

Mark Scheme (Provisional)

Summer 2021

Pearson Edexcel International Advanced Level In Physics (WPH14) Paper 01 Further Mechanics, Fields and Particles

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. It is not a set of model answers.

For example:

(iii) Horizontal force of hinge on table top

66.3 (N) or 66 (N) **and** correct indication of direction [no ue] ✓ 1 [Some examples of direction: acting from right (to left) / to the left / West / opposite direction to horizontal. May show direction by arrow. Do not accept a minus sign in front of number as direction.]

This has a clear statement of the principle for awarding the mark, supported by some examples illustrating acceptable boundaries.

1. Mark scheme format

- 1.1 You will not see 'wtte' (words to that effect). Alternative correct wording should be credited in every answer unless the ms has specified specific words that must be present. Such words will be indicated by underlining e.g. 'resonance'
- **1.2** Bold lower case will be used for emphasis.
- **1.3** Round brackets () indicate words that are not essential e.g. "(hence) distance is increased".
- **1.4** Square brackets [] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

- **2.1** A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.
- 2.2 Incorrect use of case e.g. 'Watt' or 'w' will not be penalised.
- **2.3** There will be no unit penalty applied in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.
- **2.4** The same missing or incorrect unit will not be penalised more than once within one question (one clip in epen).
- **2.5** Occasionally, it may be decided not to penalise a missing or incorrect unit e.g. the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.
- **2.6** The mark scheme will indicate if no unit error penalty is to be applied by means of [no ue].

3. Significant figures

- **3.1** Use of an inappropriate number of significant figures in the theory papers will normally only be penalised in 'show that' questions where use of too few significant figures has resulted in the candidate not demonstrating the validity of the given answer.
- **3.2** The use of $g = 10 \text{ m s}^{-2}$ or 10 N kg⁻¹ instead of 9.81 m s⁻² or 9.81 N kg⁻¹ will be penalised by one mark (but not more than once per clip). Accept 9.8 m s⁻² or 9.8 N kg⁻¹

4. Calculations

- **4.1** Bald (i.e. no working shown) correct answers score full marks unless in a 'show that' question.
- **4.2** If a 'show that' question is worth 2 marks then both marks will be available for a reverse working; if it is worth 3 marks then only 2 will be available.
- **4.3 use** of the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.
- **4.4 recall** of the correct formula will be awarded when the formula is seen or implied by substitution.
- 4.5 The mark scheme will show a correctly worked answer for illustration only.
- **4.6** Example of mark scheme for a calculation:

'Show that' calculation of weight

Use of $L \times W \times H$

Substitution into density equation with a volume and density

Correct answer [49.4 (N)] to at least 3 sig fig. [No ue] [If 5040 g rounded to 5000 g or 5 kg, do not give 3rd mark; if conversion to kg is omitted and then answer fudged, do not give 3rd mark] [Bald answer scores 0, reverse calculation 2/3]

Example of answer:

 $80 \text{ cm} \times 50 \text{ cm} \times 1.8 \text{ cm} = 7200 \text{ cm}^3$

 $7200 \text{ cm}^3 \times 0.70 \text{ g cm}^{-3} = 5040 \text{ g}$

 $5040 \times 10^{-3} \text{ kg} \times 9.81 \text{ N/kg}$

= 49.4 N

5. Graphs

- 5.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.
- **5.2** Sometimes a separate mark will be given for units or for each axis if the units are complex. This will be indicated on the mark scheme.
- **5.3** A mark given for choosing a scale requires that the chosen scale allows all points to be plotted, spreads plotted points over more than half of each axis and is not an awkward scale e.g. multiples of 3, 7 etc.

3

- **5.4** Points should be plotted to within 1 mm.
 - Check the two points furthest from the best line. If both OK award mark.
 - If either is 2 mm out do not award mark.
 - If both are 1 mm out do not award mark.
 - If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.
 - For a line mark there must be a thin continuous line which is the best-fit line for the candidate's results.

| number | | |
|--------|--|-----|
| | The only correct answer is B muon Incorrect answers A antiproton is made of antiquarks C neutron is made of quarks D Pion is made of quark-antiquark | (1) |

| Question | Answer | Mark |
|----------|--|------|
| number | | |
| 2 | The only correct answer is B The nucleus of the atom is positively charged because the deflection could have been caused by a concentration of negative charge Incorrect answers A,C,D these are clear conclusions | (1) |

| Question | Answer | Mark |
|----------|--|------|
| number | | |
| 3 | The only correct answer is C because lepton number and charge are equal before and after the interaction Incorrect answers A lepton number is not conserved B charge is not conserved D lepton number is not conserved and charge is not conserved | (1) |
| | | |

| Question number | Answer | Mark |
|--------------------|--|------|
| 4 | The only correct answer is A Incorrect answers B a baryon cannot mix q and anti-q, a mson cannot be qq C both have the wrong number of quarks D both have the wrong number of quarks | (1) |

| Question number | Answer | Mark |
|--------------------|---|------|
| 5 | The only correct answer is B increase the anode potential V because this will increase momentum and decrease de Broglie wavelength and decrease the angle Incorrect answers A this does not affect the angle C this does not affect the angle, just the intensity D this will increase the angle | (1) |

| Question | Answer | Mark |
|----------|--------|------|
| number | | |

| | 6 | The only correct answer is D because this will decrease the rate of change of flux linkage and therefore the induced emf and therefore the current Incorrect answer A, B, C these will all increase the rate of change of flux linkage and therefore the induced emf and therefore the current | (1) |
|--|---|--|-----|
|--|---|--|-----|

| Question number | Answer | Mark |
|--------------------|---|------|
| 7 | The only correct answer is B because each sphere has half of the original kinetic energy and if ke is decreased by a factor of ½, speed is decreased by the square root of this Incorrect answers A,C,D | (1) |

| Question | Answer | Mark |
|----------|---|------|
| number | | |
| 8 | The only correct answer is C because $E = V/d$ so these changes decrease the electric field strength and therefore the force on the particle and therefore the acceleration and therefore the angle Incorrect answers A,B,D – these all increase the electric field strength | (1) |
| | | |

