Pearson Edexcel

Mark Scheme (Results)

October 2021

Pearson Edexcel International Advanced Level in Physics (WPH14) Paper 01 Physics 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 schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate.

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 means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be 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 mean that one mark will not be awarded. (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 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.

5. Quality of Written Communication

5.1 Indicated by QoWC in mark scheme. QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.

5.2 Usually it is part of a max mark, the final mark not being awarded unless the QoWC condition has been satisfied.

6. Graphs

6.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.

6.2 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.

6.3 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.

6.4 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.

Question Number	Answer	Mark
1	The only correct answer is **C** *A is not correct because an atom consists of fundamental particles* *B is not correct because a baryon consists of three quarks* *D is not correct because a pion is a meson*	**1**
2	The only correct answer is **A** *B is not correct because KE is conserved* *C is not correct because momentum is conserved* *D is not correct because momentum is conserved*	**1**
3	The only correct answer is **C** *A is not correct because* 2^2 */ 2 equals 2* *B is not correct because* 2^2 */ 2 equals 2* *D is not correct because* 2^2 */ 2 equals 2*	**1**
4	The only correct answer is **B** *A is not correct because when r increases by 2, E should decrease to ¼* *C is not correct because when r increases by 2, E should decrease to ¼* *D is not correct because when r increases by 2, E should decrease to ¼*	**1**
5	The only correct answer is **D** *A is not correct because the flux after the rotation is* $-N\phi$ *B is not correct because the flux after the rotation is* $-N\phi$ *C is not correct because the flux after the rotation is* $-N\phi$	**1**
6	The only correct answer is **B** *A is not correct because the gradient is zero* *C is not correct because the gradient is less than at B* *D is not correct because the gradient is less than at B*	**1**
7	The only correct answer is **C** *A is not correct because the work done by the battery is QV* *B is not correct because the work done by the battery is QV* *D is not correct because the energy stored on the capacitor is QV/2*	**1**
8	The only correct answer is **B** *A is not correct because high energies are required* *C is not correct because electrons need to display wave behaviour* *D is not correct because wavelengths do need to be comparable to nuclei*	**1**
9	The only correct answer is **C** *A is not correct because pions consist of 2 quarks* *B is not correct because pions consist of 2 quarks* *D is not correct because a meson has a quark antiquark*	**1**
10	The only correct answer is **B** *A is not correct because* $BIl\sin\theta$ *means the graph follows a sine curve* *C is not correct because* $BIl\sin\theta$ *means the graph follows the first quadrant of a sine curve* *D is not correct because* $BIl\sin\theta$ *means the graph follows a sine curve*	**1**

Question Number	Answer		Mark
11a	Recognises Q is 2 (× unit charge) Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$ V = 108 V <u>Example of Calculation</u> $V = \frac{8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2} \times 2 \times 1.6 \times 10^{-19}\text{C}}{26.6 \times 10^{-12}\text{m}}$ $V = 108 \text{ V}$	(1) (1) (1)	**3**
11b	the (electric) field is radial **Or** the nucleus can be regarded as a point (charge) **Or** no other charged particles are nearby **Or** distance is measured from the centre of the nucleus	(1)	**1**
	Total for question 11		**4**

Question Number	Answer		Mark
12a	Arrow upwards along wire labelled tension (accept *T*) Arrow downwards from bob labelled weight (accept *W*, *mg*, gravitational force, force due to gravity)	(1) (1)	**2**
12bi	Resolve vertically $T\cos\theta = mg$ Resolve horizontally $T\sin\theta = m\omega^2 r$ **Or** $T\sin\theta = \frac{mv^2}{r}$ Use radius of circular path = $l \times \sin\theta$ Suitable algebra <u>Example of derivation</u> $T\cos\theta = mg$ $T\sin\theta = m\omega^2 r$ $T\sin\theta = ml\sin\theta\,\omega^2$ $\cos\theta = \frac{g}{l\omega^2}$ $\omega = \sqrt{\frac{g}{l\cos\theta}}$	 (1) (1) (1) (1)	**4**
12bii	Use of $\omega = \sqrt{\frac{g}{l\cos\theta}}$ Use of $T = \frac{2\pi}{\omega}$ Confirmation of value of *T* = 5.0 (s) with conclusion **Or** *l* = 6.4 (m) with conclusion **Or** θ = 13.9 (°) with conclusion **Or** *g* = 9.81 (N kg^{-1}) with conclusion **Or** calculates ω = 1.26 (s^{-1}) from both equations with conclusion <u>Example of calculation</u> $\omega = \frac{2\pi}{5.0\text{s}} = 1.26\ \text{s}^{-1}$ $\omega = \sqrt{\frac{9.81\ \text{N kg}^{-1}}{6.4\ \text{m} \times \cos 13.9°}}$ $\omega = 1.26\ \text{s}^{-1}$	(1) (1) (1)	**3**
	Total for question 12		**9**

