Mark Scheme (Results)

June 2024

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.**

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. '<u>resonance</u>'

1.2 Bold lower case will be used for emphasis e.g. '**and**' when two pieces of information are needed for 1 mark.

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 This does not apply in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.

2.4 Occasionally, it may be decided not to insist on a 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.

2.5 The mark scheme will indicate if no unit error is to be applied by placing brackets around the unit.

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not prevent a mark being awarded if the answer given rounds to the answer in the MS.

3.2 Too few significant figures will mean that the final mark cannot be awarded in 'show that' questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.

3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.

3.4 The use of g = 10 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}

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 **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.

4.2 If a ‘show that’ question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.

4.3 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Expression

5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.

5.2 Marks are awarded for indicative content and for how the answer is structured.

5.3 Linkage between ideas, and fully-sustained reasoning is expected.

Question Number	**Answer**	**Mark**
1	**A is the correct answer** because ampere is the only SI base unit given B is not correct because coulomb is not a base unit in SI C is not correct because joule is not a base unit in SI D is not correct because tesla is not a base unit in SI	**1**
2	**D is the only correct answer** because it shows the correct vector diagram A is not correct because this shows R – Q B is not correct because this shows the correct magnitude in the opposite direction C is not correct because this shows Q – R	**1**
3	**A is the only correct answer** because the force is down the page using FLHR B is not correct because it does not show the force down the page C is not correct because it does not show the force down the page D is not correct because it does not show the force down the page	**1**
4	**C is the only correct answer** because using $F = BIl$ gives $I = F / Bl$ A is not correct because it is not $I = F / Bl$ B is not correct because it is not $I = F / Bl$ D is not correct because it is not $I = F / Bl$	**1**
5	**A is the only correct answer** because the particles are accelerated by electric fields across the gap and magnetic fields in the dees B is not correct because the particles follow a semi-circular path of constant radius followed by a straight portion across the gap and then a semi-circular path of greater constant radius and so on C is not correct because the electric field changes direction when the particles are in the dees, not when the particles are in the gaps D is not correct because the magnetic field does not change direction	**1**
6	**D is the only correct answer** because $t = \frac{-t}{\ln\left(\frac{V}{V_0}\right)}$ A is not correct because it is not $\frac{-t}{\ln\left(\frac{V}{V_0}\right)}$ B is not correct because it is not $\frac{-t}{\ln\left(\frac{V}{V_0}\right)}$ C is not correct because it is not $\frac{-t}{\ln\left(\frac{V}{V_0}\right)}$	**1**
7	**B is the only correct answer** because neutrons were not demonstrated to exist until Chadwick's experiments A is not correct because this is a valid conclusion C is not correct because this is a valid conclusion D is not correct because this is a valid conclusion	**1**

8	**C is the only correct answer** because the area under a force-time graph is the change in momentum A is not correct because the area under a force-time graph is not acceleration B is not correct because the area under a force-time graph is not force D is not correct because the area under a force-time graph is not distance	**1**
9	**A is the only correct answer** because the kinetic energy of the particle decreases by synchrotron radiation and, if not in a vacuum, ionisation and the path therefore decreases in radius because decreasing ke decreases momentum and r = p/BQ B is not correct because this would increase the radius C is not correct because this would increase the radius D is not correct because this would increase the radius	**1**
10	**B is the only correct answer** because $r = p/Bq = mv/Bq$ and mass is 4 times mass of a proton and charge is twice the charge of a proton while B and v remain the same, so the multiplying factor is 4/2 = 2 and the initial radius is $2r$ A is not correct because the initial radius is $2r$ C is not correct because the initial radius is $2r$ D is not correct because the initial radius is $2r$	**1**

Question Number	Answer		Mark
11(a)	Top numbers: 4 (9) 12, 1	**(1)**	
	Bottom numbers 2 (4) 6, 0	**(1)**	**2**
	<u>Example of formula</u> $^{4}_{2}\alpha + ^{9}_{4}\mathrm{Be} \rightarrow ^{12}_{6}\mathrm{C} + ^{1}_{0}\mathrm{n}$		
11(b)	**Max 2 from**		
	A neutron is not a <u>fundamental</u> particle	**(1)**	
	(Because) it is made of <u>quarks</u>	**(1)**	
	It is correct that a neutron is not made of an electron and a proton	**(1)**	**2**
	Total for question 11		**4**