| Question number | Answer | Mark |
|--------------------|--|------|
| 9 | The only correct answer is B because $F = Bqv$ so $v=F/Bq$ Incorrect answers A,C,D | (1) |
| | | |

| Question | Answer | Mark |
|----------|---|------|
| number | | |
| 10 | The only correct answer is D because short de Broglie wavelengths are needed to investigate the structure of nucleons at smaller scales Incorrect answers A these experiments are not about the creation of new particles B negative electrons do not experience repulsive electrostatic forces from positive protons or neutral neutrons C particle lifetime is not relevant as all of the particles involved are believed to be stable, as long as neutrons are in a nucleus | (1) |
| | | |
| | | |

| Question number | Answer | Mark |
|--------------------|---|------|
| 11(a) | • Calculate period = $8.3 \text{ s} \div 10 = 0.83 \text{ s}$ • $\text{calculate } f = 10/8.3 \text{ s} = 1.2 \text{ Hz}$ (1) • Use of $\omega = 2\pi / T$ • $\omega = 7.6 \text{ rad s}^{-1}$ (1) Example of calculation $T = 8.3 \text{ s} \div 10 = 0.83 \text{ s}$ | 3 |
| | Use of $\omega = 2\pi / T$ $\omega = 7.6 \text{ rad s}^{-1}$ | |
| 11(b) | • Use of $F = BIl \sin\theta$ (1) • $F = 2.0 \times 10^{-3}$ N (1) • direction is out of page (1) Example of calculation F = 0.053 T × 1.1 A × 3.5 × 10 ⁻² m × sin 80° $= 2.0 \times 10^{-3}$ N | 3 |
| | Total for question 11 | 6 |

| Question number | Answer | Mark |
|--------------------|--|------|
| 12 (a) | • Evidence of $E_k = \frac{1}{2} mv^2$ and $p = mv$ (1) • Correct algebraic link to $E_k = \frac{p^2}{2m}$ (1) Example of derivation $E_k = \frac{1}{2} mv^2$ $[= m \times mv^2 / 2 \times m]$ $= (mv)^2 / 2m$ [p = mv] $E_k = \frac{p^2}{2m}$ | 2 |
| 12(b) | • Use of $F = Eq$ (1) • Use of $W = Fs$ (1) • Use of $E_k = p^2/2m$ Or Use of $E_k = \frac{1}{2} mv^2$ and $p = mv$ in conjunction (1) • Momentum = 9.33×10^{-20} kg m s ⁻¹ (1) Example of calculation $F = 7.64 \times 10^6$ V m ⁻¹ × 1.60×10^{-19} C $= 1.22 \times 10^{-12}$ N $W = 1.22 \times 10^{-12}$ N × 5.50×10^{-3} m $= 6.72 \times 10^{-15}$ J 6.72×10^{-15} J + 6.42×10^{-15} J = 1.31×10^{-14} J 1.31×10^{-14} J = $p^2 / 2 \times 3.32 \times 10^{-25}$ kg $p = 9.33 \times 10^{-20}$ kg m s ⁻¹ | 4 |
| (\bigcirc) | Total for question 12 | 6 |