Question Number	Answer	Mark
***13a**	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.	**6**

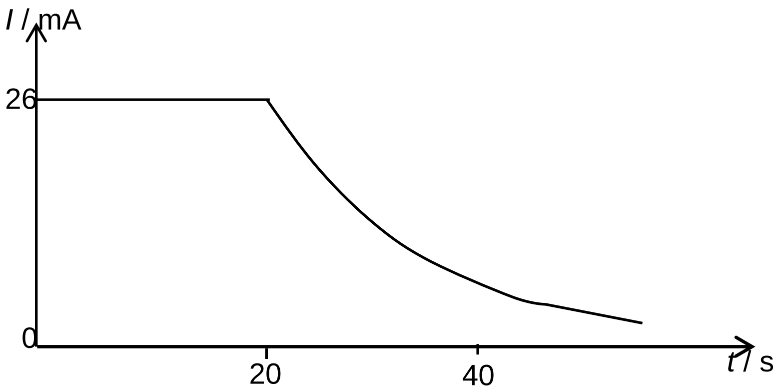
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	Max linkage mark available	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

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
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

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** plum pudding model of atom prior to experiment **Or** J J Thomson model of atom prior to experiment **Or** atom believed to have an equally distributed mass/charge throughout **IC2** alpha particles expected to go straight through **Or** alpha particles expected to have only a small deflection **IC3** a small number of alphas deflected through very large angles **Or** a small proportion of alphas come straight back **IC4** (changed to) model of the atom having very small nucleus **Or** (changed to) model of atom where most is empty space **IC5** nucleus contains (almost) all the mass **IC6** nucleus is charged	(1) (1) (1) (1) (1) (1)	
13(b)	**Either** a thin sheet would contain few layers of atoms so alpha particles would be less likely to undergo multiple deflections **Or** so alpha particles would be less likely to be absorbed **OR** alpha particles are strongly ionising so alpha particles can only penetrate a thin sheet **or** so alpha particles have low penetration	(1) (1) (1) (1)	**2**
	Total for question 13		**8**

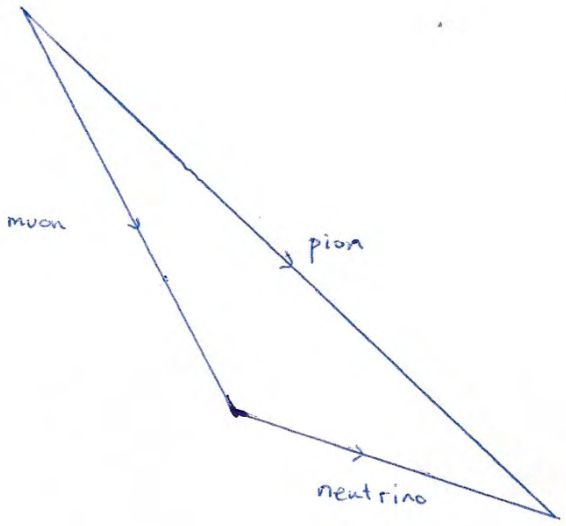
Question Number	Answer		Mark
14a	The capacitor stores charge/energy	(1)	**3**
	(if the switch is open) the capacitor discharges through resistor/controller **Or** (if the switch is open) the p.d across the resistor/controller is maintained by the capacitor	(1)	
	p.d. across capacitor will remain high enough to operate the controller for a short time **Or** current in circuit will remain high enough to operate the controller for a short time **Or** charge/energy stored is limited and will only last for a short time	(1)	
14b	Use of $\ln V = \ln V_0 - \frac{t}{RC}$	(1)	**2**
	t = 24 s	(1)	
	<u>Example of calculation</u> $\ln 4 = \ln 12 - \frac{t}{470 \times 47 \times 10^{-3}\text{s}}$ t = 24.3 s		
14c	Horizontal line of non-zero I from 0 to 20 s	(1)	**4**
	(Initial value of) I = 26 mA	(1)	
	(From 20 s) approximate exponential decrease	(1)	
	Approximately drops to 1/3 after about 44 s (24 s after start of decrease)	(1)	
	ECF depending on calculation from (b) <u>Example of calculation</u> I = 12 V / 470 Ω = 0.026 A 		
	Total for question 14		**9**