Question Number	Answer		Mark
12(a)	Complete circuit with ammeter **and** cell / battery in series with the capacitor and the resistor	**(1)**	**1**
12(b)(i)	Use of $I = I_0 / e$ to find time constant **Or** Intercept with t axis using initial tangent to find time constant Use of time constant = RC $C = 0.018$ (F) (2 s.f.) **OR** Attempts a pair of readings of I and t from graph Use of $I = I_0\,e^{-t/RC}$ **or** Use of $\ln I = \ln I_0 - \frac{t}{RC}$ $C = 0.018$ (F) (2 s.f.) <u>Example of calculation</u> $I = 2.4$ mA / e = 0.9 mA Time constant = 90 s $C = 90$ s / 5100 Ω = 0.0176 F	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
12(b)(ii)	Use of $V = IR$ for initial p.d. using initial current Use of $C = Q / V$ (ecf from (b)(i)) $Q = 0.22$ C <u>Example of calculation</u> $V = 0.0024\text{ A} \times 5100\ \Omega = 12.2\text{ V}$ $Q = 1.8 \times 10^{-2}\text{ F} \times 12.2\text{ V} = 0.22\text{ C}$	**(1)** **(1)** **(1)**	**3**
12(b)(iii)	Use of suitable equation, e.g. $W = \frac{1}{2} QV$ (ecf from (b)(i) and (b)(ii)) $W = 1.3$ J <u>Example of calculation</u> $W = \frac{1}{2} \times 0.22\text{ C} \times 12.2\text{ V}$ $W = 1.34$ J	**(1)** **(1)**	**2**
	Total for question 12		**9**

Question Number	Answer	Mark
13(a)	Use of trigonometry suitable to determine sine or cosine of angle of disk with horizontal or vertical **(1)** Use of $W = mg$ **(1)** Use of component of W with correct function and angle, eg $F = W \sin \theta$ **(1)** $F = 0.018$ (N) **(1)** **OR** Use of $E_{\text{grav}} = mgh$ **(1)** State and justify use of conservation of energy **(1)** Use of work done = force × distance **(1)** $F = 0.018$ (N) **(1)** <u>Example of calculation</u> $\sin \theta = 6.3 \text{ cm} / 30 \text{ cm} = 0.21$ $W = 0.0088 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.086 \text{ N}$ $F = 0.086 \text{ N} \times 0.21 = 0.018 \text{ N}$	**4**
13(b)(i)	Use of $\omega = 2\pi / T$ **(1)** 4.7 radian s^{-1} **(1)** <u>Example of calculation</u> $\omega = 2\pi / (60 \text{ s} / 45) = 4.71 \text{ radian s}^{-1}$	**2**
13(b)(ii)	Use of $F = m\omega^2 r$ **(1)** Subtracts r from radius **(1)** 4.8 cm from edge with comparison and conclusion (ecf from (b)(i)) **(1)** **OR** Subtracts distance from edge from radius **1)** Use of $F = m\omega^2 r$ **Or** Use of $F = mv^{2\cdot}/r$ **and** $v = r\omega$ **(1)** $F = 0.019$ N with comparison and conclusion (ecf from (b)(i)) **(1)** <u>Example of calculation</u> $0.02 \text{ N} = 0.0088 \text{ kg} \times (4.71 \text{ radian s}^{-1})^2 \times r$ $r = 0.102 \text{ m}$ $0.15 \text{ m} - 0.102 \text{ m} = 4.8 \text{ cm}$ which is just less than 5 cm	**3**
	Total for question 13	**9**

