm [1 mark]
	Transition from –5.7 eV to –7.8 eV gives 2.1 eV $\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{(2.1)(1.60 \times 10^{-19})} = 592 \text{ nm}$	• identifies the energy change corresponding to 590 nm [1 mark]
	None of the other possible transitions would produce a 520 nm line.	• identifies that none of the other possible transitions would produce a 520 nm line. [1 mark]
	The only spectrum that shows the three visible spectrum lines highlighted above is Element A.	• identifies Element A, giving a reason [1 mark]

6	The concept of wave–particle duality means that light can exhibit either wave or particle properties depending on the situation. The alternating dark and light bands produced in Young's double slit experiment can only be explained by referring to the wave properties of light such as interference and diffraction. From the graph showing the luminosity and wavelength of light emitted from a black body, we can see that the experimental data is not consistent with the classical model for light which predicts that $I \sim \frac{1}{\lambda^4}$. Planck suggested a solution to this that electron energy levels are quantised. As particles move from higher energy to lower energy, energy is released as a photon. These photons' energies are also quantised (having discrete values).	• describes wave-particle duality [1 mark] • identifies interference and/or diffraction as wave characteristics observable in Young's experiment [1 mark] • identifies that the wave characteristic/s of light in Young's experiment cannot be explained by a particle model [1 mark] • identifies evidence of particle characteristics from the black-body radiation curve [1 mark] • identifies that the particle characteristic/s of light in black-body radiation cannot be explained by a wave model [1 mark]
7	$t_{B\,total} = 2\,t_{B_{max\,height}}$ $\therefore 4.20 = 2\,t_{B_{max\,height}}$ $t_{B_{max\,height}} = 2.10\ s$ $v_y = gt + u_y$ $0 = (9.8)(2.1) + u_y$ $u_y = 20.58\ \text{m s}^{-1}$	• provides 2.1 as the time taken for B to reach maximum height [1 mark] • shows substitution correctly performed [1 mark] • provides 20.6 as initial vertical velocity [1 mark]
	$\tan 30^o = \frac{20.58}{u_x}$ $u_x = \frac{20.58}{\tan 30^o}$ $u_x = 35.64\ \text{m s}^{-1}$	• determines initial horizontal velocity [1 mark]
	$s_x = u_x t_{B_{total}}$ $s_x = 35.64 \times 4.2$ Horizontal displacement = 150 m (to the nearest whole number)	• shows substitution correctly performed [1 mark] • determines horizontal displacement [1 mark]

8	From observer B's frame of reference, the ladder would be length contracted: $L = L_o\sqrt{1-\left(\frac{v^2}{c^2}\right)}$ $L = 20\sqrt{1-\left(\frac{(0.9c)^2}{c^2}\right)} = 8.7 \text{ m}$ The ladder would be 8.7 m long and would fit into the 15 m barn. From observer A's frame of reference, the barn would be length contracted: $L = 15\sqrt{1-\left(\frac{(0.9c)^2}{c^2}\right)}$ $L = 6.5 \text{ m}$ The ladder of 20 m long will not fit into the 6.5 m barn.	• identifies that length contraction occurs [1 mark] • calculates ladder length from B's frame of reference and identifies that the ladder will fit [1 mark] • calculates barn length from A's frame of reference and identifies that the ladder will not fit [1 mark]
	This could be viewed as a paradox because in one frame of reference the 8.7 m long ladder will fit into the 15 m long barn, while in another frame of reference the 20 m long ladder will not fit into the 6.5 m barn.	• identifies the paradox [1 mark]
	The concept of simultaneity resolves this problem. This concept states that two events that appear to be simultaneous in one frame of reference will not be in another frame of reference. In observer B's frame of reference, the doors open and close at the same instant. However, in observer A's frame of reference, the doors do not open and close at the same instant. The key is what happens while the ladder is partially inside the barn. The door in front of the ladder opens before the ladder reaches it, while the door behind the ladder only closes after the back of the ladder is inside the barn. The conclusion is that the ladder does not make contact with the barn doors	• identifies that simultaneity is required to resolve the paradox [1 mark] • identifies that the doors are not closed simultaneously in A's frame of reference [1 mark] • identifies the position of the ladder in relation to the doors in A's frame of reference [1 mark] • concludes that the ladder does not make contact with the barn doors [1 mark]