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RECOGNISING ACHIEVEMENT

GCE

# Physics B (Advancing Physics)

Advanced GCE

Unit **G495:** Field and Particle Pictures

# Mark Scheme for June 2012

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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**Annotations available in Scoris**

| Annotation | Meaning |
|---|---|
|  | Benefit of doubt given |
|  | Contradiction |
|  | Incorrect response |
|  | Error carried forward |
|  | Follow through |
|  | Not answered question |
|  | Benefit of doubt not given |
|  | Power of 10 error |
|  | Omission mark |
|  | Rounding error |
|  | Error in number of significant figures |
|  | Correct response |
|  | Arithmetic error |
|  | Wrong physics or equation |

**Annotations in Mark Scheme**

| Annotation | Meaning |
|---|---|
| **/** | alternative and acceptable answers for the same marking point |
| **(1)** | Separates marking points |
| **reject** | Answers which are not worthy of credit |
| **not** | Answers which are not worthy of credit |
| **IGNORE** | Statements which are irrelevant |
| **ALLOW** | Answers that can be accepted |
| **( )** | Words which are not essential to gain credit |
| **__** | Underlined words must be present in answer to score a mark |
| **ecf** | Error carried forward |
| **AW** | Alternative wording |
| **ORA** | Or reverse argument |

