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PHYSICS
PH02

Unit 2 Electricity, waves and particles

Mark scheme

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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from oxfordaqaexams.org.uk

Level of response marking instructions

Level of response mark schemes are broken down into levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Step 1 Determine a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level, ie if the response is predominantly level 3 with a small amount of level 4 material it would be placed in level 3 but be awarded a mark near the top of the level because of the level 4 content.

Step 2 Determine a mark

Once you have assigned a level you need to decide on the mark. The descriptors on how to allocate marks can help with this. The exemplar materials used during standardisation will help. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the Indicative content to reach the highest level of the mark scheme.

An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Answers	Additional comments/Guidelines	Mark	AO
01	uses $E = hf$ or 2.2×10^{-4} (J) seen ✓ value that rounds to 1.4×10^{3} (TeV) ✓		2	2 × AO1
Total			**2**	

Question	Answers	Additional comments/Guidelines	Mark	AO
02	comment about circuit when switch was open ✓ comment that closing the switch produces a current in circuit/cell **AND** cell has internal resistance ✓ conclusion that voltmeter reading decreases with relevant reason ✓	Condone 'battery' for 'cell'. MP1 e.g. voltmeter reading is the emf **OR** the emf is 1.53 V **OR** no current present, so no lost volts/energy loss. MP2: Reject idea that current causes internal resistance. Reject idea that there was any current when switch is open. MP3: e.g. 'terminal pd/voltage' decreases; idea of 'lost volts' in cell; pd exists across internal resistance. Allow explanation in terms of $\varepsilon = I(R + r)$ if terms defined. Allow explanation in terms of a potential divider circuit.	3	3 × AO2
Total			**3**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03	idea that a photon transfers, or an electron receives, a discrete amount of energy **OR** idea that a photon transfers all its energy to an electron ✓ maximum kinetic energy (of electron) equals photon energy minus work function ✓ idea that some electrons have lower KE because: more energy (than work function) is needed to be emitted **OR** (extra) energy loss occurs during emission ✓	MP1: Allow 'an electron absorbs a photon'. MP2: Allow idea that electrons with max KE are emitted from surface of metal. MP2: Allow use of '$hf - \phi$' if at least one term is defined. MP3: Condone idea that energy to remove electron varies with depth. Reject idea that the work function varies.	3	3 × AO1
Total			**3**	

Question	Answers	Additional comments/Guidelines	Mark	AO
04.1	Max 2 from: ✓✓ different wavelengths take different times to travel (through core) (because) different wavelengths travel at different speeds (in core) (because) refractive index of fibre varies with wavelength	Do not allow suggestion of modal dispersion. Condone 'frequency' for 'wavelength'. 'Spread out more' is insufficient for 'different times'. Ignore any specific correlation between wavelength and wave speed.	2	2 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	idea that increased length of fibre leads to: increased pulse broadening **OR** reduced intensity / amplitude ✓ idea that (max) transmission rate depends on: having distinct time gaps between (adjacent) pulses **OR** pulses having a minimum intensity ✓	MP1: Condone 'dispersion' will increase with length. Reference to dispersion can be for material or modal. MP1: Allow a specific reason for reduced intensity e.g. absorption / scattering / refraction (out of core) / attenuation. Allow 'weaker signal' for reduced intensity. For full credit their MP1 and MP2 must correlate.	2	2 × AO2
Total			**4**	

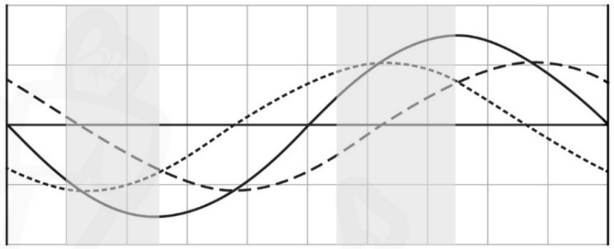
Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	One from: ✓ lithotripsy / breaking stones cleaning (surgical) equipment cleaning teeth / plaque removal monitor blood speed/flow deep-tissue heating ultrasonic scalpel	Accept 'A scans'.	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	uses $c = f\lambda$ with $3.5\ (\text{km s}^{-1})$ ✓ 1.1×10^{-3} (m) ✓	For MP1 condone POT errors. Allow 1 mark max for correct λ of another tissue: fat 4.4×10^{-4} m; muscle 5.0×10^{-4} m. Calculator value is 1.09375×10^{-3} (m)	2	2 × AO2
Total			**3**	

Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	mass per unit length ✓	Condone 'linear density'. Accept 'mass of wire/string divided by length of wire/string'.	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
06.2	Max 4: ✓ ✓ ✓ ✓ **Mark** / **Description** 4 – Detailed comments about any two areas **AND** one basic comment about any area 3 – Detailed comment about any one area **AND** one basic comment about another area 2 – Detailed comment about one area **OR** basic comments about two or three areas 1 – Basic comment about any area 0 – No relevant content Treat annotations (on Figure 2) as Basic level only.	B = Basic; D = Detailed (A) Determining l: • measure with a ruler / tape (B) • reference to distance of string between vibration generator and (top of) pulley (D) (B) Process: • change l and record f, or vice versa (B) • move vibration generator to change l (B) • change f of vibration generator (B) • change f by adjusting signal generator (D) • description of first harmonic e.g. max amplitude/antinode in middle of string or one loop seen (D) (C) Control variables: • same string / μ (B) • same tension (B) • same mass (B) • same tension by using same mass (D)	4	4 × AO4

Question	Answers	Additional comments/Guidelines	Mark	AO
06.3	second / 2nd ✓		1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.4	(reasonably) sinusoidal line drawn with: correct amplitude (~ 1 box) for two peaks ✓ correct wavelength and correct phase difference ✓	MP2: Trough and crest should fall within grey shaded areas shown. 	2	2 × AO3
Total			8	

Question	Answers	Additional comments/Guidelines	Mark	AO
07.1	combines $W = VQ$ and $E_k = \frac{1}{2}mv^2$ to give final formula ✓	Expect to see $Ve = \frac{1}{2}mv^2$ **AND** $v^2 = \frac{2Ve}{m_e}$	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
07.2	$v = \sqrt{\frac{2 \times 5.0 \times 10^4 \times 1.60 \times 10^{-19}}{9.11 \times 10^{-31}}}$ seen ✓ substitutes into an equation for wavelength and gives a value to at least 3 sf that rounds to 5.5×10^{-12} m ✓	Need v or λ as subject at least once. Condone use of m_e and e in substitutions. Allow MP1 for showing that $\lambda = \frac{h}{\sqrt{2m_eVe}}$ v must be correct if used in de Broglie equation. Expect 1.325×10^8 m s^{-1}. Reject 5.6×10^{-12} m from using v to 2 sf.	2	2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
07.3	uses $w = \frac{\lambda D}{s}$ ✓ 9.6×10^{-7} (m) ✓	All 3 values need to be substituted. Allow POT error for s. Only allow λ value that rounds to 5.5×10^{-12} or 5.6×10^{-12}. Allow 9.8×10^{-7} (m).	2	2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
07.4	diffraction (when passing through slits) ✓ superposition / interference (at the screen) ✓	Allow coherence.	2	2 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
07.5	fringe spacing decreases because (de Broglie) wavelength decreases ✓ (because the) momentum or speed increases ✓		2	2 × AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
07.6	bright fringes / maxima arise from waves arriving in-phase or with $n\lambda$ path difference ✓ Max 2 from: ✓ ✓ diffraction occurs (at each slit) superposition occurs (at screen) (leading to) constructive interference **AND** destructive interference	Allow an equivalent explanation of dark fringes / minima. Do not accept 'out of phase' for 'antiphase'. Do not allow 'superimposition'.	3	3 × AO2
Total			**12**	

