Mark Scheme (Results)
June 2022

Pearson Edexcel
International Advanced Subsidiary 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. '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 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.

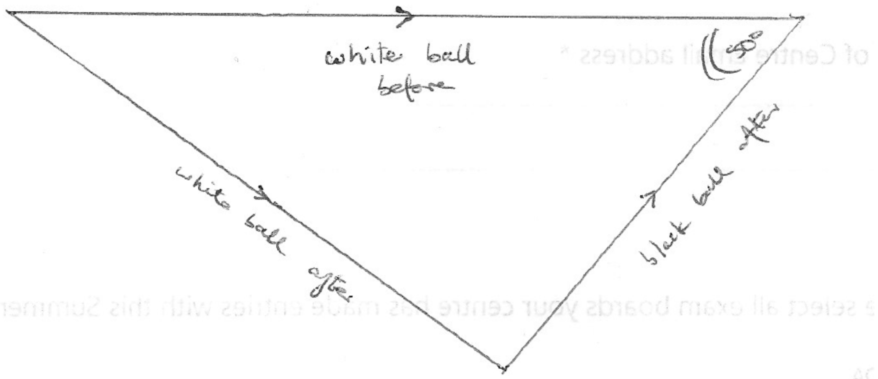
- Check the two points furthest from the best line. If both OK award mark.
- If either is 2 mm out do not award mark.
- If both are 1 mm out do not award mark.
- If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.

  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** *A is not correct because a pion consists of quarks* *B is not correct because a proton consists of quarks* *D is not correct because a neutron consists of quarks*	**1**
2	The only correct answer is **D** *A is not correct because this does not conserve charge* *B is not correct because this does not conserve baryon number* *C is not correct because this does not conserve lepton number*	**1**
3	The only correct answer is **D** *A is not correct because* $W \propto V^2$ *B is not correct because* $W \propto V^2$ *C is not correct because* $W \propto V^2$	**1**
4	The only correct answer is **A** *B is not correct because* $Q = \sqrt{F \times r^2 \times 4\pi\varepsilon_0}$ *C is not correct because* $Q = \sqrt{F \times r^2 / k}$ *D is not correct because* $Q = \sqrt{F \times r^2 \times 4\pi\varepsilon_0}$	**1**
5	The only correct answer is **A** *B is not correct because FLHR gives force into the page* *C is not correct because in this case the component of field is* $B\cos\emptyset$ *D is not correct because in this case the component of field is* $B\cos\emptyset$	**1**
6	The only correct answer is **A** *B is not correct because this isn't relevant* *C is not correct because this isn't relevant* *D is not correct because this isn't relevant*	**1**
7	The only correct answer is **D** *A is not correct because lifetime and mass increase at speed close to c* *B is not correct because lifetime and mass increase at speed close to c* *C is not correct because lifetime and mass increase at speed close to c*	**1**
8	The only correct answer is **D** *A is not correct because the frequency should be constant* *B is not correct because the magnetic field should be constant* *C is not correct because the p.d. should be constant*	**1**
9	The only correct answer is **A** *B is not correct because this is equivalent to coulombs* *C is not correct because this is equivalent to (farad)* $^{-1}$ *D is not correct because this is equivalent to (watt)* $^{-1}$	**1**
10	The only correct answer is **B** *A is not correct because the flux* $\emptyset$ *in coil 2 will be proportional to the current and the induced e.m.f. is proportional to* $-\Delta\emptyset/\Delta t$ *C is not correct because the flux* $\emptyset$ *in coil 2 will be proportional to the current and the induced e.m.f. is proportional to* $-\Delta\emptyset/\Delta t$ *D is not correct because the flux* $\emptyset$ *in coil 2 will be proportional to the current and the induced e.m.f. is proportional to* $-\Delta\emptyset/\Delta t$	**1**

Question Number	Answer		Mark
11	Use of $W = mg$	(1)	**3**
	Use of $F\,\Delta t = \Delta p$	(1)	
	v = 15 m s^{-1}	(1)	
	Example of calculation W = 175 kg × 9.81 N kg^{-1} = 1717 N 1717 N × 1 s = 114 kg × v v =15.1 m s^{-1}		
	Total for question 11		**3**