Question Number	Answer		Mark
15ai	Use of $F\Delta t = \Delta p$ and $p = mv$ **Or** Use of $F = ma$ and $v = at$ $v = 42\ \text{m s}^{-1}$ <u>Example of calculation</u> $109000\ \text{N} \times 2.9\ \text{s} = 7500\ \text{kg} \times v$ $v = 42\ \text{m s}^{-1}$	(1) (1)	**2**
15aii	Use of $E_k = ½\ mv^2$ (ecf for v from part ai) Use of $\Delta E_{grav} = mg\Delta h$ It reaches the top of the tower as initial $E_k = 6.6 \times 10^6$ J is greater than energy required, $\Delta E_{grav} = 6.0 \times 10^6$ J **Or** It reaches the top of the tower as it can reach a height of 90 m which is greater than the required 81 m **Or** It reaches the top of the tower because 42 m s^{-1} is greater than the required speed of 40 m s^{-1} **Or** It reaches the top of the tower because speed at top is 13 m s^{-1} so it is still moving (Do not award marks for use of equations of motion for uniform acceleration) <u>Example of calculation</u> $E_k = \dfrac{7500\text{kg} \times (42\ \text{ms}^{-1})^2}{2}$ $E_k = 6.6 \times 10^6$ J $\Delta E_{grav} = 7500\ \text{kg} \times 9.81\ \text{m s}^{-2} \times 81\ \text{m} = 6.0 \times 10^6$ J Use of show that gives $E_k = 6.0 \times 10^6$ J	(1) (1) (1)	**3**
15b	There is a change in flux linkage of the magnetic field and the metal fin **Or** The fin cuts magnetic field/flux This <u>induces</u> an <u>emf</u> (across the fin) Current is produced in the fin (accept eddy current) Force acts on the fin, as there is a current in a magnetic field **Or** field due to current in fin interacts with field due to magnets to cause force on fin The force opposes the motion due to Lenz's law **Or** Energy dissipated by current comes from (reduction in) kinetic energy of vehicle	 (1) (1) (1) (1) (1)	**5**
	Total for question 15		**10**

Question Number	Answer	Mark
16a	At least three parallel vertical lines touching the plates at top and bottom (1) Lines equi-spaced (1) Arrow on at least one line pointing down (1) (Ignore whatever is drawn at left and right edges of the plates)	**3**
16bi	Use of $E = V/d$ (1) Use of $E = F/Q$ (1) $F = 2.63 \times 10^{-13}$ (N) (more than 2 s.f.) (1) <u>Example of calculation</u> $F = 1.6 \times 10^{-19}\text{C} \times \frac{10500\text{ V}}{0.0064\text{ m}}$ $F = 2.625 \times 10^{-13}$ N	**3**
16bii	Use of $\Delta W = F\Delta s$ (1) $\Delta W = 5.3 \times 10^{-20}$ J so less than ionisation energy so does not cause further ionisation **Or** required force = 1.95×10^{-12} N, which is greater than 2.6×10^{-13} N, so does not **Or** required distance = 1.5×10^{-6} m, which is greater than 0.2×10^{-6} m, so does not (1) <u>Example of calculation</u> $\Delta W = 2.6 \times 10^{-13}\text{ N} \times 0.2 \times 10^{-6}\text{ m} = 5.26 \times 10^{-20}$ J	**2**
16c	muons travelling close to speed of light (1) relativistic effect increases particle lifetime (for observer) (1) so travels further than normally expected (before decaying) (1)	**3**
	Total for question 16	**11**