Question Number	Answer	Mark
14(a)	Baryon: 3 quarks (or 3 antiquarks) **(1)** Meson: a quark and an antiquark **(1)**	**2**
14(b)(i)	Identifies charges (of quark) (+)2e/3 **and** (charge of lepton) (+)1e **(1)** Identifies a quark with +2/3 charge (u,c,t) **(1)** Identifies an anti-lepton with charge +1 (e^+, μ^+, τ^+ - accept bar notation) **(1)** Baryon number = 1/3 **(1)** Lepton number = –1 **(1)** Example of calculation +5e/3 = +2e/3 + 1e	**5**
14(b)(ii)	Use of eV to J conversion **(1)** Use of $\Delta E = c^2 \Delta m$ **(1)** $m = 2.7 \times 10^{-24}$ (kg) (2 sf) **(1)** Example of calculation $(2 \times 6.8 \times 10^{12}\ \text{eV} \times 1.6 \times 10^{-19}\ \text{V}) \times 11 / 100 = 2.39 \times 10^{-7}\ \text{J}$ $m = 2.39 \times 10^{-7}\ \text{J} / (3.00 \times 10^{8}\ \text{m s}^{-1})^2 = 2.66 \times 10^{-24}\ \text{kg}$	**3**
14(b)(iii)	Reasonable suggestion, such as: • Leptoquarks must have a mass greater than 2.7×10^{-24} kg (ecf from (b)(ii)) **(1)** • Its mass is too high **(1)** • Energy needed is too high **(1)** • The energy of the collision is too low **(1)**	**1**
	Total for question 14	**11**

Question Number	Answer	Mark
15(a)	No/minimal/negligible friction (between the surfaces) **(1)** So there are no resultant/net/unbalanced external forces acting on the pucks **(1)** **Or (**so the pucks) can be treated as a closed system	**2**
15(b)(i)	Use of trigonometrical function for *x* component of A momentum after collision **Or** Use of trigonometrical function for *y* component of A momentum after collision **(1)** Applies conservation of momentum **(1)** Applies trigonometry to calculate final angle for B **(1)** Angle between A and B = 91(°) **(1)** Comparison between calculated angle and 90° including conclusion in words **(1)** <u>Example of calculation</u> x component of A after = 0.039 kg m s^{-1} × cos 33° = 0.0327 kg m s^{-1} y component of A after = 0.039 kg m s^{-1} × sin 33° = 0.0212 kg m s^{-1} x component of B after = 0.046 kg m s^{-1} – 0.0327 kg m s^{-1} = 0.0133 kg m s^{-1} y component of B after = 0.0212 kg m s^{-1} tan θ = 0.0212 kg m s^{-1} ÷ 0.0133 kg m s^{-1} = 1.59 θ = 57.9° 58° + 33° = 91° which is about 90°	**5**
15(b)(ii)	Applies trigonometry or Pythagoras appropriate to calculate magnitude of B momentum [mark may be awarded if calculated in (b)(i)] **(1)** Use of $E_{\mathrm{k}} = \frac{p^2}{2m}$ **Or** Use of $E_{\mathrm{k}} = \frac{1}{2} mv^2$ **and** $p = mv$ **(1)** Correct calculation of one kinetic energy (ecf from (a)) **(1)** Correct calculation of all kinetic energies (ecf from (a)) **(1)** Comparison and conclusion consistent with calculated values of kinetic energy (ecf from (a)) **(1)** <u>Example of calculation</u> Momentum of B = y component of B / sin 58° = 0.0212 kg m s^{-1} / sin 58° = 0.025 kg m s^{-1} $E_{\mathrm{k}} = \frac{(0.046\ \mathrm{kg\ m\ s^{-1}})^2}{2 \times 0.11\ \mathrm{kg}}$ = 9.62 × 10^{-3} J (A before) $E_{\mathrm{k}} = \frac{(0.039\ \mathrm{kg\ m\ s^{-1}})^2}{2 \times 0.11\ \mathrm{kg}}$ = 6.91 × 10^{-3} J (A after) $E_{\mathrm{k}} = \frac{(0.025\ \mathrm{kg\ m\ s^{-1}})^2}{2 \times 0.11\ \mathrm{kg}}$ = 2.84 × 10^{-3} J (B after) 6.91 × 10^{-3} J + 2.84 × 10^{-3} J = 9.75 × 10^{-3} J = initial disc A kinetic energy, so it is elastic	**5**
	Total for question 15	**12**

