Pearson Edexcel

Mark Scheme (Results)

January 2023

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 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. 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.

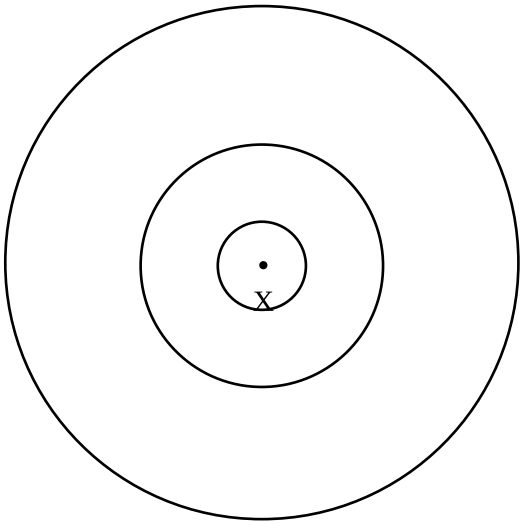
5.4 Points should be plotted to within 1 mm.

- 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.

Question Number	Answer	Mark
1	The only correct answer is **C** because duu gives a charge of +1 and ddu gives a charge of 0 **A** is not correct because ddd has a charge of –1 and uuu +2 **B** is not correct because duu gives a charge of +1 and ddu gives a charge of 0 **D** is not correct because ddd has a charge of –1 and uuu +2	**1**
2	The only correct answer is **D** because the angular velocity is 1500 revolutions per minute × 2 π / 60 s **A** is not correct because it is not 1500 revolutions per minute × 2 π / 60 s **B** is not correct because it is not 1500 revolutions per minute × 2 π / 60 s **C** is not correct because it is not 1500 revolutions per minute × 2 π / 60 s	**1**
3	The only correct answer is **B** because X has 237 nucleons and 93 protons so it has 144 neutrons **A** is not correct because the number of protons is incorrect **C** is not correct because the number of neutrons is incorrect **D** is not correct because the number of neutrons is incorrect and the number of protons is incorrect	**1**
4	The only correct answer is **D** because it must be travelling from Y to X as the radius is decreasing as energy is lost by ionisation and synchrotron radiation and it must be negative if it is travelling from Y to X **A** is not correct because a track from X to Y shows momentum increasing whereas energy would be lost **B** is not correct because a positron would follow an anticlockwise path **C** is not correct because a track from X to Y shows momentum increasing whereas energy would be lost	**1**
5	The only correct answer is **C** the conclusion is that there is a concentration of one type of charge whereas if the nucleus contained all of the charge there would be no deflecting force **A** is not correct because this is a valid conclusion **B** is not correct because this is a valid conclusion **D** is not correct because this is a valid conclusion	**1**
6	The only correct answer is **B** **A** is not correct because there are field lines from negative to positive **C** is not correct because there are field lines from the negative charge and to the positive charge and this shows the field pattern for like charges **D** is not correct because this shows the field pattern for like charges	**1**
7	The only correct answer is **C** because cyclotrons use alternating electric fields to keep particles moving in a circular path **A** is not correct because neutrons are uncharged and cyclotrons accelerate charged particles **B** is not correct because cyclotrons use magnetic fields to keep particles on a curved path and electric fields to increase their speed **D** is not correct because cyclotrons use magnetic fields to keep particles on a curved path and electric fields to increase their speed	**1**
8	The only correct answer is **D** because $E_K = p^2/2m$ so doubling p and halving m results in 8 times the initial kinetic energy **A** is not correct because this is not 8 times the initial kinetic energy **B** is not correct because this is not 8 times the initial kinetic energy **C** is not correct because this is not 8 times the initial kinetic energy	**1**
9	The only correct answer is **A** because this is (mass × change in velocity) / time **B** is not correct because this is not (mass × change in velocity) / time **C** is not correct because this is not (mass × change in velocity) / time **D** is not correct because this is not (mass × change in velocity) / time	**1**
10	The only correct answer is **B** because the force is doubled and the mass is quadrupled so the acceleration is halved and the time is doubled **A** is not correct because the correct time is 2t **C** is not correct because the correct time is 2t **D** is not correct because the correct time is 2t	**1**

Question Number	Answer	Mark
11(a)	Opposite charge **Or** Opposite lepton number **(1)** Do not allow Lepton number of an electron = –1 Do not allow charge of an electron = +1	1
11(b)	Charge of particles shown: –1, –1, 0, 0 **(1)** Lepton number of particles shown: 1, 1 ,1, –1 **(1)** Charge conserved **and** lepton number conserved, so possible **Or** But muon lepton number: 1 does not = –1, not obeyed, so not possible **Or** But electron lepton number: 0 does not = 1+1, not obeyed, so not possible **(1)**	3
	Total for question 11	**4**