| number(1)13• Use of $\Delta E_{grav} = mg\Delta h$ (1)• Idea that centripetal force at top of loop equals weight for minimum speed(1)• Use of $F = mn^2/r$ (1)• Use of $E_k = \frac{1}{2} mn^2$ (1)• Or Subtract E_{grav} at top of loop and required E_k Or Subtract required E_k from E_{grav} at launch Or Subtract required E_k from E_{grav} at launch(1)• (ΔE_{grav} at top of loop and required E_k , so insufficient energy), so it does not complete the loop Or (Height required 0).025 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop Or E_k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.324$ N Ar minimum speed $W = mv^2/r$ 0.324 N $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.25$ m $= 0.0809$ J $W = 0.033$ kg $\times (1.04$ m $s^{-1}^2 = 0.0178$ J AE_{grav} at release point $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.25$ m $= 0.0712$ J Total energy required to complete loop 0.0178 J AE_{grav} at release point $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.22$ m $= 0.0712$ J Total energy required to complete loop 0.0178 J AE_{grav} at release point $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.22$ m $= 0.0712$ J Total energy required to complete loop 0.0178 J AE_{grav} top of loop $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.22$ m $= 0.0712$ J Total energy required to complete loop 0.00718 J AE_{grav} top of loop $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.22$ m $= 0.0712$ J Total energy required to complete loop <br< th=""><th>Question</th><th>Answer</th><th>Mark</th></br<> | Question | Answer | Mark |
|--|----------|--|------|
| 13• Use of $\Delta E_{gav} = mg\Delta h$ (1)• Idea that centripetal force at top of loop equals weight for minimum speed(1)• Use of $F = mn^2/r$ (1)• Use of $F = mn^2/r$ (1)• Add E_{gav} at top of loop and required E_k (1)• Add E_{gav} at top of loop and required E_k (1)• Or Subtract E_{gav} at top of loop and required E_k (1)• Or Subtract required E_k from E_{gav} at launch(1)• (ΔE_{gav} at top 00 pod ng and required E_k so insufficient energy), so it does not complete the loop(1)• Or (Height required 0) 0.275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop(1)• Or E_k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop(1)• Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop(1)• Or and the required 1.04 m s ⁻¹ so it does not complete the loop(1)• Or and the required 0.071 J (so insufficient energy), so it does not complete the loop(1)• Or a multiple the loop(1)• Or a multiple the required 0.04 m s^{-1} so it does not complete the loop(1)• Or a multiple the required 1.04 m s^{-1} so it does not complete the loop(1)• Or a theight of top of loop would be 0.25 m = 0.0809 J $W = 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.25$ m = 0.0809 J $W = 0.033$ kg $\times 7^2/0.11$ m $v = 1.04$ m s ⁻¹ • $E_k = b_k = 0.033$ kg $\times 7^2/0.11$ m $v = 1.04$ m s ⁻¹ (2)• | number | | |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | 13 | • Use of $\Delta E_{\text{grav}} = mg\Delta h$ (1) • Idea that constrained forms at tag of loop equals unight for | |
| Immunoptic(1)• Use of $F = mv^2/r$ (1)• Use of $E_k = \frac{1}{2}mv^2$ (1)• Add E_{gav} at top of loop and required E_k Or Subtract E_{gav} at po of loop from E_{gav} at launch Or Subtract required E_k from E_{gav} at launch (1)(1)• (ΔE_{gav} at start of) 0.081 J is less than 0.089 J (for sum of | | • Idea that centripetal force at top of foop equals weight for (1) | |
| • Use of $E_k = \frac{1}{2} mv^2$ (1) • Use of $E_k = \frac{1}{2} mv^2$ (1) • Add E_{grav} at top of loop and required E_k Or Subtract E_{grav} at top of loop from E_{grav} at launch Or Subtract E_{grav} at top of loop and required E_k , so insufficient energy), so it does not complete the loop Or (Height required of) 0.275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop Or E_k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop Or v at height of top of loop would be 0.77 m s ⁻¹ which is less than the required 1.04 m s ⁻¹ so it does not complete the loop Or mv ² /r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop Or mv ² /r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop Or mv ² /r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop (1) b onot credit parts of calculation or derivation unambiguously using the formula for uniform acceleration $v^2 = 2as$, i.e. if the symbols are seen and substitution is from them and not from $mg\Delta h$ $= \frac{1}{2} mv^2$ Example of calculation ΔE_{grav} at release point = 0.033 kg × 9.81 N kg ⁻¹ × 0.25 m = 0.0809 J W = 0.033 kg × 0.033 kg × 10.11 m $v = 1.04 m s^{-1}$ $E_k = \frac{1}{2} \times 0.033 kg × (1.04 m s^{-1})^2 = 0.0178 J$ ΔE_{grav} at top of loop = 0.033 kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J Total energy required to complete loop = 0.0178 J + 0.0712 J = 0.089 J Total for question 13 6 | | • Use of $E = mv^2/r$ (1) | |
| • Add E_{grav} at top of loop and required E_k Or Subtract E_{grav} at top of loop from E_{grav} at launch (1) • (AE_{grav} at start of) 0.081 J is less than 0.089 J (for sum of E_{grav} at top of loop and required E_k , so insufficient energy), so it does not complete the loop Or (Height required of) 0.275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop Or E_k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop Or E_k at height of top of loop would be 0.77 m s ⁻¹ which is less than the required 1.04 m s ⁻¹ so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop ΔE_{grav} at release point $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $\times 0.25$ m $= 0.0809$ J W $= 0.033$ kg $\times 9.81$ N kg ⁻¹ $= 0.324$ N At minimum speed W $= mv^2/r$ 0.324 N $= 0.033$ kg $\times \sqrt{^2}/1.01$ m v = 1.04 m s ⁻¹ $E_k = \frac{1}{2} \times 0.033$ kg $\times \sqrt{^2}/1.01$ m v = 1.04 m s ⁻¹ $E_k = \frac{1}{2} \times 0.033$ kg $\times \sqrt{^2}/1.01$ m v = 1.04 m s ⁻¹ $E_k = \frac{1}{2} \times 0.033$ kg $\times \sqrt{^2}/1.01$ m $v = 0.0178$ J $\rightarrow 0.089$ J 0.0809 J < 0.089 J Total for question 13 6 | | • Use of $F_{\rm L} = \frac{1}{2} mv^2$ (1) | |
| Or Subtract Egrev at top of loop from E_{grav} at launch(1)• (AE $grav$ at start of) 0.081 J is less than 0.089 J (for sum of E_{grav} at top of loop and required E_k , so insufficient energy), so it does not complete the loop(1)• (AE $grav$ at top of loop from 0.0275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop(1)• Or E_k at height of pool floop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop(1)• Or E_k at height of top of loop would be 0.77 m s ⁻¹ which is less than the required 1.04 m s ⁻¹ so it does not complete the loop(1)• Or $w 2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop(1)• Or mv ² /r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop(1)• Do not credit parts of calculation or derivation unambiguously using the formula for uniform acceleration $v^2 = 2as$, i.e. if the symbols are seen and substitution is from them and not from $mgAh = \frac{1}{2} w m^2$ • Example of calculation ΔE_{grav} at release point = 0.033 kg × 9.81 N kg ⁻¹ × 0.25 m = 0.0809 J $W = 0.033$ kg × $\frac{1}{2}$ 0.11 m $v = 1.04$ m s ⁻¹ • $E_k = \frac{1}{2} \times 0.033$ kg × $\frac{1}{2}$ 0.11 m $v = 1.04$ m s ⁻¹ • $E_k = \frac{1}{2} \times 0.033$ kg × $\frac{1}{2} \times 0.033$ kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J Total energy required to complete loop $= 0.0178$ J AE_{grav} at top of loop $= 0.033$ kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J Total energy required to complete loop $= 0.0178$ J AE_{grav} at top of loop $= 0.033$ kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J Total energy required to complete loop $= 0.0178$ | | • Ose of $E_{\rm K} = 72 mv$ • Add $E_{\rm c}$ at top of loop and required $E_{\rm c}$ | |
| Or Subtract required Ex from E_{grav} at launch(1)• (ΔE_{grav} at start of) 0.081 J is less than 0.089 J (for sum of E_{grav} at top of loop and required E_k , so insufficient energy), so it does not complete the loop Or (Height required of) 0.275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop Or E_k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop Or v at height of top of loop would be 0.77 m s ⁻¹ which is less than the required 1.04 m s ⁻¹ so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.18$ N which is less than weight of 0.32 N so it does not complete the loop Or $mv^2/r = 0.38$ kg × 9.81 N kg ⁻¹ × 0.25 m = 0.0809 J W = 0.033 kg × 9.81 N kg ⁻¹ = 0.324 N At minimum speed W = mv^2/r 0.324 N = 0.033 kg × 10.11 m V = 1.04 m s ⁻¹ $E_k = \frac{1}{2} \times 0.033$ kg × 10.11 m $V = 1.04$ m s ⁻¹ $E_k = \frac{1}{2} \times 0.033$ kg × 10.11 m $V = 1.04$ m s ⁻¹ $E_k = \frac{1}{2} \times 0.033$ kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J Total energy required to complete loop $= 0.0178$ J + 0.0712 J = 0.089 J 0.0809 J < 0.089 J | | • Add E_{grav} at top of loop and required E_{k} Or Subtract E_{grav} at top of loop from E_{grav} at launch | |
| • (AE _{grav} at start of) 0.081 J is less than 0.089 J (for sum of E _{grav} at top of loop and required E _k , so insufficient energy), so it does not complete the loop Or (Height required of) 0.275 m is greater than 0.25 m, (the height of launch position, so insufficient energy), so it does not complete the loop Or E _k at height of top of loop would be 0.0097 J which is less than the required 0.071 J (so insufficient energy), so it does not complete the loop Or v at height of top of loop would be 0.77 m s ⁻¹ which is less than the required 1.04 m s ⁻¹ so it does not complete the loop Or n m ² /r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop Or n m ² /r = 0.18 N which is less than weight of 0.32 N so it does not complete the loop Or a credit parts of calculation or derivation unambiguously using the formula for uniform acceleration v ² = 2as, i.e. if the symbols are seen and substitution is from them and not from mgAh = ½ mv ² Example of calculation ΔE_{grav} at release point = 0.033 kg × 9.81 N kg ⁻¹ × 0.25 m = 0.0809 J W = 0.033 kg × 9.81 N kg ⁻¹ = 0.324 N At minimum speed W = mv ² /r 0.324 N = 0.033 kg × (1.04 m s ⁻¹) ² = 0.0178 J ΔE_{grav} at top of loop = 0.033 kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J Total energy required to complete loop = 0.0178 J + 0.0712 J = 0.089 J Total for question 13 6 | | Or Subtract required E_k from E_{grav} at launch (1) | |
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| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | | E_{grav} at top of loop and required E_k so insufficient energy) | |
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| $ \frac{\text{Example of calculation}}{\Delta E_{\text{grav}} \text{ at release point} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.25 \text{ m} = 0.0809 \text{ J} \\ W = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.324 \text{ N} \\ \text{At minimum speed } W = mv^2/r \\ 0.324 \text{ N} = 0.033 \text{ kg} \times v^2 / 0.11 \text{ m} \\ v = 1.04 \text{ m s}^{-1} \\ E_k = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.0178 \text{ J} \\ \Delta E_{\text{grav}} \text{ at top of loop} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J} \\ \text{Total energy required to complete loop} \\ = 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J} \\ 0.0809 \text{ J} < 0.089 \text{ J} \\ \hline \text{Total for question 13} \qquad 6 $ | | $= \frac{1}{2} mv^2$ | |
| $ \begin{array}{ c c c c c c } \hline Example of calculation \\ & \Delta E_{grav} \text{ at release point} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.25 \text{ m} = 0.0809 \text{ J} \\ & W = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.324 \text{ N} \\ & \text{At minimum speed } W = mv^2/r \\ & 0.324 \text{ N} = 0.033 \text{ kg} \times v^2 / 0.11 \text{ m} \\ & v = 1.04 \text{ m s}^{-1} \\ & E_k = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.0178 \text{ J} \\ & \Delta E_{grav} \text{ at top of loop} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J} \\ & \text{Total energy required to complete loop} \\ & = 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J} \\ & 0.0809 \text{ J} < 0.089 \text{ J} \end{array} $ | | | |
| $\begin{array}{l} \Delta E_{\rm grav} \mbox{ at release point} = 0.033 \mbox{ kg} \times 9.81 \mbox{ N kg}^{-1} \times 0.25 \mbox{ m} = 0.0809 \mbox{ J} \\ W = 0.033 \mbox{ kg} \times 9.81 \mbox{ N kg}^{-1} = 0.324 \mbox{ N} \\ \mbox{At minimum speed} \ W = mv^2/r \\ 0.324 \mbox{ N} = 0.033 \mbox{ kg} \times v^2 \slash 0.11 \mbox{ m} \\ v = 1.04 \mbox{ m s}^{-1} \\ E_k = \frac{1}{2} \times 0.033 \mbox{ kg} \times (1.04 \mbox{ m s}^{-1})^2 = 0.0178 \mbox{ J} \\ \Delta E_{\rm grav} \mbox{ at top of loop} = 0.033 \mbox{ kg} \times 9.81 \mbox{ N kg}^{-1} \times 0.22 \mbox{ m} = 0.0712 \mbox{ J} \\ \Delta E_{\rm grav} \mbox{ at top of loop} = 0.033 \mbox{ kg} \times 9.81 \mbox{ N kg}^{-1} \times 0.22 \mbox{ m} = 0.0712 \mbox{ J} \\ \mbox{ Total energy required to complete loop} \\ = 0.0178 \mbox{ J} + 0.0712 \mbox{ J} = 0.089 \mbox{ J} \\ 0.0809 \mbox{ J} < 0.089 \mbox{ J} \\ \mbox{ Total for question 13} \mbox{ 6} \end{array}$ | | Example of calculation | |
| $W = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.324 \text{ N}$ At minimum speed $W = mv^2/r$ $0.324 \text{ N} = 0.033 \text{ kg} \times v^2 / 0.11 \text{ m}$ $v = 1.04 \text{ m s}^{-1}$ $E_k = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.0178 \text{ J}$ ΔE_{grav} at top of loop = $0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J}$ Total energy required to complete loop = 0.0178 J + 0.0712 J = 0.089 J 0.0809 J < 0.089 J Total for question 13 6 | | ΔE_{grav} at release point = 0.033 kg × 9.81 N kg ⁻¹ × 0.25 m = 0.0809 J | |
| At minimum speed $W = mv^2/r$ $0.324 \text{ N} = 0.033 \text{ kg} \times v^2 / 0.11 \text{ m}$ $v = 1.04 \text{ m s}^{-1}$ $E_k = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.0178 \text{ J}$ ΔE_{grav} at top of loop = $0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J}$ Total energy required to complete loop $= 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J}$ $0.0809 \text{ J} < 0.089 \text{ J}$ 6 | | $W = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.324 \text{ N}$ | |
| $\begin{array}{c c} 0.324 \text{ N} = 0.033 \text{ kg} \times v^2 / 0.11 \text{ m} \\ v = 1.04 \text{ m s}^{-1} \\ E_k = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.0178 \text{ J} \\ \Delta E_{\text{grav}} \text{ at top of loop} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J} \\ \text{Total energy required to complete loop} \\ = 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J} \\ 0.0809 \text{ J} < 0.089 \text{ J} \end{array}$ | | At minimum speed $W = mv^2/r$ | |
| $v = 1.04 \text{ m s}^{-1}$ $E_k = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.0178 \text{ J}$ $\Delta E_{\text{grav}} \text{ at top of loop} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J}$ $\text{Total energy required to complete loop}$ $= 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J}$ $0.0809 \text{ J} < 0.089 \text{ J}$ $\text{Total for question 13}$ 6 | | $0.324 \text{ N} = 0.033 \text{ kg} \times v^2 / 0.11 \text{ m}$ | |
| $E_{k} = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^{2} = 0.0178 \text{ J}$ $\Delta E_{\text{grav}} \text{ at top of loop} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J}$ Total energy required to complete loop $= 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J}$ $0.0809 \text{ J} < 0.089 \text{ J}$ Total for question 13 6 | | $v = 1.04 \text{ m s}^{-1}$ | |
| $\Delta E_{\text{grav}} \text{ at top of loop} = 0.033 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.22 \text{ m} = 0.0712 \text{ J}$ Total energy required to complete loop = 0.0178 J + 0.0712 J = 0.089 J 0.0809 J < 0.089 J Total for question 13 6 | | $E_{\rm k} = \frac{1}{2} \times 0.033 \text{ kg} \times (1.04 \text{ m s}^{-1})^2 = 0.01/8 \text{ J}$ | |
| 1 otal energy required to complete loop $= 0.0178 \text{ J} + 0.0712 \text{ J} = 0.089 \text{ J}$ $0.0809 \text{ J} < 0.089 \text{ J}$ Total for question 13 6 | | ΔE_{grav} at top of loop = 0.033 kg × 9.81 N kg ⁻¹ × 0.22 m = 0.0712 J | |
| = 0.0178 J + 0.0712 J = 0.089 J $0.0809 J < 0.089 J$ Total for question 13 6 | | I otal energy required to complete loop | |
| Total for question 13 6 | | = 0.01/8 J + 0.0/12 J = 0.089 J | |
| 1 otal for question 13 0 | | 0.0809 J < 0.089 J | |
| | | 1 otal for question 13 | 0 |

