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PHYSICS

PH02

Unit 2 Electricity, waves and particles

Mark scheme

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226XPH02/MS

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	Marking guidance	Mark	Comments
01.1	The temperature (at and/or) below which the material has zero resistivity/resistance ✓	1	Condone 'no' for 'zero' Answer must reference resistance or resistivity

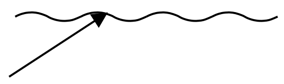
Question	Marking guidance	Mark	Comments
01.2	(current in the coil) has no heating effect ✓	2	Condone no energy lost to heat/no resistive heating. Accept reference to "I^2R **and** $R = 0$" Treat $I = 0$ as a talkout. Condone 'less energy lost to heat' etc
	Reduces (energy) costs ✓		MP2 should be linked to the application: 'no energy losses' is insufficient. Condone prevents melting of coils
Total		**3**	

Question	Marking guidance	Mark	Comments
02	V is (terminal) potential difference AND ε is emf (of the battery) ✓ Any statement that voltage is the work done/energy transferred per unit charge wtte ✓ ε is the work done/energy per unit charge moving charge through the complete circuit(including the internal resistance)/provided by source OR V is work done/energy per unit charge moving charge through R / the external circuit✓	3	Condone 'electromotive force' for emf and p.d. for potential difference/drop BOD for poor QWC but **not** if it is ambiguous (e.g. electric motor force) "energy per unit charge' is insufficient for MP2 Condone use of 'through' for 'across'. Accept 'available to R' Treat incorrect but not-contradictory comments about ε or V as neutral.

Total		**3**

Question	Marking guidance	Mark	Comments
03.1	Uses $n = \frac{\text{speed of light in air}}{\text{speed of light in water}}$ OR sin $c = \frac{1}{\text{their } n}$ ✓ 48.6° to at least 3 sf ✓	2	Allow $\frac{3\,(\times 10^8)}{2.25\,(\times 10^8)}$ seen for MP1 Do not condone confusion between n and c. Expect to see sin $c = 0.75$ Use of rounded n=1.33 (to give 48.8) gets MP1 only. (Calculator answer is 48.5903779)

Question	Marking guidance	Mark	Comments
03.2	Calculation of angle of incidence of light from L at P = 54(.5)° ✓ Compares their angle of incidence with the critical angle and makes consistent comment about whether the light will emerge OR undergo total internal reflection. ✓	2	Expect to see $i = \tan^{-1}\left(\frac{3.5}{2.5}\right)$ (calculator answer is 54.46232221) Expect: 54.5°> c and therefore the light does not emerge. Accept their answer to **3.1** for c. Interpret 'no' as it does not emerge. Alternative for MP2: Determines whether sin (r) would be greater 1 for their i, and makes consistent comment about whether the light will emerge OR undergo total internal reflection.

Question	Marking guidance	Mark	Comments
03.3	Yes, light can escape. wtte ✓ At least one sketch showing ray hitting appropriate part of wave such that a labelled angle of incidence seems to be less than the critical angle ✓ Statement or diagram showing angle of incidence < critical angle or similar justification ✓	3	Accept idea that light will emerge intermittently Allow idea that light 'may' be able to escape. Evidence for MP1 may be seen in the diagram. For MP2, • part of wave must be drawn E.g.  • condone rays not parallel to line LP • Either the angle of incidence or normal must be shown.

Total		7

Question	Marking guidance	Mark	Comments
04.1	(Electromagnetic) radiation of one/single frequency or wavelength ✓	1	Accept: ‘light’ for ‘radiation’ Accept: light that all has the same OR light that has a certain frequency or wavelength Treat references to colour as neutral Reject answers that have extra conditions e.g. ‘constant phase’ or ‘high intensity’

Question	Marking guidance	Mark	Comments
04.2	Idea that (monochromatic) light all travels at the same speed or has the same refractive index ✓ ... which eliminates material dispersion. ✓	2	Allow reverse argument In MP2 do not allow dispersion or modal dispersion Condone ‘avoids’ or ‘reduces’ etc. for ‘elminates’ Allow consequence of reduced material dispersion e.g. less pulse broadening / greater signal rate