Question Number	Answer	Mark
17a	The beam/electron/positron is gaining speed (1) The length of tubes increases **or** the length of gaps between tubes increases (1) So time between beam exiting (successive) tubes is constant **Or** time spent in each tube is constant **Or** time spent between (each successive pair of) tubes is constant (1) The p.d. has to reverse in this time period and hence frequency is constant (1)	**4**
17bi	Use of $m_\Omega = 3272 \times m_e$ (1) Use of $\Delta E = c^2 \Delta m$ (1) Use of conversion factor for eV (1) mass of omega baryon = 1680 MeV/c^2 (1) Example of calculation $\text{mass} = 3272 \times 9.11 \times 10^{-31}\text{kg}$ $\text{Energy} = 2.981 \times 10^{-27}\text{kg} \times (3 \times 10^{8}\ \text{ms}^{-1})^2$ $\text{Energy} = \dfrac{2.68 \times 10^{-10}\text{J}}{1.6 \times 10^{-19}\text{JeV}^{-1}}$ $\text{mass} = 1677\ \text{MeV/c}^2$	**4**
17bii	Total energy of electron and positron = 29 GeV **Or** total energy available for each omega baryon = 14.5 GeV **Or** $\Delta E = c^2 \Delta m$ for omega rest mass energy **Or** Use of conversion factor for GeV to J for electron and positron energy (ignore rest mass of electron and positron) (1) Uses Kinetic Energy = Total Energy – Rest mass energy of baryon (1) Kinetic energy of either omega = 12.8 GeV **Or** Kinetic energy of either omega = 2.05×10^{-9} J (1) Example of calculation Kinetic energy of both omegas = 29 GeV – 2 ×1.7 GeV = 25.6 GeV So kinetic energy of either omega baryon = 12.8 GeV	**3**
17c	If both omega, it would break the conservation of baryon number (1) Must be omega and anti-omega (1) Further detail of baryon number: If both omega, before collision baryon number = 0 and after collision baryon number = 2 (which breaks conservation law) **Or** If omega and anti-omega before collision baryon number = 0 and after 1 – 1 = 0 (which obeys conservation law) (1)	**3**
	Total for question 17	**14**

Question Number	Answer		Mark
18a	(to conserve charge, as) no other charged particle is produced **Or** no other track is produced It has the same direction of curvature (as the pion track)	(1) (1)	**2**
18b	The radius of the (spiral) path decreases (following it clockwise) The momentum/velocity/speed of the particle is decreasing as energy is transferred from the anti-muon (by ionisation and electromagnetic radiation)	(1) (1) (1)	**3**
18c	out of page	(1)	**1**
18d	Use of $r = p/BQ$ Substitute $Q = 1.6 \times 10^{-19}$ C radius = 0.21 m <u>Example of calculation</u> $r = \frac{1.2 \times 10^{-19}\ \text{Ns}}{3.5\text{T} \times 1.6 \times 10^{-19}\ \text{C}}$ $r = 0.21$ m	(1) (1) (1)	**3**
18ei	$\pi^+ \rightarrow (\mu^+) + \nu_{(\mu)}$ **Or** $\pi^+ \rightarrow \bar{\mu} + \nu_{(\mu)}$ (accept anything reasonable for “muon”)	(1)	**1**
18eii	draws a straight line labelled for any of pion, muon or neutrino (accept momentum values) uses a recognisable scale e.g. 7.5 cm for muon or 12 cm for pion or 5.4 cm for neutrino vectors drawn correctly end to end correct arrows on at least two vectors (dependent on MP3) statement such as the three lines form a closed triangle so follows conservation of momentum (requires 3 arrows in correct direction) **Or** conclusion that a quantity resulting from scale drawing has the correct value (e.g. sss → correct angle or sas → correct length) (accept calculations showing conservation of momentum)	(1) (1) (1) (1) (1)	**5**

	Example of vector diagram 	
	Total for question 18	**15**