| This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content Number of marks awarded for indicative mark available marking points in answer Max linkage mark available mark available 6 4 2 6 5 3 2 5 4 3 1 4 3 2 1 3 2 2 0 2 1 1 0 1 0 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 1 1 0 1 1 1 reasoning. reasoning 1 0 1 1 1 1 0 0 0 0 0 1 1 reasoning reasoning Reasoning | Answer | | | | | Mark |
|--|--|--|----------------------------------|---|-------------------------------------|------|
| Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content Number of marks awarded for indicative marking points seen marking points seen marking points are marking points and for indicative marking points are marking points and for indicative marking points are marking points in answer Max final mark 6 4 2 6 5 3 2 5 4 3 1 4 3 2 0 2 1 1 0 1 0 0 0 0 The following table shows how the marks should be awarded for structure and lines of reasoning. Number of marks awarded for structure of answer and sustained line of reasoning. Number of reasoning. Answer shows a coherent and logical structure of inlikages and fully sustained lines of reasoning. 2 2 Answer is partially structured with is of reasoning. 2 2 3 Answer has no linkages between points and is unstructured 0 0 0 | This question a answer with lin | assesses a student's nkages and fully-sus | ability to sho stained reason | ow a coherent and ning. | logically structured | |
| Number of indicative marking pointsMax linkage mark availableMax final mark mark mark mark mark mark | Marks are awa shows lines of The following | rded for indicative of reasoning. table shows how the | content and f | or how the answer | r is structured and | |
| 6426532543143213220211010000Number of marks awarded for structure and lines of reasoning.The following table shows how the marks should be awarded for structure and lines of reasoning.Number of marks awarded for structure and lines of reasoning.Answer shows a coherent and logical structure with linkages and fully sustained line of reasoning demonstrated throughoutAnswer is partially structured with some linkages and lines of reasoning2Answer has no linkages between points and is unstructured0 | Number of indicative marking points seen in answer | Number of marks awarded for indicative marking points | Max linkaş mark avail | ge Max final able mark | | |
| 532543143213220211010000The following table shows how the marks should be awarded for structure and lines of marks awarded for structure of answer and sustained line of reasoningAnswer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout2Answer is partially structured with some linkages and lines of reasoning1Answer has no linkages between points and is unstructured0 | 6 | 4 | 2 | 6 | | |
| 4314321322021101000The following table shows how the marks should be awarded for structure and lines of reasoning.Number of marks awarded for structure of answer and sustained line of reasoning.Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning.2Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning.1Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning.1Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning.0Answer has no linkages between points and is unstructured0 | 5 | 3 | 2 | 5 | | |
| 3213220211010000The following table shows how the marks should be awarded for structure and lines of marks awarded for structure of answer and sustained line of reasoningNumber of marks awarded | 4 | 3 | 1 | 4 | | |
| 220211010000The following table shows how the marks should be awarded for structure and lines of marks awarded for structure of answer and sustained line of reasoningAnswer shows a coherent and logical structure with linkages and fully sustained lines of reasoning2Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning2Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning1Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning2Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning2Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning0Answer has no linkages between points and is unstructured0 | 3 | 2 | 1 | 3 | | |
| 11010000The following table shows how the marks should be awarded for structure and lines of marks awarded for structure of answer and sustained line of reasoningAnswer shows a coherent and logical structure with linkages and fully sustained lines of reasoning2Answer is partially structured with some linkages and lines of reasoning1Answer has no linkages between points and is unstructured0 | 2 | 2 | 0 | 2 | | |
| 000The following table shows how the marks should be awarded for structure and lines of marks awarded for structure of answer and sustained line of reasoningAnswer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout2Answer is partially structured with some linkages and lines of reasoning1Answer has no linkages between points and is unstructured0 | 1 | 1 | 0 | 1 | | |
| The following table shows how the marks should be awarded for structure and lines of reasoning. reasoning. Number of marks awarded for structure of answer and sustained line of reasoning reasoning. Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout 2 Answer is partially structured with some linkages and lines of reasoning 1 Answer has no linkages between points and is unstructured 0 | 0 | 0 | 0 | 0 | | |
| structure with linkages and fully Image: Constraint of the solution of the solut | The following Answer show | table shows how the | e marks shou gical | Id be awarded for Number of marks awarded for structure of answer and sustained line o reasoning 2 | f structure and lines of reasoning. | |
| Answer is partially structured with some linkages and lines of reasoning1Answer has no linkages between points and is unstructured0 | structure with sustained line demonstrated | n linkages and fully es of reasoning l throughout | | | | |
| Answer has no linkages between 0 points and is unstructured | Answer is par some linkage | rtially structured wi s and lines of reason | th ning | 1 | | |
| | Answer has points and is | no linkages between unstructured | 1 | 0 | | |
| | | | | | | |