**Subject specific Marking Instructions**

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 1 | (a) | | C | 1 | |
| | (b) | | I = 200 x 1.8/ 400<br>= 0.90 A (1) | 1 | No ecf from 1(a) |
| 2 | (a) | | neutron | 1 | |
| | (b) | | neutron | 1 | |
| 3 | | | Units of k = N $C^{-1}$ $m^2$ $C^{-1}$ (1) (which = N $m^2$ $C^{-2}$) | 1 | Allow unit derived from algebraic rearrangement to $k=Fr^2/Q_1Q_2$ or $Fr^2/Q^2$ |
| 4 | (a) | | A | 1 | |
| | (b) | | mass lost $s^{-1}$ = power/$c^2$ = 4 x $10^{26}$/ 9.0 x $10^{16}$ (1)<br>= 4 x $10^9$ kg (1) | 2 | **This is the only question for which a sig fig penalty applies.** No more than two sig fig for second mark.<br>Bald correct answer to one or two sig fig scores 2. (eg 4 x $10^9$ or 4.4 x $10^9$ )<br>Bald correct answer to more than two sig fig scores 1.<br>4.4 recurring scores 1 |
| 5 | (a) | | V = 9.0 x $10^9$ x 1.6 x $10^{-19}$ / 5.0 x $10^{-6}$ (1)<br>= 2.9 x $10^{-4}$ $JC^{-1}$ (1) | 2 | Allow V (= Er) = 58 x 5 x $10^{-6}$ (1)<br>= 2.9 x $10^{-4}$ J $C^{-1}$ (1)<br>Penalise 1 mark for use of V = Ed (uniform field equation)<br>Allow 3 x $10^{-4}$ $JC^{-1}$, 2.88 x $10^{-4}$ $JC^{-1}$<br>Allow bald answer |
| | (b) | | Zero (1) | 1 | Ignore unit |
| | (c) | | Twice the value (1) | 1 | Accept 2 x value from 5(a) and allow ecf.<br>Ignore unit and any spurious justifications. |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 6 | | | $r = 2.5 \times 10^{-20}/0.7 \times 1.6 \times 10^{-19}$ (1)<br>= 0.22 (m)(1) | 2 | Award 1 mark for mv/Bq<br>Need to see own value<br>Award 1 mark only for bald correct answer to two or more sig figs<br>Allow reverse arguments leading to correct comparison of momentum ($2.24 \times 10^{-20}$ kg m $s^{-1}$) and field strength (0.781 T) with given values. |
| 7 | | | 26 yrs = 0.864 half lives (1)<br>$(1/2)^{0.864}$ (1)<br>= 0.549 = 55 % (1)<br><br>or<br><br>$\lambda = 0.693/30.1$ (1)$= 0.023$ ($yr^{-1}$)<br>$N/N_0 = e^{-(0.693/30.1)26}$ (1)<br>= 0.549 = 55% (1) | 3 | Allow use of 30 yr for half life (gives 54.8 %).<br><br>Beware: assumption of linear decay gives 56.8% – scores one mark if correct $\lambda$ or correct number of half lives.<br><br>Credit $\lambda$ in years or seconds (= $7.3 \times 10^{-10}$)<br>Accept activity equation and arbitrary values of $N_0$ or $A_0$ in calculation. Allow use of activity A rather than number, N. |
| 8 | | | F = 0.23 x 0.15 x 0.4 (1)<br>= 0.014 N (1) | 2 | One mark only if any power of ten error.<br>Accept 0.0138 N and 0.01 N. |
| | | | **Section A Total** | **19** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 9 | (a) | | Any three from:<br>• electrons attracted to nucleus (along line joining centre of particles)<br>• Force or acceleration increases as distance from nucleus decreases AW<br>• So curvature of track increases as distance from nucleus decreases AW | 3 | **Use ticks to indicate marks awarded when marking this question.**<br>In cases of contradiction between the written answer and a diagram the written answer overrides the diagram.<br>Accept F varies with $1/r^2$ for second mark<br>QWC mark only available if path and force variation are clearly linked. Do not award if the answer includes inappropriate physics such as incorrect application of centripetal force. |
| | (b) | (i) | Units of *E* identified as kg $m^2$ $s^{-2}$ or $kg(ms^{-1})^2$(1)<br>Units of *E/c* expressed as kg $m^2$ $s^{-2}$/m $s^{-1}$<br>or $kg(ms^{-1})^2$/m $s^{-1}$ (1)<br>OR<br>*E/c* has units N m/m $s^{-1}$ = N s (1)<br>p units of N s from f = rate of change of momentum (1) | 2 | Allow: p = E/c = $mc^2/c$ = mc (1)<br>mc has units $kgms^{-1}$ (1)<br>Argument must be clearly made. (Going from Nm to answer is not sufficient) |
| | | (ii) | $\lambda = 3.0 \times 10^8 \times 6.6 \times 10^{-34} / 6.8 \times 10^{-11}$ (1)<br>$= 2.91 \times 10^{-15}$ (1) | 2 | (For information momentum is $2.26 \times 10^{-19}$ $kgms^{-1}$)<br>Need own value of final answer<br>Allow reverse argument leading to energy $6.6 \times 10^{-11}$J<br>Any evidence of direct use of E = hf scores zero |
| | (c) | | $\theta$ found as $49 - 50^o$ (1)<br>$b = 1.2 \times 2.91 \times 10^{-15} / \sin 50^o$ (1)<br>$= 4.6 \times 10^{-15}$m (1) | 3 | Credit answers in range $4.5 - 4.8 \times 10^{-15}$ m, but also allow ecf on $\lambda$ values which round to $3 \times 10^{-15}$ m.<br>**Allow ecf within part question for incorrect angle for 2 max** |
| | | | **Total** | **10** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **10** | (a) | (i) | $mc^2$ (at rest)<br>OR<br>$m_0c^2$ | 1 | Accept "the energy equivalence of rest mass" |
| | | (ii) | (940 +220)/940 = 1.23 | 1 | Need own value or clear working |
