Mark Scheme (Results)

January 2024

Pearson Edexcel International Advanced Subsidiary Level In Physics (WPH12)
Paper 01: Waves and Electricity

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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.

For example:

(iii) Horizontal force of hinge on tabletop

66.3 (N) or 66 (N) **and** correct indication of direction [no ue] ✓ **1**
[Some examples of direction: acting from right (to left) / to the left / West / opposite direction to horizontal. May show direction by arrow. Do not accept a minus sign in front of number as direction.]

This has a clear statement of the principle for awarding the mark, supported by some examples illustrating acceptable boundaries.

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.

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 Incorrect use of case e.g. 'Watt' or 'w' will **not** be penalised.

2.3 There will be no unit penalty applied in 'show that' questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.4 The same missing or incorrect unit will not be penalised more than once within one question (one clip in epen).

2.5 Occasionally, it may be decided not to penalise a missing or incorrect 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.

2.6 The mark scheme will indicate if no unit error penalty is to be applied by means of [no ue].

3. Significant figures

3.1 Use of an inappropriate number of significant figures in the theory papers will normally only be penalised in ‘show that’ questions where use of too few significant figures has resulted in the candidate not demonstrating the validity of the given answer.

3.2 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 be penalised by one mark (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}

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.

4.6 Example of mark scheme for a calculation:

<u>‘Show that’ calculation of weight.</u>

Use of L × W × H ✓

Substitution into density equation with a volume and density ✓

Correct answer [49.4 (N)] to at least 3 sig fig. [No ue] ✓
[If 5040 g rounded to 5000 g or 5 kg, do not give 3rd mark; if conversion to kg is omitted and then answer fudged, do not give 3rd mark]
[Bald answer scores 0, reverse calculation 2/3] **3**

Example of answer:

80 cm × 50 cm × 1.8 cm = 7200 cm^3
7200 cm^3 × 0.70 g cm^{-3} = 5040 g
5040 × 10^{-3} kg × 9.81 N/kg
= 49.4 N

5. Quality of Written Communication

5.1 Indicated by QoWC in mark scheme. QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.

5.2 Usually, it is part of a max mark, the final mark not being awarded unless the QoWC condition has been satisfied.

6. Graphs

6.1 A mark given for axes requires both axes to be labelled with quantities and units and drawn the correct way round.

6.2 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.

6.3 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.

6.4 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.

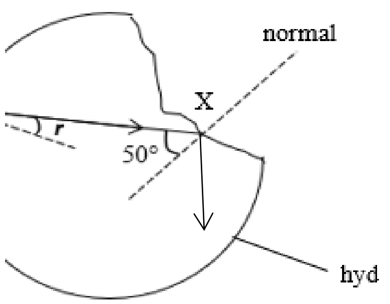
For a line mark there must be a thin continuous line which is the best-fit line for the candidate's results.

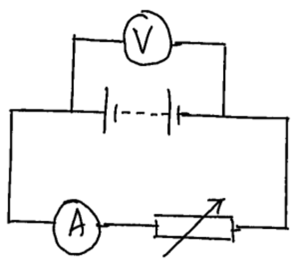
Question Number	Answer
1	**A is the correct answer** B is not correct because the light would refract towards the normal C is not correct because the light moves into a material with a greater refractive index D is not correct because the light would not be transmitted along the normal
2	**C is the correct answer** A is not correct because the number of conduction electrons should increase B is not correct because the number of conduction electrons should increase and the resistance should decrease D is not correct because the resistance should decrease
3	**A is the correct answer** B is not correct because this would give the momentum of the electron C is not correct because this gives $\frac{1}{\text{velocity}}$ D is not correct because this would give $\frac{1}{\text{momentum}}$ for the electron
4	**C is the correct answer** A is not correct because this describes an energy of 1 J B is not correct because this describes a current of 1 A D is not correct because this describes a charge of 1 C
5	**D is the correct answer** A is not correct because 0.15 (A) is the current in the 10 Ω resistor. B is not correct because 0.50 V is the potential difference across the 5 Ω resistor when the switch is open. C is not correct because 1.00 V is the potential difference across the 10 Ω resistor when the switch is open.
6	**C is the correct answer** A is not correct because the line should start at the origin. B is not correct because the line should start at the origin and should not cross the x-axis D is not correct because the gradient should be positive
7	**D is the correct answer** A is not correct because this gives the time period of the wave. B is not correct because this gives half the time period of the wave. C is not correct because the denominator is half the time period.

