GCE 2004
June Series

ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark Scheme

Physics A
Unit PA10

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Instructions to Examiners

1 Give due credit to alternative treatments which are correct. Give marks for what is correct; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the script to the Awards meeting if poor presentation forbids a proper assessment. In each paper candidates may be awarded up to two marks for the Quality of Written Communication in cases of required explanation or description. Use the following criteria to award marks:

2 marks: Candidates write legibly with accurate spelling, grammar and punctuation; the answer containing information that bears some relevance to the question and being organised clearly and coherently. The vocabulary should be appropriate to the topic being examined.

1 mark: Candidates write with reasonably accurate spelling, grammar and punctuation; the answer containing some information that bears some relevance to the question and being reasonably well organised. Some of the vocabulary should be appropriate to the topic being examined.

0 marks: Candidates who fail to reach the threshold for the award of one mark.

3 An arithmetical error in an answer should be marked AE thus causing the candidate to lose one mark. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks (indicated by ticks). These subsequent ticks should be marked CE (consequential error).

4 With regard to incorrect use of significant figures, normally two, three or four significant figures will be acceptable. Exceptions to this rule occur if the data in the question is given to, for example, five significant figures as in values of wavelength or frequency in questions dealing with the Doppler effect, or in atomic data. In these cases up to two further significant figures will be acceptable. The maximum penalty for an error in significant figures is **one mark per paper**. When the penalty is imposed, indicate the error in the script by SF and, in addition, write SF opposite the mark for that question on the front cover of the paper to obviate imposing the penalty more than once per paper.

5 No penalties should be imposed for incorrect or omitted units at intermediate stages in a calculation or which are contained in brackets in the marking scheme. Penalties for unit errors (incorrect or omitted units) are imposed only at the stage when the final answer to a calculation is considered. The maximum penalty is **one mark per question**.

6 All other procedures, including the entering of marks, transferring marks to the front cover and referrals of scripts (other than those mentioned above) will be clarified at the standardising meeting of examiners.

Unit 10: PA10
Synoptic Unit

1

(a)(i) h (= ct) (= $3.0 \times 10^8 \times 68 \times 10^{-3}$) = $2.0(4) \times 10^7$ m ✓

(ii) $g = (-)\dfrac{GM}{r^2}$ ✓

r (= $6.4 \times 10^6 + 2.04 \times 10^7$) = 2.68×10^7 (m) ✓

(allow C.E. for value of h from (i) for first two marks, but not 3rd)

$g = \dfrac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{(2.68 \times 10^7)^2}$ ✓ (= 0.56 N kg^{-1}) (*4*)

(b)(i) $g = \dfrac{v^2}{r}$ ✓

$v = [0.56 \times (2.68 \times 10^7)]^{½}$ ✓

= 3.9×10^3 m s^{-1} ✓ (3.87×10^3 m s^{-1})

(allow C.E. for value of r from a(ii))

[or $v^2 = \dfrac{GM}{r}$ ✓

$v = \left(\dfrac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{2.68 \times 10^7}\right)^{1/2}$ ✓

= 3.9×10^3 m s^{-1} ✓]

(ii) $T\left(= \dfrac{2\pi r}{v}\right) = \dfrac{2\pi \times 2.68 \times 10^7}{3.87 \times 10^3}$ ✓

= $4.3(5) \times 10^4$ s ✓ (12.(1) hours)

(use of $v = 3.9 \times 10^3$ gives $T = 4.3(1) \times 10^4$ s = 12.0 hours)

(allow C.E. for value of v from (I))

[alternative for (b):

(ii) $T^2 = \left(\dfrac{4\pi^2}{GM}\right) r^3$ ✓

$\left(= \dfrac{4\pi^2}{6.67 \times 10^{-11} \times 6.0 \times 10^{24}} \times (2.68 \times 10^7)^3\right) = (1.90 \times 10^9$ (s^2)) ✓

$T = 4.3(6) \times 10^4$ s ✓

(i) $v\left(= \dfrac{2\pi r}{T}\right) = \dfrac{2\pi \times 2.68 \times 10^7}{4.36 \times 10^4}$ ✓

= $3.8(6) \times 10^3$ m s^{-1} ✓]

(allow C.E. for value of r from (a)(ii) and value of T) (*5*)

(*9*)

2

(a) graph to show: maximum power at 0°, 180° and 360° ✓
zero power at 90° and 270° ✓
correct shape and same maximum power at the maxima ✓ *(3)*

(b)(i) $f\left(=\frac{c}{\lambda}=\frac{3.0\times10^{8}}{650\times10^{-9}}\right)=4.6(2)\times10^{14}\,(\text{Hz})$ ✓

$E(=hf=6.63\times10^{-34}\times4.62\times10^{14})=3.1\times10^{-19}\,\text{J}$ ✓ $(3.06\times10^{-19}\,\text{J})$

(ii) number of photons/sec $=\left(=\frac{0.50\times10^{-3}}{3.06\times10^{-19}}\right)=1.6(3)\times10^{15}$ ✓

(allow C.E. for energy of photon from (i))