| | | (iii) | $1.23^2 = 1/(1 - v^2/c^2)$ (1)<br>(= 1.51 )<br>$v^2/c^2$ = 0.339<br>v/c = 0.58 (1) | 2 | Have to give own value of v (or of v/c, or both)<br>Allow using gamma = 1.2 giving v/c = 0.55<br>Allow reverse argument:<br>$gamma^2 = 1/(1 - 0.6^2)$ (1)<br>gamma = 1.25 (1) |
| | (b) | | Proton energy = $220 \times 10^6 \times 1.6 \times 10^{-19} = 3.52 \times 10^{-11}$ (1)<br>Dose equivalent per proton = $1.17 \times 10^{-6}$ Sv (1)<br>Number of protons to deliver dose equivalent = $1.1 \times 10^5$ (1)<br><br>OR<br>energy = $(125 \times 10^{-3} \times 3.0 \times 10^{-4})/10 = 3.75 \times 10^{-6}$ J (1)<br><br>No. of protons = $3.75 \times 10^{-6}/ (220 \times 10^6 \times 1.6 \times 10^{-19})$ (1)<br>= $1.1 \times 10^5$ (1) | 3 | Credit all other valid methods<br><br>Accept any answer which will round to $1.1 \times 10^5$<br><br>Allow reverse argument starting from $10^5$ protons:<br>**E.G.**<br>Energy = $10^5 \times 220 \times 10^6 \times 1.6 \times 10^{-19} = 3.52 \times 10^{-6}$ (1)<br>Effective dose equivalent = $3.52 \times 10^{-6} \times 10/3.0 \times 10^{-4}$ (1)<br>= 117 mSv (1) |
| | (c) | (i) | Answer = 13-14 cm (1)<br>This is (the depth at which) the steepest gradient occurs (1)<br>(At this depth) the energy loss per cm is greatest (1) | 3 | Accept greatest rate |
| | | (ii) | Calculation in (b) assumes all energy is absorbed by the cells (1)<br>Graph shows energy is transferred over a range of depths (1) | 2 | Accept alternative wording |
| | | | **Total** | **12** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 11 | (a) | (i) | Five lines, equally spaced by eye (1)<br>Arrows pointing to the left. (1) | 2 | lines must be straight, touching the plates, perpendicular to the plates and approximately symmetrical about the centre of the plates. Allow edge effects illustrated. |
| | (a) | (ii) | vertical line in middle of gap (by eye) | 1 | label not required |
| | (b) | | $E = 48 \times 10^3 / 0.28 = 0.17$ (1) (MV $m^{-1}$) | 1 | Need own value or clear working. POT error scores zero. |
| | (c) | (i) | Drag = weight **and** calculation showing weight is<br>$1.3 \times 10^{-6} \times 9.8 = 1.3 \times 10^{-5}$ N (1) | 1 | Both parts needed; don't accept force for drag.<br>Need own value or clear working. |
| | | (ii) | $F = 2.2 \times 10^{-13} \times 0.17 \times 10^6 = 3.7 \times 10^{-8}$ N (1) | 1 | If 0.2 MV $m^{-1}$ is used accept $4.4 \times 10^{-8}$ N<br>If 0.171 MV $m^{-1}$ is used accept $3.8 \times 10^{-8}$ N<br>Need own value or clear working.<br>Allow ecf from (b) if (b) value rounds to 0.2 MV $m^{-1}$ |
| | | (iii) | $a = 3.7 \times 10^{-8} / 1.3 \times 10^{-6} = 0.0285$ (1)<br>$t = 1.9/0.8 = 2.38$ (1)<br>$s = 0.5 \times 0.0285 \times 2.38^2 = 0.081$m (1) | 3 | If $4.4 \times 10^{-8}$ N used = 0.096 m<br>If $3.8 \times 10^{-8}$ N used = 0.083 m<br>If $4.0 \times 10^{-8}$ N used = 0.087 m<br>Accept minor variations depending on rounding in intermediate working.<br>Allow ecf from cii if value rounds to $4 \times 10^{-8}$<br>**Accept ecf within part question** |
| | (d) | | Deflection halved (1)<br>E-field halved (1)<br>so force or acceleration halved (1) | 3 | Correct qualitative response including all three points: max 1 mark. |
| | | | **Total** | **12** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **12** | (a) | | $4.6 \times 10^{-6} / 150 \times 31 \times 10^{-3} = 9.9 \times 10^{-7}$ (1) Wb A-turns $^{-1}$ (1) | 2 | Accept Wb $A^{-1}$ or H as the only alternative units.<br>Accept $1 \times 10^{-6}$<br>Beware POT errors e.g $9.9 \times 10^{-10}$<br>Accept bald answers |
| | (b) | | permeability = $9.9 \times 10^{-7} \times 0.27/2.6 \times 10^{-4}$ (1)<br>= $1.0 \times 10^{-3}$ (1) | 2 | Accept ecf.<br>Accept $1 \times 10^{-3}$ Accept $1.03 \times 10^{-3}$<br>Don't accept $1.02 \times 10^{-3}$ (rounding error).<br>Accept bald answers |
| | (c) | (i) | air has a much lower permeability | 1 | Accept 'a lower permeability' |
| | | (ii) | flux reduces when <u>permeance</u> reduces. (1)<br>as current-turns value is unchanged (1)<br>or<br>explicit analogy between electric circuit and magnetic circuit: flux analogous to current and current- turns to p.d (1);<br><u>permeance</u> analogous to conductance and reduces (1) | 2 | |
| | (d) | | Any two from:<br>• Permeability a property of material<br>• Permeability of iron remains constant<br>• Equation is not applicable as it does not account for the permeability of the air gap. | 2 | Answer must relate to permeability not permeance |
| | | | **Total** | **9** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **13** | | | Any two from:<br>Stress concentration at crack (1)<br>Rock fails when local stress at crack exceeds fracture stress (1)<br>Crack propagates through material (1)<br>Under tensile load (1)<br>(clean break with) no plastic flow (1) | 2 | These points may be made by annotated diagrams<br><br>Accept breaking stress. |