8	**B is the correct answer** A is not correct because doubling *d* causes the area over which the light is spread out to quadruple C is not correct because doubling *d* causes the area to quadruple and *I* already takes into account the area of the sphere over which the light is spread out D is not correct because *I* already takes into account the area of the sphere over which the light is spread out	1
9	**C is the correct answer** A is not correct because 180° - 90° is 90° B is not correct because 270° - 180° is 90° D is not correct because 270° - 360° is -90°	1
10	**B is the correct answer** A is not correct because E_1 should be added to the energy of the photon. C is not correct because the speed of light should be part of the numerator and wavelength should be the denominator and E_1 should be added to the energy of the photon. D is not correct because the speed of light should be part of the numerator and wavelength should be the denominator.	1

Question Number	Answer		Mark
11(a)	There is a constant phase relationship/difference	**(1)**	1
11(b)	(Reflected light) interferes / superposes (with the light from the laser)	**(1)**	1
	Total for question 11		**2**

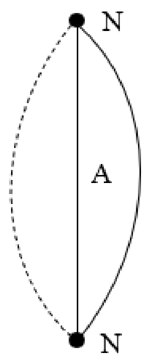
Question Number	Answer		Mark
12	Use of $R = \frac{V}{I}$ Use of $I = \frac{\Delta Q}{\Delta t}$ Time taken = 4.2 s **Or** Use of $P = \frac{V^2}{R}$ Use of $P = \frac{W}{t}$ **and** $V = \frac{W}{Q}$ Time taken = 4.2 s <u>Example calculation</u> $I = \frac{8.9\text{ V}}{7.5\ \Omega} = 1.19\text{ A}$ $\Delta t = \frac{5.0\text{ C}}{1.19\text{ A}} = 4.20\text{ s}$	(1) (1) (1) (1) (1) (1)	3
	Total for question 12		**3**

Question Number	Answer		Mark
13(a)	There is little /no refraction **Or** There will be little/no change in direction (of light) **Or** Incident angle ≈ refracted angle **Or** Light (from observers side) is (transmitted and) not reflected Because there is only a small change in the speed/no change in speed of light (at the boundary between water and the hydro-beads)	**(1)** **(1)**	**2**
13(b)(i)	Use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $r = 29°$ <u>Example of calculation</u> $1 \times \sin(42°) = 1.38 \sin(r)$ $r = \sin^{-1}\left(\frac{\sin(42°)}{1.38}\right) = 29°$	**(1)** **(1)**	**2**
13(b)(ii)	**EITHER** Use of $\sin C = \frac{1}{n}$ $C = 46(°)$ Total internal reflection shown on diagram (dependent on MP2) **OR** Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\sin\theta = 1.06$ (which is > 1) Total internal reflection shown on diagram (dependent on MP2) <u>Example of calculation</u> $\sin(C) = \frac{1}{1.38}$ $C = \sin^{-1}\left(\frac{1}{1.38}\right) = 46.4°$  	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**

	Total for question 13	**7**
Question Number	**Answer**	**Mark**
14(a)	There was no current (in the battery) **(1)** So there was no potential difference across the internal resistance **(1)**	**2**
14(b)	Voltmeter connected across battery **and** ammeter in series with battery **(1)** Variable resistor in series with battery **Or** potential divider **(1)** <u>Example of circuit</u>  	**2**
14(c)(i)	e.m.f. = 8.8 V **(1)** Calculates gradient of graph **(1)** Internal resistance = 2.2 to 2.4 Ω **(1)** <u>Example of calculation</u> $r = \frac{(8.8-0)\ \mathrm{V}}{(3.8-0)\ \mathrm{A}} = 2.3\ \Omega$	**3**
14(c)(ii)	As the current (in the battery) increases, the potential difference across the internal resistance increases **(1)** Until the p.d. across the internal resistance equals the e.m.f. (and current can no longer increase) **(1)**	**2**
	Total for question 14	**9**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>15(a)</td><td>Oscillations / vibrations are perpendicular to the <u>direction</u> of energy transfer
Or Oscillations / vibrations are perpendicular to the <u>direction</u> of wave travel
(allow propagation for wave travel)</td><td>(1)</td><td>1</td></tr>
<tr><td>15(b)</td><td>Shape of wave correct