Question Number	Answer		Mark
12(a)	Circles with point X at centre (at least 2) Increasing spacing with increasing distance from centre (at least 3)  	**(1)** **(1)**	 **2**
12(b)	Use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ (accept use of $F = \frac{k\,Q_1 Q_2}{r^2}$) F = 1.8 × 10^{-4} N <u>Example of calculation</u> $F = \frac{-4.5 \times 10^{-9}\text{ C} \times 7.0 \times 10^{-9}\text{ C}}{4\pi \times 8.85 \times 10^{-12}\text{F m}^{-1} \times (0.040\text{ m})^2}$ F = (−) 1.77 × 10^{-4} N	**(1)** **(1)**	 **2**
12(c)	Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$ (accept use of $V = \frac{kQ}{r}$) and $V = \frac{W}{Q}$ Subtract *W* at 9.0 cm from *W* at 4.0 cm **Or** Subtract *V* at 9.0 cm from *V* at 4.0 cm Work done = 3.9 × 10^{-6} J <u>Example of calculation</u> $W = \frac{-4.5 \times 10^{-9}\text{ C} \times 7.0 \times 10^{-9}\text{ C}}{4\pi \times 8.85 \times 10^{-12}\text{F m}^{-1} \times 0.040\text{ m}}$ $\frac{-4.5\text{ nC} \times 7.0\text{ nC}}{4\pi \times 8.85 \times 10^{-12}\text{F m}^{-1} \times 0.09\text{ m}}$ = −3.15 × 10^{-6} J − − 7.08 × 10^{-6} J Work done = 3.93 × 10^{-6} J	**(1)** **(1)** **(1)**	 **3**
	Total for question 12		**7**

Question Number	Answer	Mark
13(a)(i)	Use of $W = mg$ **(1)** Use of suitable trigonometry to calculate lift **(1)** Use of suitable trigonometry to calculate resultant force **(1)** Use of $F = mv^2/r$ **(1)** r = 820 (m) (at least 2 s.f.) **(1)** <u>Example of calculation</u> W = 1200 kg × 9.81 N kg^{-1} = 11772 N $L = W / \cos\theta$ = 11772 N / cos 20° = 12527 N $L_h = L \sin\theta$ = 12527 N × sin 20° = 4285 N 4285 N = mv^2/r = 1200 kg (54 m s^{-1})^2 / r r = 816 m	**5**
13(a)(ii)	Use of $v = 2\pi r/T$ **Or** Use of $v = r\omega$ **and** $\omega = 2\pi/T$ **(1)** t = 24 s (ecf from a(i)) **(1)** <u>Example of calculation</u> t = (2π × 816 m / 4)/ 54m s^{-1} t = 23.8 s	**2**
13(b)	An explanation that makes reference to: Resultant upwards force **Or** lift is greater than weight **Or** vertical component of lift is now greater than weight **(1)** Aeroplane will accelerate upwards **(1)**	**2**
	Total for question 13	**9**

Question Number	Answer		Mark
14(a)	Total momentum before an interaction = total momentum after interaction If no (external) unbalanced / resultant force acts **Or** in a closed system	**(1)** **(1)**	**2**
14(b)(i)	Use of $E_K = ½\ mv^2$ Correct value for one object Not elastic collision because total E_k before ≠ E_k after **Or** elastic collision total E_k before is (about) the same as E_k after (**all** values must have been correctly calculated) <u>Example of calculation</u> Before $E_K = ½\ mv^2$ $= ½ \times 0.85\ \text{kg} \times (1.30\ \text{m s}^{-1})^2 = 0.72\ \text{J}$ After $E_K = ½\ mv^2$ $= ½ \times 0.85\ \text{kg} \times (0.98\ \text{m s}^{-1})^2 = 0.41\ \text{J}$ $E_K = ½\ mv^2$ $= ½ \times 1.70\ \text{kg} \times (0.54\ \text{m s}^{-1})^2 = 0.25\ \text{J}$ Total = 0.66 J	**(1)** **(1)** **(1)**	**3**
14(b)(ii)	Use of $p = mv$ Use of trigonometry to find a component of momentum after collision Shows momentum before in x direction = momentum after in original direction Shows perpendicular component of A = perpendicular component of B **Or** Shows total momentum in perpendicular direction after collision is approximately zero Conclusion that momentum before = momentum after (in both directions) so conservation of momentum is demonstrated successfully (**all** values must have been correctly calculated) **Or** Conclusion that momentum before ≠ momentum after (in either direction) so conservation of momentum is not demonstrated successfully (**all** values must have been correctly calculated) <u>Example of calculation</u> Before $p = mv$ $= 0.85\ \text{kg} \times 1.30\ \text{m s}^{-1} = 1.11\ \text{kg m s}^{-1}$ horizontal, 0 vertical After – original direction $p = 0.85\ \text{kg} \times 0.98\ \text{m s}^{-1} \times \cos 54.5° = 0.484\ \text{kg m s}^{-1}$ $p = 1.70\ \text{kg} \times 0.54\ \text{m s}^{-1} \times \cos 48.0° = 0.614\ \text{kg m s}^{-1}$ Total = $1.11\ \text{kg m s}^{-1}$ After – perpendicular to original direction $p = 0.85\ \text{kg} \times 0.98\ \text{m s}^{-1} \times \sin 54.5° = 0.68\ \text{kg m s}^{-1}$ $p = -1.70\ \text{kg} \times 0.54\ \text{m s}^{-1} \times \sin 48.0° = -0.68\ \text{kg m s}^{-1}$	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question 14		**10**