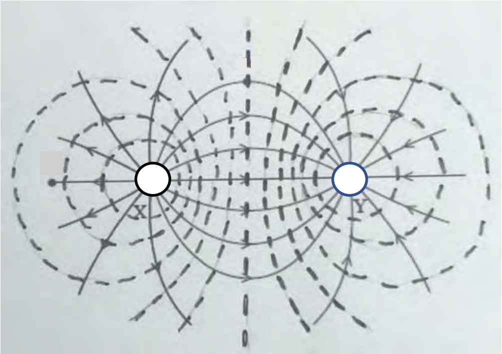
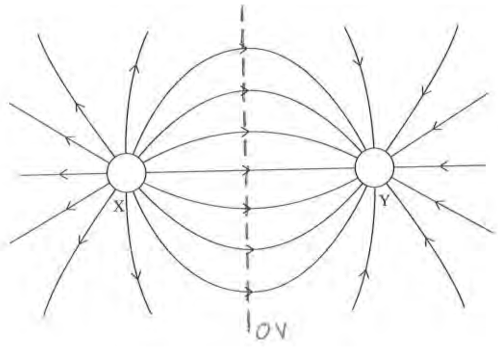
<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>16(a)</td><td>Use of GeV to J conversion (1)

Use of $E_k = ½ mv^2$ (1)

$v = 1.5 \times 10^{11}$ m s^{-1} which is greater than the speed of light (so particle speed relativistic) (1)

<u>Example of calculation</u>
$(60 \times 10^9$ eV $\times 1.6 \times 10^{-19}$ V$) = 9.6 \times 10^{-9}$ J
9.6×10^{-9} J $= ½ \times 9.11 \times 10^{-31}$ kg $\times v^2$
$v = 1.5 \times 10^{11}$ m s^{-1} which is greater than the speed of light, which is impossible, so they must be travelling at relativistic speeds</td><td>3</td></tr>
<tr><td>*16(b)</td><td>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.
<table>
<tr><td>IC points</td><td>IC mark</td><td>Max linkage mark</td><td>Max final mark</td></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Indicative content
IC1 The electrons are accelerated by an <u>electric field</u> between the drift tubes
IC2 The (a.c) polarity changes (when the electrons are in the tubes) so the (electric) field is in the same direction when the particle is in the gaps
Or The (a.c.) polarity changes so it is always accelerating the particles
IC3 The a.c. frequency is constant
IC4 The length of the drift tubes increases (along the Linac) so the electrons spend the same time in the tubes / gaps
Or The length of the gaps increases (along the Linac) so the electrons spend the same time in the tubes / gaps
IC5 The tubes have constant length at the end
IC6 As the electrons approach (but do not achieve) the speed of light their speed no longer increases</td><td>6</td></tr>
</table>

16(c)	(High energy particles have) large momentum **(1)** (So) the (de Broglie) wavelength is small **Or** to make (de Broglie) wavelength the size of proton **(1)** (This produces) better resolution (for small objects) **Or** (This results in) more detailed observations **Or** allows the electrons to penetrate the protons **(1)**	**3**
	Total for question 16	**12**

Question Number	**Answer**	**Mark**
17(a)(i)	Central straight line equidistant from spacecraft and satellite **and** at least one of the diverging lines between spacecraft and the central line **and** at least one of the diverging lines between the central line and satellite **(1)** At least one line looping spacecraft **and** one line looping satellite **(1)** Line spacing between spacecraft and satellite smaller than line spacing to the left of spacecraft **and** to the right of satellite **(1)** <u>Example of diagram</u> 	**3**
17(a)(ii)	Straight line equidistant from spacecraft and satellite and labelled 0 V. **(1)** <u>Example of diagram</u> 	**1**
17(b)(i)	Use of $V = Q / 4\pi\varepsilon_0 r$ **Or** Use of $V = kQ / r$ **(1)** Use of $W = QV$ **(1)** Minimum energy = 1.7×10^{-15} (J) **(1)** <u>Example of calculation</u> $V_{\text{spacecraft}}$ (= $V_{\text{satellite}}$) = 1.5×10^{-6} C / 4 × π × 8.85×10^{-12} F m $^{-1}$ × 2.5 m = 5400 V $W = 2 \times 5400$ V × 1.6×10^{-19} J = 1.7×10^{-15} J	**3**