| produces a force (on the magnet) that opposes the motion of magnet causing it upward force on magnet, so (increased) downward force on tube | 6 | |
|--|---|--|
| produces a force (on the magnet) that opposes the motion of magnet causing it upward force on magnet, so (increased) downward force on tube | 6 | |
| produces a force (on the magnet) that opposes the motion of magnet causing it upward force on magnet, so (increased) downward force on tube | | |
| produces a force (on the magnet) that opposes the motion of magnet causing it | | |
| produces a force (on the magnet) that opposes the motion | | |
| | | |
| • (by Lenz's law the) magnetic field (due to the induced current) | | |
| current produces magnetic field | | |
| • full conducting path available, so current in metal | | |
| • <u>e.m.f induced</u> | | |
| Or change of flux linked to copper tube | | |
| change of flux linked to surrounding metal | | |
| ndicative content: | | |
| arout ve content and no marks for mikages). | | |
| dicative content and no marks for linkages) | | |
| Id some linkages and lines of reasoning). If there are no linkages between points, the | | |
| asoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure | | |
| dicative marking points which is partially structured with some linkages and lines of | | |
| uidance on how the mark scheme should be applied. The mark for indicative content ould be added to the mark for lines of reasoning. For example, an answer with five | | |
| | uidance on how the mark scheme should be applied: The mark for indicative content ould be added to the mark for lines of reasoning. For example, an answer with five dicative marking points which is partially structured with some linkages and lines of asoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure d some linkages and lines of reasoning). If there are no linkages between points, the me five indicative marking points would yield an overall score of 3 marks (3 marks for dicative content and no marks for linkages). ndicative content: change of flux linked to surrounding metal Or change of flux linked to copper tube <u>e.m.f induced</u> full conducting path available, so current in metal current produces magnetic field (by Lenz's law the) magnetic field (due to the induced current) | uidance on how the mark scheme should be applied: The mark for indicative content ould be added to the mark for lines of reasoning. For example, an answer with five dicative marking points which is partially structured with some linkages and lines of asoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure d some linkages and lines of reasoning). If there are no linkages between points, the me five indicative marking points would yield an overall score of 3 marks (3 marks for dicative content and no marks for linkages). ndicative content: change of flux linked to surrounding metal Or change of flux linked to copper tube <u>e.m.f induced</u> full conducting path available, so current in metal current produces magnetic field (by Lenz's law the) magnetic field (due to the induced current) |



