Advanced Extension Award

Physics

Summer 2007

Mark Scheme

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NORTHERN IRELAND GENERAL CERTIFICATE OF SECONDARY EDUCATION (GCSE) AND NORTHERN IRELAND GENERAL CERTIFICATE OF EDUCATION (GCE)

MARK SCHEMES (2007)

Foreword

Introduction

Mark Schemes are published to assist teachers and students in their preparation for examinations. Through the mark schemes teachers and students will be able to see what examiners are looking for in response to questions and exactly where the marks have been awarded. The publishing of the mark schemes may help to show that examiners are not concerned about finding out what a student does not know but rather with rewarding students for what they do know.

The Purpose of Mark Schemes

Examination papers are set and revised by teams of examiners and revisers appointed by the Council. The teams of examiners and revisers include experienced teachers who are familiar with the level and standards expected of 16- and 18-year-old students in schools and colleges. The job of the examiners is to set the questions and the mark schemes; and the job of the revisers is to review the questions and mark schemes commenting on a large range of issues about which they must be satisfied before the question papers and mark schemes are finalised.

The questions and the mark schemes are developed in association with each other so that the issues of differentiation and positive achievement can be addressed right from the start. Mark schemes therefore are regarded as a part of an integral process which begins with the setting of questions and ends with the marking of the examination.

The main purpose of the mark scheme is to provide a uniform basis for the marking process so that all the markers are following exactly the same instructions and making the same judgements in so far as this is possible. Before marking begins a standardising meeting is held where all the markers are briefed using the mark scheme and samples of the students' work in the form of scripts. Consideration is also given at this stage to any comments on the operational papers received from teachers and their organisations. During this meeting, and up to and including the end of the marking, there is provision for amendments to be made to the mark scheme. What is published represents this final form of the mark scheme.

It is important to recognise that in some cases there may well be other correct responses which are equally acceptable to those published: the mark scheme can only cover those responses which emerged in the examination. There may also be instances where certain judgements may have to be left to the experience of the examiner, for example, where there is no absolute correct response – all teachers will be familiar with making such judgements.

The Council hopes that the mark schemes will be viewed and used in a constructive way as a further support to the teaching and learning processes.

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[H7651]

THURSDAY 28 JUNE, AFTERNOON

MARK SCHEME

Subject-specific Instructions

In numerical problems, the marks for intermediate steps shown in the mark scheme are for the benefit of candidates who do not obtain the correct final answer. A correct answer and unit, if obtained from a valid starting-point, gets full credit, even if all the intermediate steps are not shown. It is not necessary to quote correct units for intermediate numerical quantities.

Note that this "correct answer" rule does not apply to formal proofs and derivations, which must be valid in all stages to obtain full credit.

Do not reward wrong physics. No credit is given for consistent substitution of numerical data, or subsequent arithmetic, in a physically incorrect equation. However, answers to late parts of questions that are consistent with an earlier incorrect numerical answer, and are based on a physically correct equation, must gain full credit. Designate this by writing **ECF** (Error Carried Forward) by your text marks.

The normal penalty for an arithmetical and/or unit error is to lose the mark(s) for the answer/ unit line. Substitution errors lose both the substitution and answer marks, but 10^n errors (e.g. writing 500 nm as 550×10^{-6} m) count only as arithmetical slips and lose the answer mark.

AVAILABLE MARKS

1 **(a)** **(i)** Spread out/low concentration [1]

(ii) frequency of rotation expressed in rad s^{-1} **or** number of radians turned through in 1 s or $2\pi/t$, where t is the period **or** $2\pi f$, where f is the frequency (expressed in Hz) **or** angle/second [1]

(iii) breaking the condition $n_i = n_e$ [1]

(b) Atmospheric pressure too high **and** temperature too low [1]

(c) **Alpha particle** scattering [1]
some/most passed straight through foil [1]
but some deflected through large angles [1]
so distribution of positive charge not uniform/much empty space [1] [4]
(electron scattering [0]/[4])

(d) **(i)** Quarter period = $\pi/2\omega_p$ [1]
$\pi/2 = 1.57$ [1]
which is of the order of **or** approximately 1 [1] [3]

(ii) $1/\omega_p$ far too short for practical purposes
depends on n
inconvenient to recalibrate so not readily reproducible
– any 2 from 4 [2]

(e) **(i)** Thunderstorms/sunspot activity/nuclear tests/tornadoes [1]

(ii) ω_p proportional to $n^{\frac{1}{2}}$/depends on n [1]
if n high, signal frequency may not be higher than ω_p [1]
signals now reflected from ionosphere [1]
possibility of interference from other/same station(s) [1] [4]

