Pearson Edexcel

Mark Scheme (Results)

October 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. 'resonance'

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	**The only correct answer is D** (thermionic emission) A is not correct because it is not caused by beta decay B is not correct because it is not caused by excitation C is not correct because it is not caused by the photoelectric effect	1
2	**The only correct answer is A** (kg m^{-3}) B is not correct because acceleration is a vector quantity C is not correct because electric field strength is a vector quantity D is not correct because impulse is a vector quantity	1
3	**The only correct answer is B** (lepton , meson) A is not correct because alpha is not fundamental C is not correct because proton is not fundamental and electron is D is not correct because muon is fundamental	1
4	**The only correct answer is A** (134 neutrons, 84 protons) B is not correct because it must be 134 neutrons, 84 protons C is not correct because it must be 134 neutrons, 84 protons D is not correct because it must be 134 neutrons, 84 protons	1
5	**The only correct answer is D** ($\frac{F}{B \times e \times \sin 66°}$, from Y to X) A is not correct because the angle between the direction of motion and the magnetic field is 66° and the direction of *v* is from Y to X B is not correct because the angle between the direction of motion and the magnetic field is 66° C is not correct because the direction of *v* is from Y to X	1
6	**The only correct answer is D** ($\sqrt{2 \times 9.11 \times 10^{-31} \times 3.5 \times 10^{-28}}$) A is not correct because this is not $\sqrt{2 \times m \times E_{\text{k}}}$ B is not correct because this is not $\sqrt{2 \times m \times E_{\text{k}}}$ C is not correct because this is not $\sqrt{2 \times m \times E_{\text{k}}}$	1
7	**The only correct answer is B** (conserved , not conserved) A is not correct because total kinetic energy is not conserved C is not correct because total momentum is conserved and total kinetic energy is not conserved D is not correct because total momentum is conserved	1
8	**The only correct answer is D** (The particles are accelerated by electric fields inside the dees.) A is not correct because this statement about cyclotrons is correct B is not correct because this statement about cyclotrons is correct C is not correct because this statement about cyclotrons is correct	1

9	**The only correct answer is B** (Most of the mass of the atom is concentrated in a small volume in the atom.) A is not correct because if all of the positive and negative charge was in the same location it would be neutral and have no effect on the alpha particles C is not correct because the experiments gave no information about energy levels D is not correct because protons and neutrons had not been identified	**1**
10	**The only correct answer is C** $\left(\frac{450 \times 10^{9} \times 1.6 \times 10^{-19}}{(3.00 \times 10^{8})^{2}}\right)$ A is not correct because this uses MeV instead of GeV and suggests that only the mass-energy of one of the colliding particles has been conserved B is not correct because this uses MeV instead of GeV D is not correct because this suggests that the mass-energy in the interaction has been doubled	**1**

Question Number	Answer		Mark
11	use of eV to J conversion	**(1)**	
	Use of $\Delta E_{grav} = mg\Delta h$	**(1)**	
	ΔE_{grav} = 30 J with comparison and conclusion that it is not justified **Or** $\Delta E_{grav} = 1.9 \times 10^{20}$ eV with comparison and conclusion that it is not justified **Or** (required) mass of brick = 3.6 kg with comparison and conclusion that it is not justified **Or** (required) height = 1.4 m with comparison and conclusion that it is not justified	**(1)**	**3**
	Example of calculation $E = 2.4 \times 10^{20} \times 1.6 \times 10^{-19}$ C = 38.4 J ΔE_{grav} = 2.8 kg × 9.81 N kg^{-1} × 1.1 m = 30.2 J 30 J < 38 J, so not justified		
	Total for question 11		**3**