(iii) volume of atom $[\approx(0.3\times10^{-9})^3]=2.7\times10^{-29}\,(\text{m}^3)$ ✓

volume of polaroid in path of beam $[=1.8\times10^{-6}\times1\times10^{-3}]=1.8\times10^{-9}\,(\text{m}^3)$ ✓

number of polaroid atoms in path of beam $\left[=\frac{1.8\times10^{-9}}{2.7\times10^{-29}}\right]\approx7\times10^{19}$ ✓

number of photons absorbed per sec per atom $\left(\approx\frac{1.63\times10^{15}}{7\times10^{19}}\right)\approx2\times10^{-5}$ ✓

(allow C.E. for number of photons from (ii)

[alternative method for (iii)

no. of layers of atoms along beam $=\frac{1\times10^{3}}{3\times10^{-10}}$ ✓ $(=3.3\times10^{6})$

no. of atoms per layer in beam $\left(=\frac{\text{beam area}}{\text{cross-sectional area of atom}}\right)$

$=\frac{1.8\times10^{6}}{(\pi/4)(3\times10^{-10})^2}$ ✓ $(=2.7\times10^{13})$

no. of photons per sec absorbed by layer $=\frac{1.6\times10^{15}}{3.3\times10^{6}}$ ✓ $(=4.8\times10^{8})$

no. of photons per sec absorbed per atom $\left(\frac{4.8\times10^{8}}{2.7\times10^{-13}}\right)\cong2\times10^{-5}$ ✓]

max *(6)*
(9)

3

(a) maximum force (from graph) = 1840 (N) (±100 N) ✓

max stress $\left(=\frac{\text{force}}{\text{contact area}}\right)=\frac{1840(\text{N})}{550\times10^{-6}(\text{m}^2)}$ ✓(for correct denominator) ✓

$=3.3\times10^{6}\,\text{N m}^{-2}$ ✓ *(4)*

(b) using shoes without cushioning:
impact time would be less ✓
maximum impact force would be greater ✓
area under the curve the same ✓ (*3*)
(*7*)

4

(a)(i) mass each sec [=(vol/sec) × density] = $5.2 \times 10^{-5} \times 1000$ ✓
= 0.052 kg (s^{-1}) ✓

(ii) power (= energy supplied per sec = $mc\Delta\theta$) = 0.052 × 4200 × (42 – 10) ✓
= 7.0×10^3 W ✓ (6.99×10^3 W)
(allow C.E. for value of mass each sec from (i)) (*4*)

(b) $h = \frac{1}{2}gt^2$ gives the time to reach the floor ✓

$$t\left(=\left(\frac{2h}{g}\right)^{1/2}\right) = \left(\frac{2 \times 2.0}{9.8}\right)^{1/2} = 0.64\ \text{s}$$ ✓ (0.639 s)

range = (horizontal) speed of projection × time = 2.5 × 0.64 = 1.6 m ✓
(allow C.E. for value of *t*) (*3*)
(*7*)

5

(a) circuit to show:
ammeter in series with coil ✓
voltmeter across coil (or across pot.div. output) ✓
potential divider or variable resistor correctly drawn ✓ (*3*)

(b)(i) values of R/Ω (all correct to 3 or 4 sig.fig.)
2.53(2)
2.70(3)
2.94(1)
3.23(3.226 to 4 sig.fig.)
3.39(0)
3.64(3.636 to 4 sig.fig.) ✓

(ii) suitable graph to give straight line (e.g. *R* vs *θ*) ✓
axes labelled ✓
5 points plotted correctly ✓

appropriate scales ✓
best fit line (drawn) ✓ (*6*)

(c)(i) R_0 (= *y* intercept) = 2.38 Ω (± 0.2 Ω) ✓

(ii) gradient = αR_0 ✓

$$\left(= \frac{3.64 - 2.38}{80}\right) = 1.58 \times 10^{-2}\,(\Omega\,°\mathrm{C}^{-1})\ \ (\pm 0.08 \times 10^{-2}\,(\Omega\,°\mathrm{C}^{-1})\ ✓$$

$$\alpha = \left(= \frac{1.58 \times 10^{-2}}{2.38}\right) = 6.6(4) \times 10^{-3}\ \ (\pm 0.3(4) \times 10^{-3})\ ✓\quad °\mathrm{C}^{-1}(\text{or K}^{-1})\ ✓$$

(allow C.E. for values of R_0 from (i) and gradient values) *(5)*

(d) resistance caused by scattering/collisions of
current/unattached/free/conduction electrons with vibrating ions/atoms ✓
increase in temperature makes the (+) ions/atoms vibrate more ✓
unattached/free/conduction electrons scatter/collide more
[or progress of electrons made more difficult] ✓ $_{\text{max}}$ *(2)*

(16)

6

(a)(i) (use of $d \sin\theta = n\lambda$ gives) $2\lambda = d \sin 35.8°$ ✓

$$d = \frac{1}{600 \times 10^3}\ (\text{m})\ ✓ \qquad (= 1.67 \times 10^{-6})$$

$$\lambda\left(= \frac{\sin 35.8}{2 \times 600 \times 10^3}\right) = 4.9 \times 10^{-7}\ \text{m}\ ✓ \qquad (4.87 \times 10^{-7}\ \text{m})$$