Node labelled at each end and antinode labelled in the middle
(MP2 dependent on MP1)

<u>Example of diagram</u>
</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td>15(c)</td><td>Use of $v = f\lambda$

Use of $v = \sqrt{\frac{T}{\mu}}$

Use of $\mu = \frac{m}{l}$ [with l = 1.5 m]

Mass of string = 3.1 (g), so string B

[Allow reverse working for full marks]

<u>Example of calculation</u>
$v = 196\ \text{Hz} \times 0.72\ \text{m} = 141\ \text{m s}^{-1}$

$\mu = \frac{41\ \text{N}}{(141\ \text{m s}^{-1})^2} = 2.06 \times 10^{-3}\ \text{kg m}^{-1}$

$m = 1.5\ \text{m} \times 2.06 \times 10^{-3}\ \text{kg m}^{-1} = 3.09 \times 10^{-3}\ \text{kg}$</td><td>(1)

(1)

(1)

(1)</td><td>4</td></tr>
<tr><td></td><td>Total for question 15</td><td></td><td>7</td></tr>
</table>

Question Number	Answer		Mark
16(a)	Use of $A = \pi r^2$	**(1)**	
	Use of $R = \frac{\rho l}{A}$	**(1)**	
	l = 63 m	**(1)**	**3**
	<u>Example calculation</u> $A = \pi \times \left(\frac{12 \times 10^{-3}\text{ m}}{2}\right)^2 = 1.13 \times 10^{-4}\text{ m}^2$ $l = \frac{0.078\ \Omega \times 1.13 \times 10^{-4}\text{ m}^2}{1.4 \times 10^{-7}\ \Omega\text{ m}} = 63.0\text{ m}$		
16(b)	Use of $W = VIt$	**(1)**	
	$W = 1.3 \times 10^8$ J	**(1)**	
	Or **c** Use of $I = \frac{\Delta Q}{\Delta t}$ **and** $V = \frac{W}{Q}$	**(1)**	
	$W = 1.3 \times 10^8$ J	**(1)**	
	Or Use of $P = VI$ **and** $P = \frac{W}{t}$	**(1)**	
	$W = 1.3 \times 10^8$ J	**(1)**	**2**
	<u>Example calculation</u> $W = 1.5 \times 10^8\text{ V} \times 1.2 \times 10^4\text{A} \times 70 \times 10^{-6}\text{s} = 1.26 \times 10^8\text{ J}$		
16(c)	The copper cable has a lower resistance (because length and diameter are the same but copper has a lower resistivity)	**(1)**	
	(With the same p.d.) there is a greater current in the copper cable	**(1)**	
	Since $I = nqvA$, it is not possible to say whether the student is correct **Or** Since $I = nqvA$, the student might be correct	**(1)**	**3**
	Total for question 16		**8**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>17(a)</td><td>Each point on a <u>wavefront</u> is (treated as) a source of (secondary) <u>wavelets</u> (1)

these further wave (let)s interfere / superpose (and the resulting waves predict the shape) (1)</td><td>2</td></tr>
<tr><td>*17(b)</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 for indicative content.
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</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>

Indicative content
IC1 Waves (from each gap) interfere / superpose

IC2 At position A there is no path / phase difference

IC3 So, there is constructive interference (leading to large amplitude oscillations)

IC4 At position B, the phase difference varies with wavelength

IC5 If there is an odd number of half wavelengths path difference, there is destructive interference leading to small oscillations
Or If the waves are in antiphase there is destructive interference leading to small oscillations