Question Number	Answer	Mark
12(a)	At least 4 radial straight lines from point **(1)** (Radial) ruled lines equally spaced **(1)** Arrow(s) on line(s) outward from point (only) **(1)**	**3**
12(b)	Use of $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ **Or** Use of $E = \frac{kQ}{r^2}$ **(1)** Addition of magnitudes of field strength due to P and field strength due to Q **(1)** $E = 9.9 \times 10^4 \text{ N C}^{-1}$ **(1)** Example of calculation $E_\text{P} = \frac{14 \times 10^{-9} \text{ C}}{4\pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times (4.0 \times 10^{-2} \text{ m})^2} = 7.9 \times 10^4 \text{ N C}^{-1}$ $E_\text{Q} = \frac{-14 \times 10^{-9} \text{ C}}{4\pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times (8.0 \times 10^{-2} \text{ m})^2} = -2.0 \times 10^4 \text{ N C}^{-1}$ $E = 7.9 \times 10^4 \text{ N C}^{-1} + 2.0 \times 10^4 \text{ N C}^{-1}$ $= 9.9 \times 10^4 \text{ N C}^{-1}$	**3**
	Total for question 12	**6**

Question Number	Answer		Mark
13(a)	Use of $s = vt$	**(1)**	
	Distance = 647 (m)	**(1)**	**2**
	<u>Example of calculation</u> $s = 0.980 \times 3.00 \times 10^{8}$ m s^{-1} $\times$ 2.20×10^{-6} s = 647 m		
13(b)	Relativistic effects occur **Or** travelling at relativistic speed	**(1)**	
	Lifetime of muon increases	**(1)**	
	Muon travels greater distance (before decaying)	**(1)**	**3**
	Total for question 13		**5**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>14*</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>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td><td>Max linkage mark available</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>
Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

Indicative content:
IC1 (When the switch is closed,) there is a <u>current</u> in the circuit

IC2 Charge on capacitor increases

IC3 p.d. across capacitor increases and p.d. across resistor decreases

IC4 ($I = V/R$, so) <u>current</u> in circuit decreases (as p.d. decreases)

IC5 (As current decreases,) rate of charging decreases
Or rate of increase of p.d. decreases

IC6 Eventually p.d. across capacitor = V_0, current = 0, no further change in p.d. across capacitor
</td><td>6</td></tr>
<tr><td></td><td>Total for question 14</td><td>6</td></tr>
</table>

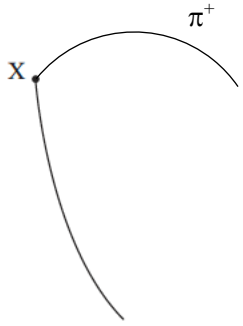
Question Number	Answer		Mark
15(a)(i)	By (Fleming's) left hand rule ((F)LHR) **Or** magnetic field perpendicular to current, so (magnetic force) Force is up on left/AC/A **and** down on right/BD/D (dependent on MP1)	**(1)** **(1)**	**2**
15(a)(ii)	Use of $F = BIl$ Use of moment = force × perpendicular distance Resultant moment = 9.1×10^{-3} N m <u>Example of calculation</u> $F = 0.68\ \text{T} \times 0.24\ \text{A} \times 0.05\ \text{m} \times 32$ $= 0.26\ \text{N}$ Moment = $(0.26\ \text{N} \times \frac{0.035\ \text{m}}{2}) \times 2$ $= 9.1 \times 10^{-3}\ \text{N m}$	**(1)** **(1)** **(1)**	**3**
15(b)(i)	Change in flux <u>linkage</u> (with coil) **Or** (Wires) cut lines of (magnetic) flux <u>Induces</u> <u>emf</u>	**(1)** **(1)**	**2**
15(b)(ii)	Calculates area of coil Applies knowledge of flux = magnetic flux density × area Use of flux linkage = $N\varphi$ Use of $\varepsilon = \text{d}N\varphi / \text{d}t$ $V = 0.48$ (V) with comparison and conclusion that it is sufficient <u>Example of calculation</u> Area = $0.05\ \text{m} \times 0.035\ \text{m} = 1.75 \times 10^{-3}\ \text{m}^2$ $\varphi = 0.68\ \text{T} \times 1.75 \times 10^{-3}\ \text{m}^2$ $= 1.19 \times 10^{-3}\ \text{Wb}$ $N\varphi = 32 \times 1.19 \times 10^{-3}\ \text{Wb} = 0.038\ \text{Wb}$ $\varepsilon = 0.038\ \text{Wb} / 0.080\ \text{s} = 0.48\ \text{V}$ $V = 0.48\ \text{V} >> 0.1\ \text{V}$ so it is sufficient	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question 15		**12**