(f) **(i)** Wavelength of 9×10^{-8} m corresponds to **angular** frequency of 2.1×10^{16} rad s^{-1} [1]
$n = \omega_p^2 \varepsilon_0 m_e/e^2$
$= (2.1 \times 10^{16})^2 \times 8.85 \times 10^{-12} \times 9.1 \times 10^{-31}/(1.6 \times 10^{-19})^2$ subs [1]
$(= 1.39 \times 10^{29}\ m^{-3})$
$n = 3/(4\pi r^3)$ for 1 electron in sphere of radius r [1]
Radius = 1.2×10^{-10}m to 1 or 2 s.f. [1] [4]
(use of f for ω gets 0, 0, 1, 0)

(ii) Realistic value of radius (**or** consistent with e.c.f.) [1]
but model requires different radius sphere for each wavelength in spectrum [1] [2] 24

AVAILABLE MARKS

2 **(a)** For Q_1: $\Delta m = 4 \times 1.00728 - (4.00150 + 2 \times 0.00055)$
(= 0.02652 u) [1]
mass difference in u
$= 0.02652 \times 1.66 \times 10^{-27}$ (= 4.4023×10^{-29} kg) [1]
convert to kg
$E = \Delta mc^2$ [1]
$\boldsymbol{Q_1} = 4.4023 \times 10^{-29} \times (3.00 \times 10^8)^2 = \mathbf{3.96 \times 10^{-12}\ J}$ [1]

For Q_2: $\Delta m = 2 \times 0.00055\,\text{u} = 1.826 \times 10^{-30}$ kg [1]
$\boldsymbol{Q_2 = 1.64 \times 10^{-13}\ J}$ [1] [6]

(b) Total power radiated = $4\pi r^2 \Phi$ [1]
$= 4\pi(1.5 \times 10^{11})^2 \times 1.4 \times 10^3$ subs [1]
$= 4.0 \times 10^{26}$ W (3.96×10^{26}) [1]

Total energy per fusion of four protons = $\boldsymbol{Q_1 + 2Q_2}$
(= 4.28×10^{-12} J) [1]
Number of reactions per second = $4.0 \times 10^{26}/4.28 \times 10^{-12}$
(= 9.2×10^{37}) (9.25×10^{37})
i.e. use of number/second = $\dfrac{\text{power}}{\text{energy per reaction}}$ [1]
(**or** e.c.f.)
Each reaction requires **4 protons**, of mass $\mathbf{4 \times 1.67 \times 10^{-27}\ kg}$ [1]
(= 6.68×10^{-27} kg)
Mass rate = $9.2 \times 10^{37} \times 6.68 \times 10^{-27}$
$= \mathbf{6.1 \times 10^{11}\ kg\ s^{-1}}$ (6.2×10^{11}) [1] [7] 13
(omits $2Q_2$ leading to 6.43×10^{11} kg s^{-1},
allow [3] + [0], [1], [1], [0] = [5] max)

3 **(a)** Centripetal force provided by gravitational attraction/held in orbit [1]
Gravitational attraction/force acts at centre of star [1]
If orbit not equatorial, there would be a component of the gravitational attraction pulling the orbit into equatorial plane [1] [3]

(b) **(i)** Density of photographic image/current from photoelectric detector/CCD device/output: device plus signal in each case [1]

(ii) **AB** exoplanet touches edge of star's disc [1]
moving to position where planet completely on disc, (with sketches) [1]
BC transit of star by planet (sketch) [1]
CD **AB** in reverse (sketch) [1] [4]

AVAILABLE MARKS

(c) **(i)** Intensity proportional to emitting area [1]
In region **BC**, fraction obscured = $\pi r^2/\pi R^2$ (= fractional reduction in intensity) [1] [2]

(ii) Fractional reduction in intensity = 0.015 or 1.5% [1]
$\boldsymbol{r = 0.122\ R}$ **to 3 s.f.** [1] [2]

(d) **(i)** Time for **AB** or **CD** = 140 min correct read-off [1]
Use of $v = 2r/t$ [1]
$\mathbf{1.71 \times 10^{-3}}\ \boldsymbol{R}\ \mathbf{min^{-1}}$ [1] [3]
No $2r$ factor, $8.6 \times 10^{-4}\,R$ [1]/[3]

(ii) Average speed in region **BC greater** than in regions **AB**, **CD** [1]
e.g. because observing projection of uniform angular velocity of planet on diameter of orbit [1]
or observer unlikely to be in equatorial plane of exoplanet, cf Saturn's rings
illustrated by, e.g. sketch **or** more detailed mathematics [1] [3] 18