| Question | Answer | | Mark |
|----------|---|------------|------|
| number | | | |
| 15 (a) | • Resultant on correct triangle or parallelogram including arrows with a clear right angle between initial asteroid momentum and initial spacecraft momentum | (1) | |
| | • Fully labelled (dependent on MP1) <u>Example of diagram:</u> asteroid + spacecraft spacecraft spacecraft asteroid | (1) | 2 |
| 15 (b) | • Use of $p = mv$ • $p = 1.1 \times 10^7$ (N s) (minimum 2 s.f.) <u>Example of calculation</u> $p = 920$ kg $\times 12\ 000$ m s ⁻¹ = 1.1×10^7 N s | (1) (1) | 2 |
| 15 (c) | • Use of correct trigonometry • Angle = 1.5×10^{-7} (rad) (minimum 2 s.f.) Allow ecf from (b) Example of calculation | (1) (1) | 2 |
| | tan $\theta = 1.1 \times 10^7$ N s \div 7.6 $\times 10^{13}$ N s $= 1.45 \times 10^{-7}$ ($\theta = 8.3^{\circ}$) $\theta = 1.45 \times 10^{-7}$ rad (Answer depends on rounding from (b), accept 1.4 or 1.5 rad) | | |
| 15 (d) | Apply principle of conservation of momentum along path at 90° to original path of asteroid Component of velocity = 3.9 × 10⁻³ m s⁻¹ Allow ecf from (b) or (c) <u>Example of calculation</u> Component of velocity = spacecraft momentum ÷ (mass of spacecraft + mass of asteroid) = 1.1 × 10⁷ N s ÷ (920 kg + 2.8 × 10⁹ kg) = 3.9 × 10⁻³ m s⁻¹ | (1) (1) | 2 |
| 15 (e) | Use of impulse = F Δt = Δp Concludes 1.8 × 10⁹ N s change in momentum from rocket engines is greater than 1.1 × 10⁷ N s change from impact Allow ecf from (b) Example of calculation Impulse = 5.1 × 10⁶ N × 6 × 60 s = 1.8 × 10⁹ N s | (1) | 2 |
| | Total for question 15 | | 10 |

