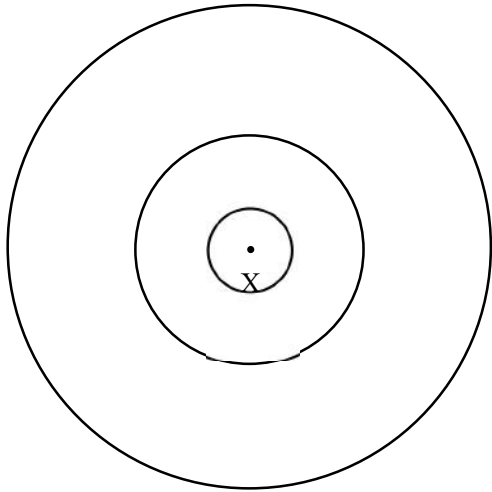# Mark Scheme (Results)

January 2023

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

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 Do not allow Lepton number of an electron = –1 Do not allow charge of an electron = +1	**(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 $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ (accept use of $F = \dfrac{k\, Q_1 Q_2}{r^2}$)	(1)	
	F = 1.8×10^{-4} N	(1)	2
	Example of calculation $F = \dfrac{-4.5 \times 10^{-9}\,C \times 7.0 \times 10^{-9}\,C}{4\pi \times 8.85 \times 10^{-1}\ F\,m^{-1} \times (0.040\ m)^2}$ F = (−) 1.77×10^{-4} N		
12(c)	Use of $V = \dfrac{Q}{4\pi\varepsilon_0 r}$ (accept use of $V = \dfrac{kQ}{r}$) and $V = \dfrac{W}{Q}$	(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 = 3.9×10^{-6} J	(1)	3
	Example of calculation $W = \dfrac{-4.5 \times 10^{-9}\,C \times 7.0 \times 10^{-9}\,C}{4\pi \times 8.85 \times 10^{-12} F\,m^{-1} \times 0.040\ m}$ $\dfrac{-4.5\ nC \times 7.0\ nC}{4\pi \times 8.85 \times 10^{-12} F\,m^{-1} \times 0.09\ m}$ $= -3.15 \times 10^{-6}$ J $-- 7.08 \times 10^{-6}$ J Work done = 3.93×10^{-6} J		
	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 $v = 52$ m s^{-1} used] Example of calculation 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 $\times \sin 20° = 4285$ N 4285 N $= mv^2/r = 1200$ kg $(54$ m s$^{-1})^2 / r$ $r = 816$ m [$r = 757$ m if $v = 52$ 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)** $t = 24$ s (ecf from a(i)) **(1)** [Accept correctly calculated values using value of r calculated in (i) with either $v = 52$ m s^{-1} or $v = 54$ m s^{-1}] Example of calculation $t = (2\pi \times 816$ m $/ 4)/ 54$m 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	**(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)**	**3**
	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)**	
	Example of calculation 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 $= 0.66 \text{ J}$		
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)**	**5**
	Example of calculation 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 $p = 0.85 \text{ kg} \times 0.98 \text{ m s}^{-1} \times \sin 54.5° = 0.68 \text{ kg m s}^{-1}$ $p = -1.70 \text{ kg} \times 0.54 \text{ m s}^{-1} \times \sin 48.0° = -0.68 \text{ kg m s}^{-1}$		
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 = $l \times h$ Use of $t = s/v$ Use of $\varphi = BA$ Use of $\varepsilon = d\varphi/dt$ Max p.d. = 0.026 V	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	<u>Example of calculation</u> $A = 0.034$ m $\times$ 0.020 m = 0.00068 m^2 $t = 0.020$ m / 2.2 m s^{-1} = 0.0091 s $\varphi = 0.35$ T $\times$ 0.034 m $\times$ 0.020 m = 0.000238 Wb Emf = (0.35 T $\times$ 0.034 m $\times$ 0.020 m) / (0.020 m /2.2 m s^{-1}) Max p.d. = 0.026 V		
	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)	2
	When discharging the resistor isn't in the circuit, **Or** with switch at Y, the resistor isn't in the circuit	(1)	
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 $V = V_0\, e^{-\frac{t}{RC}}$ $R = 1.1 \times 10^7\ \Omega$	(1) (1) (1)	
	Or Draws initial tangent to curve and determines t intercept (range 22 s - 26 s) Use of $T = RC$ $R = 1.1 \times 10^7\ \Omega$	(1) (1) (1)	
	Or Read value of t at which $V = V_o / e$ (2.3 V at 24 s) Use of $T = RC$ $R = 1.1 \times 10^7\ \Omega$	(1) (1) (1)	3