(ii) $$f\left(= \frac{c}{\lambda} = \frac{3.0 \times 10^8}{4.87 \times 10^{-7}} = 6.1(6) \times 10^{14}\,(\text{Hz})\right)$$

$E\ (= hf = 6.63 \times 10^{-34} \times 6.16 \times 10^{14}) = 4.1 \times 10^{-19}\,(\text{J})$ ✓ $(4.0(8) \times 10^{-19}\,(\text{J}))$

$$E\left(= \frac{4.08 \times 10^{-19}}{1.6 \times 10^{-19}}\right) = 2.6\,(\text{eV})\ ✓ \qquad (2.55\,(\text{eV}))$$

(for $E = 4.1 \times 10^{-19}\,(\text{J}) = 2.56\,(\text{eV})$) *(5)*

(b)(i) from C to A ✓

(ii) (use of $E_k = {}^3/_2 kT$ gives) $E_k = 1.5 \times 1.38 \times 10^{-23} \times 5000 = 1.0(4) \times 10^{-19}$ J
[or = 0.64(7) eV] ✓

(iii) some gas atoms have enough kinetic energy to cause excitation by collision ✓
photons (of certain energies) only released when de-excitation
or electron transfer to a lower level, occurs ✓
gas atoms have a spread of speeds/kinetic energies ✓
mean E_k (of gas atoms) proportional to T ✓
excitation can occur to level C ✓
de-excitation from C to B produces 2.6 eV photon/light of this wavelength ✓ $_{\text{max}}$ *(6)*

(11)

7

(a)(i) $m = 4\text{u}\ (= 4 \times 1.67 \times 10^{-27}) = 6.68 \times 10^{-27}$ (kg)) ✓
$E_k\ (= 2.8 \times 1.6 \times 10^{-13}) = 4.4(8) \times 10^{-13}$ (J) ✓
(use of $E_k = ½mv^2$ gives) $v\left(=\left(\frac{2E_k}{m}\right)^{1/2}\right)$
$= \left(\frac{2 \times 4.48 \times 10^{-13}}{6.68 \times 10^{-27}}\right)^{1/2}$ ✓ $(= 1.16 \times 10^7\ \text{m s}^{-1})$

(ii) (use of $\lambda = \frac{h}{mv}$ gives) $\lambda = \left(\frac{6.63 \times 10^{-34}}{6.68 \times 10^{-27} \times 1.16 \times 10^7}\right) = 8.5(6) \times 10^{-15}$ m ✓
(use of $m = 6.7 \times 10^{-27}$ and $v = 1.2 \times 10^7$ gives $\lambda = 8.2 \times 10^{-15}$ m) (*4*)

(b)(i) $½mv^2 = \frac{Q_1Q_2}{4\pi\varepsilon_0 r}$
[or loss of E_k = gain of E_p $\left(\text{or} \frac{Q_1Q_2}{4\pi\alpha\varepsilon_0 r}\right)$] ✓
$Q_1 = 2e$ and $Q_2 = 79e$ ✓
$r\left(=\frac{2e \times 79e}{4\pi\varepsilon_0 E_k}\right) = \frac{2 \times 1.6 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times 4.5 \times 10^{-13}}$ ✓
$= 8.1 \times 10^{-14}$ m ✓ $(8.08 \times 10^{-14}$ m)
(allow C.E. for value of E_k from(a)(i))

(ii) $\lambda << 2r$ (so diffraction negligible) ✓ (*5*)
(*9*)

8

(a)(i) (use of $W = QV$ gives) $W\ (= 1.6 \times 10^{-19} \times 2.5 \times 10^{10}) = 4.(0) \times 10^{-9}$ (J) ✓

(ii) $\Delta m\left(=\frac{\text{gain of energy}}{c^2}\right) = \frac{4 \times 10^{-9}}{(3 \times 10^8)^2}$ ✓
$= 4.4(4) \times 10^{-26}$ (kg) ✓
(allow C.E. for value of W from (i))

[or $W = 4 \times 10^{-9}$ (J) $= 2.5 \times 10^4$ MeV ✓
$(\Delta)\ m = \frac{2.5 \times 10^4 \text{(MeV)} \times 1.66 \times 10^{-27} \text{(kg / u)}}{931.3 \text{(MeV / u)}} = 4.4(4) \times 10^{-26}$ (kg) ✓] (*3*)

(b)(i) $BQv = \frac{mv^2}{r}$ ✓ (to give $v = \frac{BQr}{m}$)

(ii) (same path) $\therefore r$ is the same ✓
(B and) Q the same ✓
$\therefore mv$ is the same and since m differs, then v must be different ✓

(iii) antiproton: up, up, down antiquarks ✓
negative pion: up antiquark, down quark ✓
correct format for both (i.e. 3 antiquarks, and quark + antiquark) ✓ (*7*)
(*10*)

Quality of Written Communication: Q5 (d) and Q6 (b) (iii) ✓✓
(*2*)
(*2*)