Question	Marking guidance	Mark	Comments
04.3	Use of (very) small diameter cylinder of glass OR Use of cladding OR Replace cylinder with glass of lower refractive index✓ Use of cladding/core of lower refractive index increases critical angle✓ Idea that light has a smaller range of possible paths/path lengths (so pulse broadening is reduced) ✓	3	Accept use of graded index fibre Allow description of cladding i.e material with lower refractive index than the core For MP2 allow naming or description of monomode fibre. Allow optical density for refractive index
Total		**6**	

Question	Marking guidance	Mark	Comments
05.1	0 or zero ✓	1	Do not credit ambiguous answers

Question	Marking guidance	Mark	Comments
05.2	Arrow drawn from any excited level (n > 1) down to n = 1 level ✓	1	Do not accept line from ionization level

Question	Marking guidance	Mark	Comments
05.3	Uses $hf = E_1 - E_2$ ✓ Multiplies by 1.6 (× 10^{-19}) ✓ Uses the (3.40 – 1.51 =) 1.89 eV transition ✓ Correct answer for any transition shown in additional comments ✓	4	for any transition look for 1.6 × 10^{-19} in the equation or for 3.024 × 10^{-19} (J) for completely correct answers expect to see 4.56 × 10^{14} (Hz) but accept 7.29 × 10^{14} (Hz) or 6.90 × 10^{14} (Hz) or 6.15 × 10^{14} (Hz) for MP4 Only 4.56 × 10^{14} (Hz) answer gets 4 marks Penalise POT and rounding errors in MP4 (calculator answer is 4.56109) Allow answer with 2 sf. Condone answer of 4 or more sf.

Total		**6**

Question	Marking guidance	Mark	Comments
06.1	$p = mv$ seen ✓ $E = \frac{1}{2}mv^2$ or $eV = \frac{1}{2}mv^2$ seen ✓ Correct and clear manipulation ✓	3	Expect to see $2eVm = m^2v^2$ or $p^2 = m^2v^2$ Using: $E = \frac{p^2}{2m}$ and $E = eV$ gets 1 mark for MP1 and MP2

Question	Marking guidance	Mark	Comments
06.2	Use of $\lambda = \frac{h}{p}$ ✓ $3.3(2) \times 10^{-24}$ kg m s^{-1} ✓	2	Either rearrangement or substitution Accept 1 sf as it is an estimate

Question	Marking guidance	Mark	Comments
06.3	(for diffraction) the spacing should be of the same order of magnitude as the (de Broglie) wavelength	1	Allow idea that wavelength and spacing should be similar

Question	Marking guidance	Mark	Comments
06.4	38 (V)	1	ecf from **06.2**
Total		**7**	

Question	Marking guidance	Mark	Comments
07.1	Resistance decreasing with increasing temperature but not down to zero	1	Must start from resistance axis

Question	Marking guidance	Mark	Comments
07.2	Means of measuring temperature eg temperature probe or thermometer ✓ Means of measuring resistance: voltmeter and ammeter OR multimeter (set to resistance range) ✓ States that resistance is measured for at least 6 temperatures (covering the range) ✓ Means of varying temperature eg waterbath or beaker/water/Bunsen ✓ Further detail eg use of ice for low temperatures; how to calculate resistance if voltmeter and ammeter used; repeats (at a particular temperature) and averages ✓	5	Condone alternative names for thermometer Condone alternative resistor symbols for thermistor Could be in the description or diagram Credit use of $R=V/I$ without symbols defined.

Total		Mark
Total		**6**

Question	Marking guidance	Mark	Comments
08.1	Same frequency ✓ Constant phase relationship/difference ✓	2	 Do not accept 'in phase'

Question	Marking guidance	Mark	Comments
08.2	MAX 3 Waves (from the loudspeakers) in anti-phase/180° out of phase/π (rad) out of phase at B ✓ Path difference at B = $\lambda/2$ or $3\lambda/2$...etc✓ Reference to superposition ✓ Destructive interference occurs ✓	3	Treat any discussion of process at A as neutral Do not accept path difference in MP1 or phase difference in MP2 Condone superimpose for superpose

Question	Marking guidance	Mark	Comments
08.3	Attempts to calculate path difference using Pythagoras Uses their path difference = $\lambda/2$ To calculate their λ ✓ Use of $v = f \times$ their λ ✓ 446 or 450 (Hz) 2 or more sf ✓ (calculator answer is 446.3596956)	3	expect to see 0.38 m For example: in MP1 condone determination of the distance from a speaker to A as one of their path lengths. allow use of path difference = λ in MP1 expect to see 0.76 m Alternative: condone use of double slit equation: Use of $w = \frac{\lambda D}{s}$ ✓ by rearrangement or substitution; allow w=0.62 m in MP1. Use of $v = f \times$ their λ ✓ 424 OR 420 (Hz) 2 or 3 sf only ✓