	Example of calculation eg $V = 4.1$ V and $t = 10$ s $\ln 4.1 = \ln 6.2 - \dfrac{10s}{R \times 2.2\ \times 10^{-6}\ F}$ $R = 1.1 \times 10^7\ \Omega$		
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	(1) (1) (1) (1)	4
	Example of calculation $Q = 2.2 \times 10^{-6}\,F \times 6.2$ V $= 1.36 \times 10^{-5}$ C $Q = 2.2 \times 10^{-6}\,F \times 1.8$ V $= 3.96 \times 10^{-6}$ C 1.36×10^{-5} C $- 3.96 \times 10^{-6}$ C $= 9.64 \times 10^{-6}$ C $I = 9.64 \times 10^{-6}$ C $\div 30$ s $I = 3.2 \times 10^{-7}$ A		
16(b)(iii)	Use of $W = \frac{1}{2}\,CV^2$ Subtract energy at 30 s from energy at 0 s Energy dissipated $= 3.9 \times 10^{-5}$ J	(1) (1) (1)	3
	Example of calculation $W = \frac{1}{2} \times 2.2 \times 10^{-6}\,F \times (6.2$ V$)^2 = 4.23 \times 10^{-5}$ J $W = \frac{1}{2} \times 2.2 \times 10^{-6}\,F \times (1.8$ V$)^2 = 3.56 \times 10^{-6}$ J 4.23×10^{-5} J $- 3.56 \times 10^{-6}$ J $= 3.87 \times 10^{-5}$ J Energy dissipated $= 3.9 \times 10^{-5}$ J		
	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)**	**3**
	Example derivation		
	$BQv = EQ$		
	$v = E/B$		
	$E = V/d$		
	$v = V/Bd$		
17(a)(ii)	Use of $v = V/dB$	**(1)**	
	$v = 2.8 \times 10^7$ m s^{-1}	**(1)**	**2**
	Example of calculation		
	$v = 231$ V/0.015 m $\times 5.5 \times 10^{-4}$ T		
	$v = 2.8 \times 10^7$ m s^{-1}		
17(a)(iii)	States $r = p/BQ$ **and** $p = mv$		
	Or States $F = mv^2/r$ **and** $F = BQv$	**(1)**	
	Derives and uses $Q/m = v/rB$	**(1)**	
	$Q/m = 1.3 \times 10^{11}$ (C kg^{-1}) is less than the accepted value	**(1)**	**3**
	Example of calculation		
	$Q/m = v/rB$		
	$= 2.8 \times 10^7$ m s^{-1} / 0.39 m $\times 5.5 \times 10^{-4}$ T		
	1.31×10^{11} C kg^{-1}		
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 So 6th quark is a pair with b By symmetry of the standard model **Or** A quark to match each lepton (Electron and muon had associated neutrino, so predict) neutrino for tau, so 6th quark would match that By symmetry of the standard model	**(1)** **(1)** **(1)** **(1)** **(1)** **(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 • So products must have high <u>kinetic</u> energy • (Therefore) less/little energy available for formation of particles • (so) less massive particles formed **Or** • If beams collide there is zero resultant momentum, so products may have no/low momentum after collision • So products do not have high <u>kinetic</u> energy • (Therefore) all/most/more energy available for formation of particles • (so) more massive particles formed	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **4**
18(b)(ii)	Use of total energy = rest mass energy + kinetic energy Use of eV to J conversion Kinetic energy = 1.16×10^{-7} J <u>Example of calculation</u> Kinetic energy = 900 GeV – 173 GeV = 727 GeV Kinetic energy = 727×10^9 eV $\times 1.6 \times 10^{-19}$ J eV^{-1} Kinetic energy = 1.16×10^{-7} J	**(1)** **(1)** **(1)**	 **3**
18(b)(iii)	Use of $\Delta E = c^2 \Delta m$ to convert from GeV/c^2 to kg Use of $E_K = \frac{1}{2} mv^2$ $v = 8.8 \times 10^8$ m s^{-1}, which is greater than the speed of light <u>Example of calculation</u> $$mass = \frac{173 \text{ GeV}/c^2 \times 10^9 \times 1.6 \times 10^{-19} \text{JeV}^{-1}}{(3 \times 10^8)^2 \text{ (m s}^{-1})^2} = 3.08 \times 10^{-25} \text{ kg}$$ 1.16×10^{-7} J = $\frac{1}{2} \times 3.08 \times 10^{-25}$ kg $\times v^2$ $v = 8.8 \times 10^8$ m s^{-1}	**(1)** **(1)** **(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**