| Question Number | Answer | | Mark |
|--------------------|---|-----|------|
| 16 (a) | • Use of $E = Q/4\pi\epsilon_0 r^2$ Or Use of $E = kQ/r^2$ (1) • Adds <i>E</i> due to X to <i>E</i> due to Y (1) • $E = 2.8 \times 10^6$ V m ⁻¹ (1) |) | 3 |
| | $ \begin{array}{l} \underline{\text{Example of calculation}} \\ \hline E \text{ due to } X = 2.5 \times 10^{-7} \text{ C} \ / \ 4 \times \pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times (4.0 \times 10^{-2} \text{ m})^2 \\ = 1.4 \times 10^6 \text{ V m}^{-1} \text{ (towards Y)} \\ \hline E \text{ due to } Y = 2.5 \times 10^{-7} \text{ C} \ / \ 4 \times \pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times (4.0 \times 10^{-2} \text{ m})^2 \\ = 1.4 \times 10^6 \text{ V m}^{-1} \text{ (towards Y)} \\ \hline E = 1.4 \times 10^6 \text{ V m}^{-1} + 1.4 \times 10^6 \text{ V m}^{-1} = 2.8 \times 10^6 \text{ V m}^{-1} \end{array} $ | | |
| 16 (b) (i) | Central straight line equidistant from X and Y and at least one of the diverging lines between X and the central line and at least one of the diverging lines between the central line and Y At least one line looping X and one line looping Y Line spacing between X and Y smaller than line spacing to the left of X and to the right of Y Example of diagram |))) | 3 |



| 16 (b) (ii) | • Field lines show direction of force on a (positive) charge (| (1) | |
|-------------|---|-----|----|
| | • (So) field line shows the direction of acceleration | (1) | |
| | • Point A - Where the line is straight, a charge (initially at rest) will | | |
| | follow the line, so true in this case | (1) | |
| | • Point B - Curved line means acceleration always changing direction | | |
| | but velocity is not in the direction of acceleration so statement not | (1) | 4 |
| | true | (1) | 4 |
| 1() | | (1) | |
| 16 (c) | • Use of $V = Q/4\pi\epsilon_0 r$ Or Use of $V = kQ/r$ | (1) | |
| | • Applies potential at each point is sum of potential due to charge at X | (1) | |
| | and potential due to charge at Y | (1) | |
| | • Applies p.d. = sum of potentials at D – sum of potentials at C | (1) | 4 |
| | • $V = (-) 2.0 \times 10^5 \text{ V}$ | (1) | 4 |
| | | | |
| | Example of calculation | | |
| | Vc due to X= 5.0×10^{-7} C / $4 \times \pi \times 8.85 \times 10^{-12}$ F m $^{-1} \times 2.5 \times 10^{-2}$ m = 1.8×10^{5} V | | |
| | $V_{\rm D}$ due to X= 5.0 × 10 ⁻⁷ C / 4 × π × 8.85 × 10 ⁻¹² F m ⁻¹ × 5.5 × 10 ⁻² m = 0.8 × 10 ⁵ V | | |
| | $V_{\rm D}$ due to Y= -5.0 × 10 ⁻⁷ C / 4 × π × 8.85 × 10 ⁻¹² F m ⁻¹ × 2.5 × 10 ⁻² m = -1.8 × 10 ⁵ V | | |
| | V _C due to Y = -5.0×10^{-7} C / $4 \times \pi \times 8.85 \times 10^{-12}$ F m $^{-1} \times 5.5 \times 10^{-2}$ m = -0.8×10^{5} V | | |
| | | | |
| | $V_{\rm C} = 1.8 \times 10^5 \text{ V} - 0.8 \times 10^5 \text{ V} = 1.0 \times 10^5 \text{ V}$ | | |
| | $V_{\rm D} = -1.8 \times 10^5 \text{ V} + 0.8 \times 10^5 \text{ V} = -1.0 \times 10^5 \text{ V}$ | | |
| | | | |
| | $V_{\rm CD} = V_{\rm D} - V_{\rm C}$ | | |
| | $= -1.0 \times 10^5 \text{ V} - 1.0 \times 10^5 \text{ V}$ | | |
| | $= -2.0 \times 10^5 \text{ V}$ | | |
| | Total for Question 16 | | 14 |

| Question number | Answer | | Mark |
|--------------------|--|-------------------|------|
| 17 (a) | Battery in series with capacitor and resistor Voltmeter/datalogger/oscilloscope in parallel with capacitor Appropriate switching mechanism and discharge circuit completed Example of diagram: | (1) (1) (1) | 3 |
| 17 (b) (i) | Exponential decline | (1) | |
| | • Symmetry with charging curve, starts at 6.00 V, curves cross at 3.00 V | (1) | 2 |
| 17 (b) (ii) | Example of graph $\int_{0}^{1} \frac{1}{y} = \int_{0}^{1} \frac{1}{y} = \int_{0}^$ | | |
| 17 (b) (ii) | • Use of $I = I_0 e^{-\frac{t}{RC}}$ with $V = IR$ • Apply total p.d. = sum of p.d.s • Suitable algebra Example of derivation $I = I_0 e^{-\frac{t}{RC}}$ $V_R = RI_0 e^{-\frac{t}{RC}}$ $I_0R = V_0$ $V_R = V_0 e^{-\frac{t}{RC}}$ $V_{cap} = V_0 - V_R$ $V = V = V e^{-\frac{t}{RC}}$ | (1) (1) (1) | 3 |

| 17 (b) (iii) | Use of V = V₀ (1-1/e) = 0.63 V₀ for V at time constant Read time constant off graph = 4.9 s (allow range 4.5 s to 5.0 s) Use of time constant = RC C = 1.5 × 10⁻⁵ E as shapes 15 × E consistent | (1) (1) (1) (1) | |
|--------------|---|--|---|
| | • $C = 1.5 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) ($C = 1.4 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) | (1) | |
| | Draws tangent to line at t = 0 s to intercept p.d. = 6.00 V line Read time constant off graph = 4.9 s (allow range 4.5 s to 5.0 s) Use of time constant = RC | (1) (1) (1) (1) | |
| | • $C = 1.5 \times 10^{-5}$ F, so choose 15 µF capacitor ($C = 1.4 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) | (1) | |
| | Record corresponding values of V and t from point (or points) on graph | (1) | |
| | • Use of $V = V_0 - V_0 e^{-\frac{1}{RC}}$ | (1) | |
| | Convert to correct logarithmic form C = 1.5 × 10⁻⁵ F, so choose 15 μF capacitor (C = 1.3 × 10⁻⁵ F to C = 1.5 × 10⁻⁵ F when rounded to 2 s.f.) | (1) (1) | |
| O | Or • $\frac{V_0}{2} = V_0 e^{-\frac{t_1}{2}}$ | | |
| X) | • $RC = t_{\frac{1}{2}} / \ln 2$ • Records time for V to increase to $\frac{1}{2} V_0$ (3.4 s) (allow range 3.0 s to 3.5 s) | (1) (1) | |
| | • $C = 1.5 \times 10^{-5}$ F, so choose 15 µF capacitor ($C = 1.3 \times 10^{-5}$ F to $C = 1.5 \times 10^{-5}$ F when rounded to 2 s.f.) | (1) (1) | |
| | Example of calculation V at time constant time = $0.63 \times 6.00 \text{ V} = 3.8 \text{ V}$ Time from graph = 4.9 s $4.9 \text{ s} = C \times 3.3 \times 10^5 \Omega$ $C = 1.48 \times 10^{-5} \text{ F}$ | | 4 |