Question	Marking guidance	Mark	Comments
08.4	(Increasing frequency decreases wavelength and therefore) At A there will be no change / at A there will (still) be a maximum as path difference (still) zero/waves (still) in phase.✓ At B the intensity will increase as the waves no longer in antiphase/ no longer cancel out/ path difference no longer half a wavelength.✓	2	For MP1 allow intensity at A does not change as it is the central maximum. For MP2 condone argument based on change in w

Question	Marking guidance	Mark	Comments
08.5	Idea that the sound is reflected from the walls ✓ (and) that this will either increase the intensity at B (by constructive interference) OR reduce the intensity at A (by destructive interference) ✓	2	Accept: will affect the intensity due to constructive/destructive interference without reference to A or B

Total		**12**

Question	Marking guidance	Mark	Comments
09.1	(The potential differences are) equal ✓	1	OWTTE

Question	Marking guidance	Mark	Comments
09.2	Uses half the range: 0.01✓ Calculates the mean: 1.18 ✓ % uncertainty = $\frac{100\times \text{their range}}{\text{their mean}}\%$ ✓	3	Accept 1.178 for MP2 Expect to see 0.9% Condone 2 sf answer (0.85%) Allow **MAX 2** if using data for x and y: Calculates mean of x and y values (539 and 457) ✓ Uses half the range (2) to determine % uncertainty of x and y And adds them (0.37 + 0.44 = 0.8(1)%) ✓ Only accept 1 or 2 sf final answer.

Question	Marking guidance	Mark	Comments
09.3	Point plotted at (1.18, 4.7) with an error bar that is 4 to 4½ small squares ✓	1	Allow +/- half a grid square for point

Question	Marking guidance	Mark	Comments
09.4	Well drawn line of best fit ✓	1	The line should pass through all the error bars with an even scatter of points either side. Candidates may have this mark even if they do not plot the final point. Expect an S intercept of 2.02 to 2.12 Do not accept multiple, thick or unruled lines.

Question	Marking guidance	Mark	Comments
09.5	Large triangle drawn on line or with values shown clearly in an acceptable way on the graph ✓ Correct data extraction from the graph ✓ Calculates a gradient to determine R that rounds to 3.7 to 3.9 Ω ✓	3	Triangle should be formed on more than half their line. 2 or 3 sf only

Total		**9**

Question	Marking guidance	Mark	Comments
10.1	Uses $R = \frac{\rho l}{A}$ ✓ Uses $A = wt$ leading to 4.45×10^{-5} (m) to at least 2 sf ✓	2	By substitution or manipulation to make *A* subject. No POT penalty. Expect to see $A = 3.34 \times 10^{-7}$ m^2

Question	Marking guidance	Mark	Comments
10.2	Voltmeter reading decreases (as the level in the fuel tank falls)✓ as resistance in parallel with voltmeter decreases OR resistance not in parallel increases✓	2	Condone 'resistance voltmeter measures' for resistance in parallel

Question	Marking guidance	Mark	Comments
10.3	Use of $P = \frac{V^2}{R}$ ✓ 0.25(3) (W) ✓	2	Allow MP1 for use of $V = IR$, and using *P* = *IV* Calculator value is 0.252631579

Question	Marking guidance	Mark	Comments
10.4	No change in operation (as the pd is divided in the same way) ✓	1	Allow idea that current is less OR power/energy consumption is less OR resistor does not get (so) hot.

Total		**7**

Question	Key	Answer
11	**B**	$\text{kg m}^2\ \text{s}^{-3}\ \text{A}^{-2}$
12	**A**	$\frac{V_s}{I_s}$ infinite
13	**D**	**Q** and **S**.
14	**A**	infinite zero
15	**C**	$0.82f$
16	**B**	500 photons $\text{m}^{-2}\ \text{s}^{-1}$
17	**D**	are reflected well at tissue boundaries.
18	**B**	$0.29T$
19	**A**	$t = 0.10$ s
20	**D**	polarisation at the slits
21	**C**	14.5°
22	**C**	the frequency of the characteristic peaks
23	**C**	electromagnetic waves can have particle-like properties.

24	**A**