



Mark Scheme (Results)

January 2023

Pearson Edexcel International Advanced
Level in Physics (WPH14)
Paper 01: Physics Further Mechanics, Fields
and Particles

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

January 2023

Question Paper Log Number P71890RA

Publications Code WPH14_01_MS_2301

All the material in this publication is copyright

© Pearson Education Ltd 2023

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 open.
- 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 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 $g = 10 \text{ m s}^{-2}$ 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

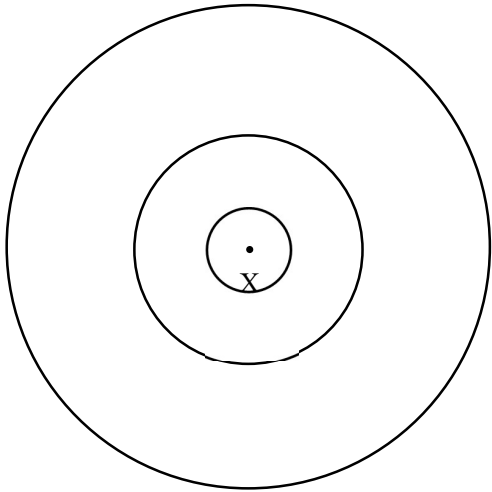
- 4.1 Bald (i.e. no working shown) correct answers score full marks unless in a 'show that' question.
- 4.2 If a 'show that' question is worth 2 marks, then both marks will be available for a reverse working; if it is worth 3 marks then only 2 will be available.
- 4.3 **use** of the formula means that 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	1
2	The only correct answer is D	1
3	The only correct answer is B	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	1
5	The only correct answer is C	1
6	The only correct answer is B	1
7	The only correct answer is C	1
8	The only correct answer is D	1
9	The only correct answer is A	1
10	The only correct answer is B	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) (1) Increasing spacing with increasing distance from centre (at least 3) (1) 	2
12(b)	Use of $F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$ (accept use of $F = \frac{k Q_1 Q_2}{r^2}$) (1) $F = 1.8 \times 10^{-4} \text{ N}$ (1) <u>Example of calculation</u> $F = \frac{-4.5 \times 10^{-9} \text{ C} \times 7.0 \times 10^{-9} \text{ C}}{4\pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times (0.040 \text{ m})^2}$ $F = (-) 1.77 \times 10^{-4} \text{ N}$	2
12(c)	Use of $V = \frac{Q}{4\pi\epsilon_0 r}$ (accept use of $V = \frac{kQ}{r}$) and $V = \frac{W}{Q}$ (1) 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 (1) Work done = $3.9 \times 10^{-6} \text{ J}$ (1) <u>Example of calculation</u> $W = \frac{-4.5 \times 10^{-9} \text{ C} \times 7.0 \times 10^{-9} \text{ C}}{4\pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times 0.040 \text{ m}}$ $\frac{-4.5 \text{ nC} \times 7.0 \text{ nC}}{4\pi \times 8.85 \times 10^{-12} \text{ F m}^{-1} \times 0.09 \text{ m}}$ = $-3.15 \times 10^{-6} \text{ J} - -7.08 \times 10^{-6} \text{ J}$ Work done = $3.93 \times 10^{-6} \text{ J}$	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) [Accept 760 (m) if $v = 52 \text{ m s}^{-1}$ used] <u>Example of calculation</u> $W = 1200 \text{ kg} \times 9.81 \text{ N kg}^{-1}$ $= 11772 \text{ N}$ $L = W / \cos \theta = 11772 \text{ N} / \cos 20^\circ$ $= 12527 \text{ N}$ $L_h = L \sin \theta = 12527 \text{ N} \times \sin 20^\circ = 4285 \text{ N}$ $4285 \text{ N} = mv^2/r = 1200 \text{ kg} (54 \text{ m s}^{-1})^2 / r$ $r = 816 \text{ m}$ [$r = 757 \text{ m}$ if $v = 52 \text{ m s}^{-1}$ used]	5
13(a)(ii)	Use of $v = 2\pi r/T$ Or Use of $v = r\omega$ and $\omega = 2\pi/T$ (1) $t = 24 \text{ s}$ (ecf from a(i)) (1) [Accept correctly calculated values using value of r calculated in (i) with either $v = 52 \text{ m s}^{-1}$ or $v = 54 \text{ m s}^{-1}$] <u>Example of calculation</u> $t = (2\pi \times 816 \text{ m} / 4) / 54 \text{ m s}^{-1}$ $t = 23.8 \text{ s}$	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 (1) If no (external) unbalanced / resultant force acts Or in a closed system (1)	2
14(b)(i)	Use of $E_k = \frac{1}{2} mv^2$ (1) Correct value for one object (1) Not elastic collision because total E_k before $\neq$ 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) (1) <u>Example of calculation</u> Before $E_k = \frac{1}{2} mv^2$ $= \frac{1}{2} \times 0.85 \text{ kg} \times (1.30 \text{ m s}^{-1})^2 = 0.72 \text{ J}$ After $E_k = \frac{1}{2} mv^2$ $= \frac{1}{2} \times 0.85 \text{ kg} \times (0.98 \text{ m s}^{-1})^2 = 0.41 \text{ J}$ $E_k = \frac{1}{2} mv^2$ $= \frac{1}{2} \times 1.70 \text{ kg} \times (0.54 \text{ m s}^{-1})^2 = 0.25 \text{ J}$ Total = 0.66 J	3
14(b)(ii)	Use of $p = mv$ (1) Use of trigonometry to find a component of momentum after collision (1) Shows momentum before in x direction = momentum after in original direction (1) Shows perpendicular component of A = perpendicular component of B Or Shows total momentum in perpendicular direction after collision is approximately zero (1) 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 $\neq$ momentum after (in either direction) so conservation of momentum is not demonstrated successfully (all values must have been correctly calculated) (1) <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 $p = 0.85 \text{ kg} \times 0.98 \text{ m s}^{-1} \times \cos 54.5^\circ = 0.484 \text{ kg m s}^{-1}$ $p = 1.70 \text{ kg} \times 0.54 \text{ m s}^{-1} \times \cos 48.0^\circ = 0.614 \text{ kg m s}^{-1}$ Total = 1.11 kg m s⁻¹ After – perpendicular to original direction $p = 0.85 \text{ kg} \times 0.98 \text{ m s}^{-1} \times \sin 54.5^\circ = 0.68 \text{ kg m s}^{-1}$ $p = -1.70 \text{ kg} \times 0.54 \text{ m s}^{-1} \times \sin 48.0^\circ = -0.68 \text{ kg m s}^{-1}$	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. <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 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).	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		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	
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																																							
	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																																									