IC6 And if there is a whole number of wavelengths path difference there is constructive interference leading to large oscillations
Or If the waves are in phase there is constructive interference leading to large oscillations</td><td>6</td></tr>
<tr><td></td><td>Total for question 17</td><td>8</td></tr>
</table>

Question Number	Answer		Mark
18(a)(i)	Use of $P = VI$ and $V = IR$ **Or** Use of $P = I^2 R$ and $V = IR$ Appropriate algebra to derive $P = \frac{V^2}{R}$	 **(1)** **(1)**	 **2**
18(a)(ii)	**EITHER** Their resistance from graph divided by 4 Use of $P = \frac{V^2}{R}$ Use of p.d. across battery = 5 × p.d. across R p.d. across battery = 9.0 – 9.2 V **OR** Their resistance from graph divided by 4 Use of $P = I^2 R$ Use of $V = I(R + R_t)$ p.d. across battery = 9.0 – 9.2 V <u>Example calculation</u> Resistance of $R = \frac{35\ \Omega}{4} = 8.75\ \Omega$ $0.38\ \text{W} = \frac{V_\text{R}^2}{8.75\ \Omega}$ $V_\text{R} = \sqrt{0.38\ \text{W} \times 8.75\ \Omega} = 1.82\ \text{V}$ $V_B = 5 \times 1.82\ \text{V} = 9.1\ \text{V}$	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **4**
18(b)(i)	Number of conduction electrons (per unit volume) increases So current increases (for the same potential difference and $R = V/I$)	**(1)** **(1)**	 **2**
18(b)(ii)	(Increased temperature caused) increased lattice/atom/ion vibrations (in the thermistor and the wire resistor) This caused an increase in collisions between electrons and the lattice/ions/atoms (in the thermistor and the wire resistor) So the resistance of the wire resistor increased (Because current decreases) total resistance of the circuit must increase So the increase in the resistance of the wire resistor must be greater than the decrease in the resistance of the thermistor	**(1)** **(1)** **(1)** **(1)** **(1)**	 **5**
	Total for question 17		**13**

Question Number	Answer		Mark
19(a)	Substitution into $hf = \phi$	**(1)**	
	Use of 1eV = 1.6×10^{-19} J	**(1)**	
	Threshold frequency = 4.5×10^{14} Hz	**(1)**	**3**
	<u>Example calculation</u> $E = 1.86 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 2.98 \times 10^{-19} \text{ J}$ $f = \dfrac{2.98 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ J s}} = 4.49 \times 10^{14} \text{ Hz}$		
19(b)	The number of photons (arriving) each second on the cell is the same	**(1)**	
	(Initially) layer 1 absorbs photons with the greater frequency (of those emitted by the Sun)	**(1)**	
	Photons reaching layer 2 have an energy greater than the work function (of layer 2) **Or** Photons reaching layer 2 have a frequency greater than the threshold frequency (of layer 2)	**(1)**	
	One photon interacts with one electron	**(1)**	
	so, the rate at which electrons are released remains the same	**(1)**	**5**
19(c)	Use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$	**(1)**	
	$R_T = 0.40$ (Ω)	**(1)**	
	Use of potential divider equation (to determine p.d. across resistor) **Or** Use of $\varepsilon = I(R+r)$ (to determine current in resistor)	**(1)**	
	Use of power equation to find power (dissipated in resistor)	**(1)**	
	$P = 5.2$ (W) which is less than half of 13 (W) so the suggestion is correct	**(1)**	**5**
	<u>Example calculation</u> $R_{\text{internal}} = \dfrac{1}{\dfrac{1}{0.80\ \Omega} + \dfrac{1}{0.8\ \Omega}} = 0.40\ \Omega$ $V = \dfrac{5.0 \text{ V} \times 4.0\ \Omega}{4.0\ \Omega + 0.4\ \Omega} = 4.55 \text{ V}$ $I = \dfrac{5.0 \text{ V}}{4.0\ \Omega + 0.40\ \Omega} = 1.14 \text{ A}$ $P = 4.55 \text{ V} \times 1.14 \text{ A} = 5.19 \text{ W}$		
	Total for question 19		**13**

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