4 **(a)** Similarity: both obey inverse square law [1]
Difference: electric fields attractive or repulsive, gravitational attractive only [1] [2]

(b) **(i)** Component of v parallel to E-field = $v \cos \theta$
Proton energy required to reach upper plate = eV [1]
K.e. due to component of v parallel to E-field = $m_p(v \cos \theta)^2$ [1]
Condition for θ_{max} is $eV = m_p(v \cos \theta_{max})^2$ [1]
$\cos \theta_{max} = (1/v)\sqrt{(2eV/m_p)}$
$= (1/8.0 \times 10^5)/[(2 \times 1.60 \times 10^{-19} \times 1200)/1.67 \times 10^{-27}]^{\frac{1}{2}}$

subs [1]

(= 0.599)
$\boldsymbol{\theta_{max}}$ **= 53.2° or 0.93 rad** [1] [5]

(ii) Deceleration in E-field = $eV/m_p d (= a)$ [1]
Time of flight (lower plate back to lower plate)
$= (2v \cos \theta_0)/a\ (= t)$ [1]
Horizontal distance $x = (v \sin \theta_0)t$ [1]
$a = [\frac{1}{2}\, m_p(v \cos \theta_0)^2]m_p d$ [1]
Horizontal distance $\boldsymbol{x = 4d \tan \theta_0}$ [1] [5] 12
(**or** use $\theta_{max} = 53.2° \rightarrow$
$x = 5.58d \sin 2\theta / 11.1d \sin \theta \cos \theta$ [5]/[5])

						AVAILABLE MARKS
5	(a)	(i)	Momentum of atom beam is backwards	[1]		
			By conservation of momentum, this must be balanced by change in forwards momentum of satellite	[1]	[2]	
			("Conservation of momentum" only, allow [1]) **or** Newton's third law [1], identify forces [1]			
		(ii)	E.g. do not want to attract charged particles back to satellite	[1]		
			this might slow it down	[1]	[2]	
		(iii)	$\frac{1}{2}mv^2 = eV$	[1]		
			$V = [131 \times 1.66 \times 10^{-27} \times (2.5 \times 10^4)^2]/(2 \times 1.60 \times 10^{-19})$ subs	[1]		
			Accelerating potential = 425 V	[1]	[3]	
	(b)		Acceleration $a = 8.0$ m s^{-1} day^{-1} = 8.0/(24 × 3600)			
			= (9.26×10^{-5} m s^{-2})	[1]		
			Force = ma = 1200 × 9.26 × 10^{-5} = **0.11 N**	[1]	[2]	
	(c)		Gravitational force of Sun	[1]		
			increases resultant force, (because attraction)	[1]		
			impulse of photon impacts on satellite/photon wind/solar wind	[1]		
			decreases resultant force, because photons come from Sun towards satellite	[1]	[4]	13
6	(a)		Realises emitted power proportional to surface area	[1]		
			realises same equilibrium temperature requires same emitted power per unit area	[1]		
			Recalls $P = I^2R$, $R = L\rho/\pi r^2$ **or** $L\rho/A$ **or** proportional to $1/r^2$, and $A = 2\pi rL$ **or** proportional to r	[1]		
			Obtains $\boldsymbol{I_1/I_2 = (r_1/r_2)^{\frac{3}{2}}}$	[1]	[4]	
	(b)		**Total magnetic flux linkage decreases** (not "changes") as coil is unwound			
			causing induced e.m.f./current (Faraday)	[1]		
			indicated as **steady reading**	[1]		
			polarity of e.m.f./current such as tend to increase flux in original direction **(Lenz)**	[1]		
			magnitude of e.m.f. greater	[1]	[4]	8

				AVAILABLE MARKS
7	Light nature: both waves and particles		[1]	
	Waves			
	• Electromagnetic, transverse	[1]		
	• Constant propagation speed in vacuum	[1]		
	Experiment:			
	• Polarisation, interference, diffraction — at least two linked to wave nature	[1]		
	• • Details of any one experiment	[2]		
	Particles			
	• Photons = indivisible energy packets	[1]		
	• $E = hf$	[1]		
	Experiment:			
	• One of: Photoelectric effect, Line spectra, Gas lasers, Optical transitions in electronic devices — linked to particle nature	[1]		
	• • Details of any one experiment	[2]		
	Any 9 of 10 bullet point marks		[9]	
	Quality of written communication:			
	Relevance/organising ideas/vocabulary	[0], [1], [2]	[2]	12
			Total	**100**