Question	Answers	Additional comments/Guidelines	Mark	AO
08.1	states Ohm's law as current is directly proportional to pd (at constant temperature) ✓ yes, component obeys law up to: allow 60 to 63 mA **OR** 1.0 to 1.2 V **OR** no, component does not obey law above: allow 60 to 63 mA **OR** 1.0 to 1.2 V ✓	MP2 is dependent on MP1. Penalise contradictions. Allow reasoned arguments about not knowing if the temperature is constant. MP1: Condone 'proportional' for 'directly proportional'. Allow comment that a graph showing Ohm's Law is linear / has constant gradient **AND** passes through origin. No credit for idea that gradient is related to the resistance. For MP2 allow 1 sf '1 V'.	2	1 × AO1 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
08.2	(as temperature increases) resistance of thermistor decreases ✓ idea that the share of pd across thermistor decreases, so pd across fixed R increases ✓	Allow MP2 for stating that current increases and for using $V = IR$ to show pd across fixed R increases. MP2: Reject 'pd across thermistor decreases, so pd across fixed R increases'.	2	2 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
08.3	correct use of 1.3 or 8.7 V in a potential divider equation **OR** uses 8.7 V in $V = IR$ to calculate current (1.4 mA) ✓	MP1: Allow 3 sf read-offs if they round to 1.3 or 8.7. Allow 6.1 for R in potential divider equation. Allow POT error for R in $V = IR$. MP1: Expect to see: $R = \frac{1.3}{8.7} \times 6100$ **OR** $8.7 = \frac{6100}{6100+R} \times 10$ **OR** $1.3 = \frac{R}{6100+R} \times 10$ **OR** $8.7 = I \times 6100$	2	2 × AO3
	correct working to give 910 (Ω) ✓	MP2: Answer must have a subject. Calculator value is 911.494 (Ω). Using 1.43 mA gives 909.0909 (Ω). Allow 930 (Ω) if rounded value of 1.4 mA used. Calculator value is 928.5714 (Ω).		

Question	Answers	Additional comments/Guidelines	Mark	AO
08.4	uses $V = IR$ to get total resistance ($6850\ \Omega$) and subtracts $6100\ \Omega$ **OR** uses potential divider formula with 8.9 V $_{1a}$✓ use of parallel resistor formula with R_T in correct place $_{2a}$✓ answer in range 3900 to 4600 (Ω) $_{3a}$✓ **OR** correct use of $V = IR$ to get current in I_T $_{1b}$✓ subtracts their I_T from 1.46 mA to get I_S and uses I_S in $V = IR$ $_{2b}$✓ answer in range 3900 to 4600 (Ω) $_{3b}$✓	$_{1a}$✓ is for getting parallel resistance (expect $750\ \Omega$). May see $R = \frac{1.1}{8.9} \times 6100$ $_{2a}$✓ is for using parallel resistor formula. Expect to see $\frac{1}{750} = \frac{1}{900} + \frac{1}{R}$ In $_{2a}$✓ allow ecf for R_T from MP1 but not from **08.3** unless the value rounds to 900 $_{1b}$✓ is for getting current in thermistor (I_T). Expect ~1.2 mA for I_T (using V_T = 1.1 V and R_T = $900\ \Omega$) $_{2b}$✓ is for getting current in **S** (I_S) and using in $V = IR$. For $_{2b}$✓ expect I_S = 0.25 mA and 1.1 V for V_S. Allow an ecf for V_S.	3	3 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
08.5	idea that more limited range of pd leads to lower resolution (V per degree)	Condone 'sensitivity' for resolution.	1	AO4
Total			**10**	

Question	Answers	Additional comments/Guidelines	Mark	AO
09.1	(radio) waves are (vertically) polarised, or description of oscillations occurring only in one plane ✓ idea that maximum signal received is when receiving aerial is aligned (parallel) to transmitting aerial ✓	MP1 is for a relevant comment about polarisation. MP2 is for a comment about signal strength and alignment. Allow 'orientation' for 'alignment'. For MP2, condone idea that signal strength would be zero when receiving aerial is horizontally aligned.	2	1 × AO3 1 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
09.2	reduction of amplitude of oscillations/vibrations **OR** dissipation of energy (in oscillating system) ✓	Condone 'dissipative force'. Allow 'reduction of energy from an oscillating system'.	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
09.3	damper needs to be at an antinode (nearest the clamp) ✓ wavelengths of highest frequencies will have shortest spacing between antinodes (and nodes) ✓	Allow 'damper shouldn't be at a node'. Allow 'an antinode occurs at d from clamp'. Allow 'maximum amplitude' for 'antinode'. Allow two marks for 'first antinode occurs at a point d from clamp' If no other mark, allow 1 mark for statement that highest frequency corresponds to shortest wavelength.	2	2 × AO3
Total			**5**	