Question Number	Answer	Mark
*15(a)	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 indicative marking points seen in answer	Number of marks awarded for indicative marking points	Max structure 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: Wire cuts lines of magnetic flux **Or** Wire cuts magnetic field lines **Or** flux <u>linkage</u> of wire changes **(1)** IC2: <u>Induces e.m.f.</u> **(1)** IC3: so current in loop of wire **(1)** IC4: Current in a wire in a magnetic field experiences a force **Or** <u>Magnetic</u> field associated with this current **(1)** IC5: Due to Lenz's law there is a force opposing the motion of the wire **Or** Upward force exerted on wire as the field is such to oppose the change that creates it **(1)** IC6: Opposite, downward force on magnets, so balance reading increases **Or** Newton's 3rd law - downward force on magnets, so balance reading increases **(1)**	**6**
15(b)	Use of area swept out = $l \times h$ **(1)** Use of $t = s/v$ **(1)** Use of $\varphi = BA$ **(1)** Use of $\varepsilon = \mathrm{d}\varphi/\mathrm{d}t$ **(1)** Max p.d. = 0.026 V **(1)** <u>Example of calculation</u> $A = 0.034\ \mathrm{m} \times 0.020\ \mathrm{m} = 0.00068\ \mathrm{m}^2$ $t = 0.020\ \mathrm{m} / 2.2\ \mathrm{m\ s}^{-1} = 0.0091\ \mathrm{s}$ $\varphi = 0.35\ \mathrm{T} \times 0.034\ \mathrm{m} \times 0.020\ \mathrm{m} = 0.000238\ \mathrm{Wb}$ Emf = $(0.35\ \mathrm{T} \times 0.034\ \mathrm{m} \times 0.020\ \mathrm{m}) / (0.020\ \mathrm{m} / 2.2\ \mathrm{m\ s}^{-1})$ Max p.d. = 0.026 V	**5**
	Total for question 15	**11**

Question Number	Answer		Mark
16(a)	When charging voltmeter is not across C, **Or** When switch at X, voltmeter is not across C, When discharging the resistor isn't in the circuit, **Or** with switch at Y, the resistor isn't in the circuit	(1) (1)	2
16(b)(i)	**Either** Takes corresponding pairs values of V and t from graph Use of $\ln V = \ln V_0 - t/RC$ **Or** Use of $V = V_0 e^{-\frac{t}{RC}}$ $R = 1.1 \times 10^7\ \Omega$ **Or** Draws initial tangent to curve and determines t intercept (range 22 s - 26 s) Use of $T = RC$ $R = 1.1 \times 10^7\ \Omega$ **Or** Read value of t at which $V = V_0 / e$ (2.3 V at 24 s) Use of $T = RC$ $R = 1.1 \times 10^7\ \Omega$ Example of calculation eg $V = 4.1$ V and $t = 10$ s $\ln 4.1 = \ln 6.2 - \frac{10\text{s}}{R \times 2.2 \times 10^{-6}\ \text{F}}$ $R = 1.1 \times 10^7\ \Omega$	(1) (1) (1) (1) (1) (1) (1) (1) (1)	3
16(b)(ii)	Use of $Q = CV$ Subtract charge at 30 s from charge at 0 s Use of $I = Q/t$ $I = 3.2 \times 10^{-7}$ A Example of calculation $Q = 2.2 \times 10^{-6}$ F × 6.2 V = 1.36×10^{-5} C $Q = 2.2 \times 10^{-6}$ F × 1.8 V = 3.96×10^{-6} C 1.36×10^{-5} C − 3.96×10^{-6} C = 9.64×10^{-6} C $I = 9.64 \times 10^{-6}$ C ÷ 30 s $I = 3.2 \times 10^{-7}$ A	(1) (1) (1) (1)	4
16(b)(iii)	Use of $W = ½ CV^2$ Subtract energy at 30 s from energy at 0 s Energy dissipated = 3.9×10^{-5} J Example of calculation $W = ½ \times 2.2 \times 10^{-6}$ F × (6.2 V)^2 = 4.23×10^{-5} J $W = ½ \times 2.2 \times 10^{-6}$ F × (1.8 V)^2 = 3.56×10^{-6} J 4.23×10^{-5} J − 3.56×10^{-6} J = 3.87×10^{-5} J Energy dissipated = 3.9×10^{-5} J	(1) (1) (1)	3
	Total for question 16		**12**