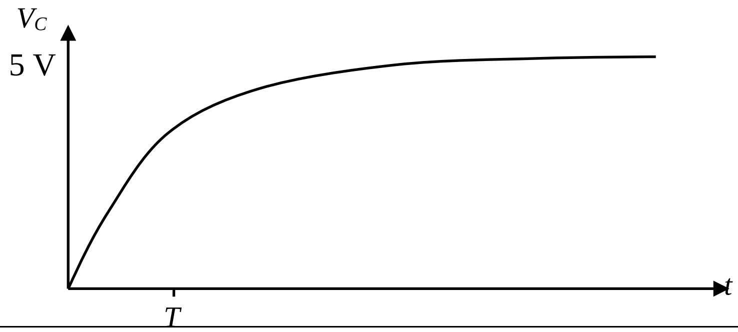
Question Number	Answer	Mark
12a	kinetic energy is not conserved (1) **Or** kinetic energy before collision not equal to kinetic energy after collision **Or** kinetic energy before collision greater than kinetic energy after collision	**1**
12b	(p = mv and mass of the balls is the same) so velocity (to scale) is proportional to momentum **Or** (conservation of momentum) (vector) sum of momentum after collision = momentum before collision (1) Velocities (drawn to scale) will form a triangle **Or** (a scaled vector diagram can show) (vector) sum of velocity after collision = velocity before collision (1)	**2**
12c	Straight line with arrow labelled for any of white ball before collision, white ball after collision, black ball (accept velocity values) (1) Evidence of correct use of a recognisable scale (1) Vectors drawn correctly end to end (e.g. white before collision is longest line) (1) Correct arrows on vectors (such that white before = resultant of white and black after) (Dependent on MP3) (1) Angle of black ball with initial white ball line measured as 50° with consistent conclusion Angle of black ball with final white ball line measured as 95° with consistent conclusion If drawn as angle-side-angle, velocity of white ball after collision = 0.92 m s^{-1}, with consistent conclusion If drawn as angle-side-angle, velocity of black ball after collision = 0.69 m s^{-1}, if supported by calculation, with consistent conclusion (1) Allow MP5 for correct value 50° (49.8°) determined by calculation and consistent conclusion Angle tolerance ± 4°, length tolerance ± 0.05 m Example of Diagram	**5**

	 	
	Total for question 12	**8**

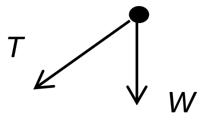
<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*13a</td><td>
This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th><th>Max structure mark available</th><th>Max final mark</th></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><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></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 is no structure and 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 structure, linkages and lines of reasoning).
</td><td>6</td></tr>
</table>

	Indicative content: IC1 Electrons accelerate in the gaps IC2 Frequency of a.c. supply is constant IC3 Time taken for an electron to travel between (consecutive) tubes is constant (and they are accelerating) IC4 Reference to $s = vt$, e.g. electrons travel further in a fixed time with a higher speed IC5 (In the last section of the linac) the electron approaches the speed of light IC6 Speed becomes (almost) constant so distance travelled in a fixed amount of time becomes (almost) constant	
13b	**Max 2 from:** Reference to $E=mc^2$ (1) There will be more kinetic energy available (for same accelerating p.d.) with colliding beams (1) (Total) momentum of two beams is zero before collision **Or** single beam and stationary target has (net) momentum before collision (1) **AND** All of the kinetic energy of the two beams available (to be converted to mass) so colliding beams more likely to produce particle with larger mass **Or** So with single beam particle(s) must have momentum after collision so less energy available (to be converted to mass) so lower mass particles produced (1) **Or** So with single beam particle(s) must have kinetic energy after collision so less energy available (to be converted to mass) so lower mass particles produced	**3max**
	Total for question 13	**9**

Question Number	Answer	Mark
14a	Determines correct radius from measurements from the paper (accept measurement of line between ends of arc as diameter) (1) Applies scale to measured distance - (1) Use of $r = p/BQ$ (1) $p = 1.9 \times 10^{-19}$ N s (range 1.6×10^{-19} N s to 1.9×10^{-19} N s) (1) <u>Example of calculation</u> radius 17 mm so actually 170 mm (range 14 mm to 17 mm) $p = 0.17 \text{ m} \times 7.0 \text{ T} \times 1.6 \times 10^{-19} \text{C}$ $p = 1.90 \times 10^{-19}$ N s (140 mm → $p = 1.57 \times 10^{-19}$ N s)	**4**
14b	Kaon does not leave a track (1) pions have opposite charge and charge is conserved (1)	**2**
14c	Antiproton: $\bar{u}\,\bar{u}\,\bar{d}$ **Or** antiup antiup antidown (1) negative pion: $\bar{u}$ d **Or** antiup down (1) (Quarks can be listed in any order for each particle)	**2**
14d	Use of $\Delta E = c^2 \Delta m$ (1) Conversion from J to eV (1) mass = 0.94 (GeV/c^2) (1) <u>Example of calculation</u> $\Delta E = (3 \times 10^8 \text{ m s}^{-1})^2 \times 1.67 \times 10^{-27} \text{ kg} = 1.503 \times 10^{-10}$ J $\Delta E = 1.503 \times 10^{-10} \text{ J} / 1.60 \times 10^{-19} \text{ J/eV} = 9.39 \times 10^8$ eV mass = 0.94 GeV/c^2	**3**
	Total for question 14	**11**