Question	Answers	Additional comments/Guidelines	Mark	AO
10.1	idea that there is 0.5 mm uncertainty in the readings at both ends of the ruler ✓		1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
10.2	$\frac{0.1}{12.8} \times 100 = 0.78\%$ seen ✓	Allow $\frac{0.01}{1.28} \times 100 = 0.78\%$ Calculator value is 0.78125%	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
10.3	$T = 2\pi\sqrt{\frac{l}{g}}$ used ✓ some working to give 9.6 (m s^{-2}) ✓	Answer to 2 sf only.	2	2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
10.4	doubles answer in **10.2 OR** $\frac{1}{400}$ or 0.0025 or 0.25% seen ✓ 1.8 or 1.9 or 2 ✓	Their value from **10.2** must round to 0.8. MP2: Accept 2 sf answers of '1.8' and '1.9', or 1 sf answer of '2'.	2	2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
10.5	Any 2 from: ✓ ✓ increase length of pendulum / string; 'increase L' record greater number (than 10) of oscillations repeat timings for T_{10} use of a fiducial mark at centre of oscillation repeat for different values of L **AND** plot appropriate graph (2 marks)	Reject 'record more times'. Reject bland 'repeat timings'. Appropriate graphs are: T^2 vs L; T vs $\sqrt{L}$	2	2 × AO2
Total			**8**	

Question	Answers	Additional comments/Guidelines	Mark	AO
11.1	uses $\sin\theta_c = \frac{n_2}{n_1}$ to give $\theta_c = 42.2(°)$ ✓	Allow $\sin\theta_c = \frac{1}{1.49}$ **OR** $\theta_c = \arcsin\left(\frac{1}{1.49}\right)$ **OR** $\theta_c = \sin^{-1}\left(\frac{1}{1.49}\right)$ Must have θ_c or 'critical angle' as subject. Allow θ for θ_c. Calculator value is $42.155°$.	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
11.2	(total internal) reflection (occurs at **P**) because angle of incidence is greater than critical angle ✓ travels horizontally right because angle of incidence is $45°$ so ray reflects at $45°$ or reflects through $90°$ **OR** leaves at right hand side of fibre because ray is: incident at normal / perpendicular to surface / at an angle of incidence of $0°$ / at angle of incidence less than critical angle ✓	Allow $45°$ for 'angle of incidence' and $42°$ for 'critical angle'. If no other mark, allow max 1 mark for a description of the path e.g. 'ray reflects at P and travels horizontally to leave at right-hand side' **OR** for drawing a fully correct path on Figure 16.	2	2 × AO3

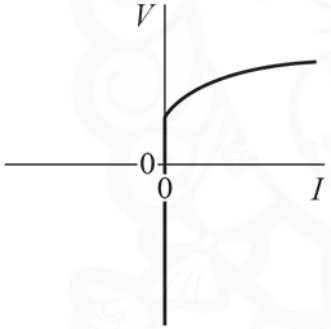
Question	Answers	Additional comments/Guidelines	Mark	AO
11.3	uses Snell's law: $1.49\sin\theta_1 = 1.39\sin\theta_2$ ✓ to give a value for θ_2 to at least 2 sf and that rounds to $49°$	Calculator value is $49.2862°$.	2	2 × AO1

	✓			

Question	Answers	Additional comments/Guidelines	Mark	AO
11.4	refracted ray shown as straight line drawn at 50° (to normal at P)	Line should deviate to right and pass to left of the 'o' in 'optical fibre' label in Figure 17.	1	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
11.5	intensity increases because (refracted) light re-enters the fibre when fuel is present (in the groove) ✓ idea that overall light intensity increases as more grooves are filled ✓	Reject 'less total internal reflection occurs'. For MP2, accept a diagram of stepped increases in intensity.	2	2 × AO2
Total			**8**	

Question	Key	Answer	AO
12	D	3.43 V	AO3
13	D	12 V | 4 V	AO3
14	C	$\frac{2E}{R}$	AO3
15	B	increasing value | no change	AO3
16	C	2.5×10^{-18} J	AO3
17	B		AO2
18	B	$\frac{d}{\sqrt{2}}$	AO2
19	D	20 cm s^{-1}	AO3

20	**A**	downwards | downwards	AO3
21	**C**	41.6°	AO1
22	**D**	90 cm	AO2
23	**A**	decreases | decreases	AO1
24	**C**	1.6 rad	AO1
25	**D**		AO1

Total = 14 marks