| **14** | (a) | | t = $2\pi r$ / v = 3.72 hours (or 3 hours 43 minutes) (1) | 1 | Answer just in seconds is not sufficient<br>Credit any valid comparison. |
| | (b) | | 6000 $ms^{-1}$/ 1s and 3000 $ms^{-1}$/ 0.5s (1)<br>Both evaluated to 6000 (m), or equated (1) | 2 | Accept double v and double f (1)<br>gives same $\lambda$ as v=f $\lambda$ (1)<br>Units, if given, must be correct otherwise maximum one mark |
| **15** | | | Transverse waves produce vibrations at right angles to direction of travel (1)<br>These vibrations can be in two perpendicular directions to each other (1)<br>Longitudinal waves produce vibrations in direction of travel (so in third spatial dimension) (1) | 3 | Correct, labelled diagrams can gain all three marks.; (-1 if T and L not labelled); (-1 if direction of travel not labelled).<br>Confusing longitudinal waves with transverse waves scores zero. |
| **16** | | | $v_2 = v_1$ x (sin $\theta_2$ / sin $\theta_1$) (1)<br>= 6.0 km/s x (sin 21 / sin 30) (1)<br>= 4300 m $s^{-1}$ (1) | 3 | Correct bald answers gain 3 marks.<br><br>No ecf if angles are reversed. |
| | | | **13 to 16 Total** | **11** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 17 | (a) | | (If driving frequency of earthquakes equals that of natural frequency of seismometer then) resonance occurs (1)<br>resulting in production of large amplitude vibrations of seismometer (1) | 2 | Do not credit constructive interference. |
| | (b) | | frequency of L waves = 0.05 Hz = $1/2\pi\ (g/L)^{1/2}$ (1)<br>Re-arranging and evaluating gives L = 99.3 m (1) | 2 | Allow use of frequency lower than 0.05 Hz if it rounds to 0.05 Hz<br>Do not credit 99.2 (rounding error).<br>Or reverse calculation from 100m<br>$f = (9.8/100)^{1/2}/2\pi$ (1)<br>= 0.0498 Hz (1) |
| | (c) | | Effective length = d / sin $\alpha$ (1)<br>So, $\alpha = \sin^{-1}(1 / 100) = 0.6^{o}$ (1) | 2 | Allow ecf from (b) if value used is in range 50m to 150 m<br>Accept $0.57^{o}$ or $0.58^{o}$ Allow tangent (small angle approx) |
| | | | **Total** | **6** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 18 | (a) | | Ref to F = ma (1)<br>Small F and large m combine to give small *a* (1) | 2 | |
| | (b) | | Displacement small so angle small (1)<br>Force equals mg sin $\alpha$ (1) | 2 | Allow evaluated acceleration based estimated displacement substituted in SHM equation (1)<br>If force then evaluated using sensible estimated mass (1) |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 19 | (a) | | each difference of 1 is factor of 10 (1)<br>so 100 times (1) | 2 | Accept $10^{6}/10^{4}$ (1) = $10^{2}$ (1) |
| | (b) | | $100^{3/2}$ (1)<br>= 1000 (1) | 2 | Allow for ecf<br>Accept bald answer |
| | | | **Question 18 & 19 Total** | **8** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **20** | (a) | | (Movement causes) change of magnetic flux linkage (1)<br>Induced emf related to the rate of change of flux (linkage or in the coil) (1) | 2 | *Accept* flux in coil changes<br><br>Accept flux (line) cutting arguments for both marks e.g. The coil cuts flux lines (1) Emf depends on rate of cutting flux lines (1). |
| | (b) | (i) | Flux = B x A = $0.15 \times 4 \times 10^{-4}$ (1)<br>$= 6 \times 10^{-5}$ (Wb) (1) | 2 | 1 mark max if POT error |
| | | (ii) | Flux linkage = $200 \times 6 \times 10^{-5}$<br>= 0.012 Wb turn (1) | 1 | Accept use of $5 \times 10^{-5}$ Wb for value of flux, leading to flux linkage of 0.01 Wb<br>Ecf from (b)(i) |
| | | (iii) | Change in flux linkage = 0.012 / 2 = $6 \times 10^{-3}$ Wb turn (1)<br>Time taken for change = $3 \times 10^{-3} / 1.8 \times 10^{-3}$ m $s^{-1}$<br>= 1.7 s (1)<br>(Magnitude of) induced emf = $\Delta N\phi / \Delta t$ (1)<br>= 3.5 mV (1) | 4 | Ecf from (b)(ii) and within this part of the question.<br><br>Allow implicit use of equation<br>Ignore sign<br>Accept 4mV..<br>Accept 3.6 mV given by t = 1.67s. Correct bald answer gains four marks.<br><br>3.5 mV, 3.6 mV, 4mV score 4 marks<br><br>7 mV, 7.1 mV, 7.2 mV score 3 marks<br><br>5.9 mV scores 3 marks |
| | | | **Total** | **9** | |

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 21 | movement between plate and field induces a voltage (in the plate) (1)<br><br>This results in (eddy) currents (1)<br><br>Currents produce magnetic fields which act to oppose the motion or change of flux which caused them (1)<br><br>Loss of energy due to $I^2R$ (1) | 4 | **Use ticks on this question to indicate mark awards.**<br>QWC : only award 4 marks for clear linking of arguments.<br><br>accept flux changing or flux cutting inducing a voltage.<br><br>Accept magnetic force on induced current opposes the motion.<br><br>Accept heating effect of current. |
| | **Total** | **4** | |
| | **Section C total** | **38** | |

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