Question Number	Answer	Mark
15ai	exponential growth curve starting at origin and levelling at 5 V (accept V_0) (1) levelling off after at approx. 4 to 5 time constants **Or** curve through approx 2/3 of maximum at T (accept labelled as 3.2 V or 63%) (1) Example of graph 	**2**
15aii	**Either** (1) p.d. would decrease exponentially from 5 V Or p.d. would decrease exponentially to 0 V Because the sum of the p.ds across the capacitor and resistor must always add up to the supply p.d. (1) **Or** as capacitor charges then p.d. across resistor must decrease from 5 V. (1) so current in resistor decreases so rate of change of p.d. decreases (1)	**2**
15aiii	$5 = V_R + V_C$ (1) Use of $V_R = V_0 e^{-t/RC}$ and $V_0 = 5$ to give required equation (1)	**2**
15b	Use of $V_C = 5 - 5e^{-t/RC}$ (1) Takes ln of both sides of equation (1) C = 48 μF so select 47 μF (1) Example of calculation $3.3 = 5 - 5e^{-3.5/68000 \times C}$ $\ln \frac{1.7}{5} = -\frac{3.5}{68000 \times C}$ $1.08\ C = 5.15 \times 10^{-5}$ $C = 4.77 \times 10^{-5}$ F So 47 μF	**3**
	Total for question 15	**9**

Question Number	Answer	Mark
16a	Most alpha particles were undeviated **Or** Most particles pass through with little or no deviation (1) Most of the atom is empty space (1) (MP2 with reference to lack of deviation) Few alpha particles were scattered by small angles (1) There is a concentration of charge in the atom (1) (MP4 with reference to scattering) Very few alpha particles were deviated by more than 90° (1) Most of the mass is concentrated in a small region of the atom (1) **Or** Most of the mass is concentrated in nucleus (Accept Mass of nucleus much greater than mass of alpha particle) (MP6 with reference to back scattering)	**6**
16bi	Applies conversion factors for MeV to J (1) Use of $V = Q/4\pi\varepsilon_0 r$ (1) Use of $W=VQ$ (1) $r = 4.8 \times 10^{-14}$ (m) (1) <u>Example of calculation</u> 4.7 MeV = 4.7×10^{6} eV × 1.6×10^{-19} J/eV = 7.52×10^{-13} J 7.52×10^{-13} J = $8.99 \times 10^{9}\,\mathrm{Nm^2C^2} \times 2 \times 1.6 \times 10^{-19}\,\mathrm{C} \times 79 \times 1.6 \times 10^{-19}\,\mathrm{C}/r$ $r = 4.8 \times 10^{-14}$ m	**4**
16bii	Use of $E = Q/4\pi\varepsilon_0 r^2$ (1) With $Q = 79 \times 1.6 \times 10^{-19}$ (1) $E = 4.9 \times 10^{19}\ \mathrm{N\,C^{-1}}$ (1) (use of show that value gives $E = 4.5 \times 10^{19}\ \mathrm{N\,C^{-1}}$) allow ecf from (i) <u>Example of calculation</u> $E = 8.99 \times 10^{9}\,\mathrm{Nm^2C^2} \times 79 \times 1.6 \times 10^{-19}\,\mathrm{C} \Big/ (4.8 \times 10^{-14})^2\,\mathrm{m^2}$ $E = 4.9 \times 10^{19}\ \mathrm{N\,C^{-1}}$	**3**
	Total for question 16	**13**

Question Number	Answer		Mark
17ai	Arrow down marked weight/W/mg Arrow labelled *T* drawn at 40° downwards from horizontal by eye 	(1) (1)	**2**
17aii	There is a resultant force due to tension and weight Resultant force is at 90° to the motion of the hammer (Accept resultant force directed towards the centre of the circular path)	(1) (1)	**2**
17aiii	Use of velocity = $f \times 2\pi r$ **Or** $\omega = f \times 2\pi$ Use of $a = v^2 / r$ **Or** $a = r\,\omega^2$ $a = 460\ \mathrm{m\,s^{-2}}$ <u>Example of calculation</u> $v = 2.8\ \mathrm{s^{-1}} \times 2\pi \times 1.5\ \mathrm{m} = 26.4\ \mathrm{m\,s^{-1}}$ $a = 26.4^2\ (\mathrm{m\,s^{-1}})^2 / 1.5\ \mathrm{m} = 464\ \mathrm{m\,s^{-2}}$	(1) (1) (1)	**3**