17(b)(ii)	Use of $F = Q_1 Q_2 / 4\pi\varepsilon_0 r^2$ **Or** Use of $F = k\,Q_1 Q_2 / r^2$ **(1)** Use of $F = ma$ **Or** Use of $Fs = ½\,mv^2$ **(1)** Use of suitable *suvat* equation(s), e.g. $s = ut + ½\,at^2$ **(1)** Correct value for s (270 km) or t (62.5 days), comparison and consistent conclusion **(1)** Example of calculation $F = 1.5 \times 10^{-6}\text{ C} \times 1.5 \times 10^{-6}\text{ C} / 4 \times \pi \times 8.85 \times 10^{-12}\text{ F m}^{-1} \times (20\text{ m})^2$ $= 5.1 \times 10^{-5}\text{ N}$ $a = 5.1 \times 10^{-5}\text{ N} / 2500\text{ kg} = 2.0 \times 10^{-8}\text{ m s}^{-2}$ $300\,000\text{ m} = ½ \times 2.0 \times 10^{-8}\text{ m s}^{-2} \times t^2$ $t = 5.4 \times 10^6\text{ s}$ $t = 5.4 \times 10^6\text{ s} / (24 \times 60 \times 60\text{ s})$ $t = 62.5$ days is approximately 60 days, so the estimate is correct	**4**
17(c)	A reasonable suggestion, such as • Some of the electrons / beam misses **(1)** • Some of the electrons are deflected **(1)** • The spacecraft is already charged from use on a previous satellite **(1)** • The spacecraft emits further electrons in another direction as a fine control on the electrostatic force **(1)** • UV (from Sun) leads to photoelectric emission **(1)**	**1**
	Total for question 17	**12**

Question Number	Answer	Mark
18(a)	Current (in primary) produces magnetic field (around secondary coil) **Or** Current (in primary) produces magnetic field (in the core) **(1)** (When switch opened) the current changes so there is a change in (magnetic) flux linkage in the secondary coil need **Or** (When switch opened) the current changes so lines of flux cut the secondary coil **(1)** An e.m.f. is induced (across the secondary coil) **(1)**	**3**
18(b)	Use of $A = \pi r^2$ **(1)** Applies knowledge of flux = flux density × area **(1)** Use of $\varepsilon = \mathrm{d}N\varphi / \mathrm{d}t$ **(1)** Use of $E = V / d$ **(1)** $E = 1.4 \times 10^8$ V m^{-1} **(1)** Example of calculation $A = \pi \times (0.016 \text{ m} / 2)^2 = 2.0 \times 10^{-4} \text{ m}^2$ $\varphi = 0.34 \text{ T} \times 2.0 \times 10^{-4} \text{ m}^2 = 6.84 \times 10^{-5} \text{ Wb}$ $\varepsilon = 30\,000 \times 6.84 \times 10^{-5} \text{ Wb} / 2.0 \times 10^{-5} \text{ s} = 1.0 \times 10^5 \text{ V}$ $E = 1.0 \times 10^5 \text{ V} / 0.00075 \text{ m}$ $E = 1.37 \times 10^8 \text{ V m}^{-1}$	**5**
18(c)	(By Lenz's law) the (direction of the) induced e.m.f. /current/field is such as to oppose the change causing it **(1)** E.m.f. / p.d. produced opposite to battery p.d. **(1)** **Or** E.m.f. / p.d. produced reduces effective battery e.m.f. / p.d. It opposes current (until rate of change of field is zero?) **Or** Reducing rate of increase of current **(1)**	**3**
	Total for question 18	**11**

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