Question Number	Answer		Mark
16(a)(i)	Use of $s = ut + \frac{1}{2}at^2$	**(1)**	
	a = 0.83 (m s^{-2}) (at least 2 sf)	**(1)**	**2**
	Example of calculation 0.02 m = ½ a × (0.22 s)^2 a = 0.83 m s^{-2}		
16(a)(ii)	Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$	**(1)**	
	Q = 1.9 × 10^{-9} (C) (at least 2 sf)	**(1)**	**2**
	Example of calculation $1800\ \text{V} = 8.99 \times 10^9\ \text{Nm}^2\ \text{C}^{-2} \times \frac{Q}{0.0095\ \text{m}}$ Q = 1.9 × 10^{-9} C		
16(a)(iii)	Use of $E = V / d$	**(1)**	
	Use of $F = EQ$ (ecf from (ii))	**(1)**	
	Use of $F = ma$	**(1)**	
	a = 0.95 m s^{-2} with comparison and conclusion that other forces must be acting **Or** (resultant) force producing the acceleration in part (i) = 1.4 × 10^{-4} N with comparison and conclusion that other forces must be acting	**(1)**	**4**
	Example of calculation E = 1800 V ÷ 0.02 m = 90 000 V m^{-1} F = 90 000 V m^{-1} × 1.9 × 10^{-9} C F = 1.7 × 10^{-4} N a = 1.7 × 10^{-4} N / 0.00018 kg a = 0.95 m s^{-2} a = 0.95 m s^{-2} > a = 0.8 m s^{-2}, so other forces must be acting		
16(b)(i)	**Similarity** In both there is no acceleration **Or** They are at constant speed in both **Or** In both there is no accelerating force	**(1)**	
	Differences (max 2) In the model there is a field, but there is no field (in the drift tube)	**(1)**	
	In the linac the particle has charge, but no charge on the ball	**(1)**	
	In the model the lengths of the sections are constant, but in a linac the lengths of the drift tubes increase	**(1)**	
	In a linac the time spent in each tube is constant, but in the model the time spent in successive sections decreases	**(1)**	**3**
16(b)(ii)	The particles must spend the same time in the drift tubes	**(1)**	
	The speed increases (between tubes), so they travel further in that time **Or** they accelerate (between tubes), so they travel further in that time	**(1)**	
	The length of the drift tubes must increase	**(1)**	**3**
	Total for question 16		**14**

Question Number	Answer		Mark
17(a)(i)	Calculates area swept out	**(1)**	
	Use of $s = vt$	**(1)**	
	Calculates volume of air	**(1)**	
	Use of $m = \rho V$	**(1)**	
	$m = 3.3 \times 10^{-3}$ (kg)	**(1)**	**5**
	Example of calculation $A = \pi \times (0.041\text{ m})^2$ $= 5.28 \times 10^{-3}\text{ m}^2$ $s = 2.4\text{ m s}^{-1} \times 0.2\text{ s} = 0.48\text{ m}$ $V = 5.28 \times 10^{-3}\text{ m}^2 \times 0.48\text{ m} = 2.53 \times 10^{-3}\text{ m}^3$ $m = 1.3\text{ kg m}^{-3} \times 2.53 \times 10^{-3}\text{ m}^3$ $m = 3.29 \times 10^{-3}$ kg		
17(a)(ii)	Use of $p = mv$	**(1)**	
	$p = 7.91 \times 10^{-3}$ kg m s^{-1} (ecf from (i))	**(1)**	**2**
	Example of calculation $p = 3.29 \times 10^{-3}\text{ kg} \times 2.4\text{ m s}^{-1}$ $p = 7.91 \times 10^{-3}$ kg m s^{-1}		
17(a)(iii)	Use of $F = \Delta mv / \Delta t$	**(1)**	
	$F = 0.039$ N (ecf from (ii))	**(1)**	**2**
	Example of calculation $F = 7.91 \times 10^{-3}\text{ kg m s}^{-1} / 0.2\text{ s}$ $F = 0.039$ N		
17(b)(i)	Vertically downward arrow from plane labelled weight/W/mg	**(1)**	
	Arrow along thread away from plane labelled tension/T	**(1)**	**2**
17(b)(ii)	States $mg = T\cos\theta$	**(1)**	
	States $mv^2 / r = T\sin\theta$	**(1)**	
	Suitable algebra to arrive at $\tan\theta = v^2 / rg$	**(1)**	**3**
	OR $\tan\theta = F_C / W$ substitute $F_C = mv^2 / r$ and $W = mg$ Suitable algebra to arrive at $\tan\theta = v^2 / rg$		
	Example derivation $mg = T\cos\theta$ $mv^2 / r = T\sin\theta$ $\sin\theta / \cos\theta = mv^2 / rmg$ $\tan\theta = v^2 / rg$		