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17b	**Either** • Use of trigonometry for a component of velocity (1) • Use of $v^2 = u^2 + 2as$ (with $a = g$) (1) • Use of $v = u + at$ (with $a = g$) (1) • Use of $v = s/t$ in the horizontal plane (1) • range = 81 m so doesn't beat record (1) **Or** • Use of trigonometry for a component of velocity (1) • Use of $s = ut + ½ at^2$ (with $a = g$) (1) • the ut term has the opposite sign to s and at^2 term (1) • Use of $v = s/t$ in the horizontal plane (1) • range = 81 m so doesn't beat record (1) <u>Example of calculation</u> Initial vertical component velocity = 28.0 sin 40° = 18.00 m s^{-1} Horizontal component velocity = 28.0 cos 40° = 21.45 m s^{-1} $s = \frac{v^2 - u^2}{2a} = \frac{0 - (18 \text{ m s}^{-1})^2}{2 \times 9.81 \text{ m s}^{-2}} = 16.5 \text{ m}$ Time to highest point, $t = \frac{v-u}{a} = \frac{(-18-0) \text{ m s}^{-1}}{-9.81 \text{ m s}^{-2}} = 1.83 \text{ s}$ Distance to ground = 16.5 m + 1.5 m = 18.0 m Time from highest point to ground, $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2\times(-18.0 \text{ m})}{-9.81 \text{ m s}^{-2}}} = 1.92 \text{ s}$ Total time of flight = 1.83 s + 1.92 s = 3.75 s Range = 21.45 m s^{-1} × 3.75 s = 80.4 m This is less than 83 m, so it would not break the record.	5
	Total for question 17	**12**

Question Number	Answer		Mark
18ai	Use of $v = s/t$	(1)	**3**
	Use of $p = mv$	(1)	
	p = 0.32 (N s)	(1)	
	<u>Example of calculation</u> v = 0.15 cm / 0.19 s = 0.79 m s^{-1} p = 0.40 kg × 0.79 m s^{-1} = 0.32 N s		
18aii	Use of $E_k = \frac{1}{2}mv^2$ **Or** $E_k = \frac{p^2}{2m}$	(1)	**3**
	Final E_k = 0.9 × Initial E_k **Or** correct use of $E_k \propto v^2$ can be awarded MP1 and 2	(1)	
	At lightgate 2 v = 0.75 m s^{-1} allow ecf from (i) 'show that' value gives v = 0.71 m s^{-1}	(1)	
	<u>Example of calculation</u> Initial E_k = ½ $\frac{0.32^2\ (\text{N s})^2}{0.4\ \text{kg}}$ = 0.125 J Final E_k = 0.9 × 0.125 J = 0.1125 J = ½ 0.4 kg × v^2 v = 0.75 m s^{-1}		
18bi	**Max 2 marks from**		**2**
	<u>e.m.f. induced</u> (in plate)	(1)	
	due to change of flux linkage **Or** due to cutting of lines of flux **Or** due to cutting of magnetic field lines	(1)	
	(Leads to current in plate) as the plate provides a (full) conducting path	(1)	
18bii	**Either**		**2**
	Current carrying conductor within a magnetic field experiences a force	(1)	
	Force opposite to direction of motion due to Lenz's law (so kinetic energy is reduced)	(1)	
	Or		
	Energy dissipated by current (in plate) (according to $P = I^2R$)	(1)	
	Energy is conserved (so kinetic energy decreases)	(1)	

18ci	Calculates a relevant ratio for a pair of values in the table (1) Shows the ratio is consistent with at least one other pair of values (1) <u>Example of calculation</u> k = 10/0.5 = 20 k = 16/0.8 = 20 k = 22/1.1 = 20	**2**

18cii	Reference to $R = \rho l/A$ **Or** refers to resistance of plate decreasing with increasing thickness/CSA (1) So current will increase (as induced emf will be the same) (1) So rate of energy transferred to surroundings increased **Or** larger braking force (1) (MP3 dependent on MP1 and 2)	**3**
	Total for question 18	**15**