	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 $\mathcal{E} = d\varphi/dt$ (1) Max p.d. = 0.026 V (1) <u>Example of calculation</u> $A = 0.034 \text{ m} \times 0.020 \text{ m} = 0.00068 \text{ m}^2$ $t = 0.020 \text{ m} / 2.2 \text{ m s}^{-1} = 0.0091 \text{ s}$ $\varphi = 0.35 \text{ T} \times 0.034 \text{ m} \times 0.020 \text{ m} = 0.000238 \text{ Wb}$ $\text{Emf} = (0.35 \text{ T} \times 0.034 \text{ m} \times 0.020 \text{ m}) / (0.020 \text{ m} / 2.2 \text{ m s}^{-1})$ 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, (1) When discharging the resistor isn't in the circuit, Or with switch at Y, the resistor isn't in the circuit (1)	2
16(b)(i)	Either Takes corresponding pairs values of V and t from graph (1) Use of $\ln V = \ln V_0 - t/RC$ (1) Or Use of $V = V_0 e^{-\frac{t}{RC}}$ (1) $R = 1.1 \times 10^7 \Omega$ (1) Or Draws initial tangent to curve and determines t intercept (range 22 s - 26 s) (1) Use of $T = RC$ (1) $R = 1.1 \times 10^7 \Omega$ (1) Or Read value of t at which $V = V_0 / e$ (2.3 V at 24 s) (1) Use of $T = RC$ (1) $R = 1.1 \times 10^7 \Omega$ (1) <u>Example of calculation</u> eg $V = 4.1$ V and $t = 10$ s $\ln 4.1 = \ln 6.2 - \frac{10\text{s}}{R \times 2.2 \times 10^{-6} \text{ F}}$ $R = 1.1 \times 10^7 \Omega$	3
16(b)(ii)	Use of $Q = CV$ (1) Subtract charge at 30 s from charge at 0 s (1) Use of $I = Q/t$ (1) $I = 3.2 \times 10^{-7} \text{ A}$ (1) <u>Example of calculation</u> $Q = 2.2 \times 10^{-6} \text{ F} \times 6.2 \text{ V} = 1.36 \times 10^{-5} \text{ C}$ $Q = 2.2 \times 10^{-6} \text{ F} \times 1.8 \text{ V} = 3.96 \times 10^{-6} \text{ C}$ $1.36 \times 10^{-5} \text{ C} - 3.96 \times 10^{-6} \text{ C} = 9.64 \times 10^{-6} \text{ C}$ $I = 9.64 \times 10^{-6} \text{ C} \div 30 \text{ s}$ $I = 3.2 \times 10^{-7} \text{ A}$	4
16(b)(iii)	Use of $W = \frac{1}{2} CV^2$ (1) Subtract energy at 30 s from energy at 0 s (1) Energy dissipated = $3.9 \times 10^{-5} \text{ J}$ (1) <u>Example of calculation</u> $W = \frac{1}{2} \times 2.2 \times 10^{-6} \text{ F} \times (6.2 \text{ V})^2 = 4.23 \times 10^{-5} \text{ J}$ $W = \frac{1}{2} \times 2.2 \times 10^{-6} \text{ F} \times (1.8 \text{ V})^2 = 3.56 \times 10^{-6} \text{ J}$ $4.23 \times 10^{-5} \text{ J} - 3.56 \times 10^{-6} \text{ J} = 3.87 \times 10^{-5} \text{ J}$ Energy dissipated = $3.9 \times 10^{-5} \text{ J}$	3
Total for question 16		12

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

Question Number	Answer	Mark
18(a)(i)	Either 1st generation, u and d, are a pair and 2nd gen, s and c, are a pair (1) So 6th 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 6th 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 = $900 \text{ GeV} - 173 \text{ GeV} = 727 \text{ GeV}$ Kinetic energy = $727 \times 10^9 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1}$ Kinetic energy = $1.16 \times 10^{-7} \text{ J}$	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) $v = 8.8 \times 10^8 \text{ m s}^{-1}$, which is greater than the speed of light (1) <u>Example of calculation</u> $\text{mass} = \frac{173 \text{ GeV}/c^2 \times 10^9 \times 1.6 \times 10^{-19} \text{ J eV}^{-1}}{(3 \times 10^8)^2 (\text{m s}^{-1})^2} = 3.08 \times 10^{-25} \text{ kg}$ $1.16 \times 10^{-7} \text{ J} = \frac{1}{2} \times 3.08 \times 10^{-25} \text{ kg} \times v^2$ $v = 8.8 \times 10^8 \text{ m s}^{-1}$	3

18(c)	(An observer will see an) increased lifetime (1)	
	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)	2
Total for question 18		16