17(b)(iii)	Use of tan $\theta = v^2 / rg$	**(1)**	
	Use of $\omega = \frac{2\pi}{T}$ and use of $v = \omega r$ **Or** Use of $v = \frac{2\pi r}{T}$	**(1)**	
	t = 1.4 s	**(1)**	**3**
	<u>Example of calculation</u> tan 22° = v^2 / 0.21 m × 9.81 N kg^{-1} v = 0.91 m s^{-1} 0.91 m s^{-1} = 2 × π × 0.21 m / T t = 1.446 s		
	Total for question 17		**17**

Question Number	Answer		Mark
18(a)	Use of $r = \frac{p}{BQ}$	**(1)**	**2**
	B = 1.15 T	**(1)**	
	Example of calculation $1.99\ \text{m} = \frac{3.67 \times 10^{-19}\ \text{kg m s}^{-1}}{B \times 1.60 \times 10^{-19}\ \text{C}}$ B = 1.15 T		
18(b)(i)	Baryon	**(1)**	**1**
18(b)(ii)	**Conservation of charge** Show charge for all particles: Σ^+ is (+)1, π^+ is (+)1, n is 0	**(1)**	**4**
	Show total charge before = total charge after, with conclusion that charge is conserved Dependent on MP1	**(1)**	
	Conservation of lepton number Show lepton number for all particles: Σ^+ is 0, π^+ is 0, n is 0	**(1)**	
	Show total lepton number before = total lepton number after, with conclusion that lepton number is conserved Dependent on MP3	**(1)**	
	Example of deduction Charge before = +1, charge after = +1 + 0 = +1 Charge before = charge after, so conservation of charge applies		
	Lepton number before = 0, charge after = 0 + 0 = 0 Lepton number before = lepton number after, so conservation of lepton applies		
18(b)(iii)	Use of trigonometrical function for x component of π momentum **Or** Use of trigonometrical function for y component of π momentum	**(1)**	**6**
	Applies conservation of momentum	**(1)**	
	Applies trigonometry to calculate final angle for neutron	**(1)**	
	Applies trigonometry or Pythagoras to calculate magnitude	**(1)**	
	Angle = 16.8°	**(1)**	
	Magnitude = 3.36×10^{-19} kg m s^{-1}	**(1)**	
	Example of calculation x component π = 1.07×10^{-19} kg m s^{-1} × sin 65° = 9.70×10^{-20} kg m s^{-1} y component of π = 1.07×10^{-19} kg m s^{-1} × cos 65° = 4.52×10^{-20} kg m s^{-1} y component of neutron = 3.67×10^{-19} kg m s^{-1} – 4.52×10^{-20} kg m s^{-1} = 3.22×10^{-19} kg m s^{-1} x component of neutron = 9.70×10^{-20} kg m s^{-1} tan θ = 9.70×10^{-20} kg m s^{-1} ÷ 3.22×10^{-19} kg m s^{-1} = 0.301 θ = 16.8° p^2 = (3.22×10^{-19} kg m s^{-1})^2 + (9.70×10^{-20} kg m s^{-1})^2 p = 3.36×10^{-19} kg m s^{-1}		

18(b)(iv)	Curving to the right (clockwise)	**(1)**	
	Correct initial direction	**(1)**	
	Smaller radius of curvature than sigma	**(1)**	
	No line for neutron (stated or dependent on seeing line definitively for pion)	**(1)**	**4**
			
	Total for question 18		**17**

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