Question Number	Answer		Mark
17(a)(i)	Equates $F = BQv$ and $F = EQ$ Uses $E = V/d$ Suitable algebra to give $v = V/Bd$ <u>Example derivation</u> $BQv = EQ$ $v = E/B$ $E = V/d$ $v = V/Bd$	**(1)** **(1)** **(1)**	**3**
17(a)(ii)	Use of $v = V/dB$ $v = 2.8 \times 10^7$ m s^{-1} <u>Example of calculation</u> $v = 231$ V/0.015 m × 5.5 × 10^{-4} T $v = 2.8 \times 10^7$ m s^{-1}	**(1)** **(1)**	**2**
17(a)(iii)	States $r = p/BQ$ **and** $p = mv$ **Or** States $F = mv^2/r$ **and** $F = BQv$ Derives and uses $Q/m = v/rB$ $Q/m = 1.3\times10^{11}$ (C kg^{-1}) is less than the accepted value <u>Example of calculation</u> $Q/m = v/rB$ = 2.8 × 10^7 m s^{-1} / 0.39 m × 5.5 × 10^{-4} T 1.31×10^{11} C kg^{-1}	 **(1)** **(1)** **(1)**	**3**
17(b)	This is a diffraction/interference pattern Diffraction only occurs for waves **Or** Particles do not undergo diffraction (So) an electron does not always behave as a particle **Or** (so) electrons can behave as waves (and as particles)	**(1)** **(1)** **(1)**	**3**
	Total for question 17		**11**

Question Number	Answer	Mark
18(a)(i)	**Either** 1^{st} generation, u and d, are a pair and 2^{nd} gen, s and c, are a pair **(1)** So 6^{th} quark is a pair with b **(1)** By symmetry of the standard model **(1)** **Or** A quark to match each lepton **(1)** (Electron and muon had associated neutrino, so predict) neutrino for tau, so 6^{th} quark would match that **(1)** By symmetry of the standard model **(1)**	3
18(a)(ii)	Mesons and baryons **(1)**	1
18(b)(i)	**Either** • If target is stationary there is resultant momentum, so products must have resultant momentum after collision **(1)** • So products must have high <u>kinetic</u> energy **(1)** • (Therefore) less/little energy available for formation of particles **(1)** • (so) less massive particles formed **(1)** **Or** • If beams collide there is zero resultant momentum, so products may have no/low momentum after collision **(1)** • So products do not have high <u>kinetic</u> energy **(1)** • (Therefore) all/most/more energy available for formation of particles **(1)** • (so) more massive particles formed **(1)**	4
18(b)(ii)	Use of total energy = rest mass energy + kinetic energy **(1)** Use of eV to J conversion **(1)** Kinetic energy = 1.16×10^{-7} J **(1)** <u>Example of calculation</u> Kinetic energy = 900 GeV – 173 GeV = 727 GeV Kinetic energy = 727×10^{9} eV × 1.6×10^{-19} J eV^{-1} Kinetic energy = 1.16×10^{-7} J	3
18(b)(iii)	Use of $\Delta E = c^2 \Delta m$ to convert from GeV/c^2 to kg **(1)** Use of $E_K = \frac{1}{2} mv^2$ **(1)** $v = 8.8 \times 10^{8}$ m s^{-1}, which is greater than the speed of light **(1)** <u>Example of calculation</u> $\text{mass} = \frac{173\ \text{GeV}/c^2 \times 10^9 \times 1.6 \times 10^{-19}\ \text{J}\,\text{eV}^{-1}}{(3 \times 10^8)^2\ (\text{m s}^{-1})^2} = 3.08 \times 10^{-25}$ kg 1.16×10^{-7} J = ½ × 3.08×10^{-25} kg × v^2 $v = 8.8 \times 10^{8}$ m s^{-1}	3

18(c)	(An observer will see an) increased lifetime But the time to form hadrons would also increase as seen by the observer, so it is incorrect **Or** the lifetime would not increase as seen by the top quark, so it is incorrect	**(1)** **(1)**	**2**
	Total for question 18		**16**

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