| 17 (b) (iv) | • Use of $Q = CV$ (ecf for C from (iii)) | (1) | |
|-------------|---|-----|----|
| | • $Q = 9.0 \times 10^{-5} \mathrm{C}$ | (1) | |
| | | | 2 |
| | Example of calculation | | |
| | $1.5 \times 10^{-5} \text{ F} \times 6.00 \text{ V} = 9.0 \times 10^{-5} \text{ C}$ | | |
| 17 (b) (v) | • Use of $W = \frac{1}{2} CV^2$ (ecf for C from (iii)) | | |
| | Or Use of $W = \frac{1}{2} QV$ (ecf for Q from (iv)) | | |
| | Or Use of $W = \frac{1}{2} \frac{Q^2}{C}$ (ecf for <i>C</i> from (iii), for <i>Q</i> from (iv)) | (1) | |
| | • $W = 2.7 \times 10^{-4} \text{ J}$ | (1) | 2 |
| | | | |
| | Example of calculation: | | |
| | $W = \frac{1}{2} \times 1.5 \times 10^{-5} \mathrm{F} \times (6.00 \mathrm{V})^2 = 2.7 \times 10^{-4} \mathrm{J}$ | | |
| | Total for question 17 | | 16 |
| | | | |

| Question | Answer | | Mark |
|-------------|---|---------|------|
| number | | (1) | |
| 18(a) | • Mass equal (to mass of electron) | (1) | |
| | • Charge equal and opposite (to charge of electron) | (1) | |
| | • Lepton number (equal and) opposite (to lepton number of | | |
| | electron) | (1) | 3 |
| 18 (b) | Curvature more in top half of picture | (1) | |
| | • Particle moving slower after passing through lead plate because | | |
| | energy lost, so moving from lower half to top half | (1) | |
| | • (Applying FLHR.) field into page | | |
| | (mark dependent on an indication of correct direction of | | |
| | positron motion) | (1) | 3 |
| 18 (c) (i) | • Use of conversion factor 1.6×10^{-19} C | (1) | |
| | • Use of $E_k = \frac{1}{2} mv^2$ | (1) | |
| | • Calculated speed -2.8×10^9 (m s ⁻¹) which is greater than the | | |
| | speed of light (so it must be relativistic) | (1) | 3 |
| | speed of light (so it must be relativistic) | (-) | - |
| | Example of calculation | | |
| | $\frac{12 \times 10^{10} \text{ cm}^{-10} \text$ | | |
| | $25 \times 10^{-12} \text{ J} = 0.5 \times 0.11 \times 10^{-31} \text{ kg} \times \text{y}^2$ | | |
| | $y = 2.8 \times 10^9 \text{ m s}^{-1}$ | | |
| | $V = 2.6 \times 10^{\circ} \text{ m/s}$ | | |
| 18 (c) (ii) | • Use of $E = ne$ (set for E from (a)(i)) | (1) | |
| 10 (C) (II) | • Use of $E = pc$ (let for E from (c)(f)) | (1) (1) | |
| | • Use of $r = p/Bq$ | (1) (1) | 3 |
| | • $B = 2.1$ T | (1) | 5 |
| | | | |
| | Do not award MP1 if $p = mv$ calculated using v from part (1) | | |
| | | | |
| | $\frac{\text{Example of calculation}}{2.7 \times 10^{-12} \text{ L}} \approx 2.00 \times 10^8 \text{ m s}^{-1}$ | | |
| | $5.7 \times 10^{-2} \text{ J} = p \times 3.00 \times 10^{\circ} \text{ m s}^{-2}$ | | |
| | $p = 1.2 \times 10^{-5} \text{ N s}$ | | |
| | $0.03 / \text{m} = 1.2 \times 10^{-20} \text{ N s} / B \times 1.6 \times 10^{-12} \text{ C}$ | | |
| | B = 2.1 T | | |

| 18 (d) | • Use of $E_{\rm k} = \frac{1}{2} mv^2$ | (1) | |
|--------|--|-----|----|
| | • Use of $\Delta E = c^2 \Delta m$ | (1) | |
| | • Use of $E = hf$ | (1) | |
| | • $f = 1.2 \times 10^{20} \text{ Hz}$ | (1) | 4 |
| | | | |
| | Example of calculation | | |
| | $E_{\rm k} = 2 \times 0.5 \times 9.11 \times 10^{-31} \rm kg \times (1.5 \times 10^7 m s^{-1})^2$ | | |
| | $= 2.0 \times 10^{-16} \mathrm{J}$ | | |
| | $\Delta E = (3.00 \times 10^8 \text{ m s}^{-1})^2 \times 2 \times 9.11 \times 10^{-31} \text{ kg}$ | | |
| | $= 1.64 \times 10^{-13} \text{ J}$ | | |
| | Total energy = $1.64 \times 10^{-13} \text{ J} + 2.0 \times 10^{-16} \text{ J} = 1.64 \times 10^{-13} \text{ J}$ | | |
| | Energy for one gamma photon = 8.2×10^{-14} J | | |
| | $8.2 \times 10^{-12} \text{ J} = 6.63 \times 10^{-34} \text{ J} \text{ s} \times f$ | | |
| | $f = 1.2 \times 10^{20} \text{ Hz}$ | | |
| | Total for question 18 | | 16 |
| | | | |

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