Mark Scheme (Results)

October 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.**

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. '<u>resonance</u>'

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 epen.

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 placing brackets around the unit.

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 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}

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 **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.

4.2 If a ‘show that’ question is worth 2 marks, then both marks will be available for a reverse working. If the question is worth 3 marks then only 2 marks will be available.

4.3 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Expression

5.1 Questions that asses the ability to show a coherent and logically structured answer are marked with an asterisk.

5.2 Marks are awarded for indicative content and for how the answer is structured.

5.3 Linkage between ideas, and fully-sustained reasoning is expected.

Question Number	Answer	Mark
1	**B is the correct answer** A is not correct because intensity is power per unit area C is not correct because intensity should be power per unit area on a surface D is not correct because intensity should be power per unit area on a surface	1
2	**D is the correct answer** A is not correct because the electrons need to move to lower energy levels and emit photons. B is not correct because the electrons need to move to lower energy levels. C is not correct because the electrons need to emit photons.	1
3	**A is the correct answer** B is not correct because the distance should be doubled. C is not correct because the time should be halved. D is not correct because the time should be halved and the expression is inverted.	1
4	**B is the correct answer** A is not correct because the 0.7s is not the time period of the wave C is not correct because the 0.4s is not the time period of the wave D is not correct because 0.4 s – 0.1 s is only half the time period of the wave	1
5	**D is the correct answer** A is not correct because both the resistance and lattice vibrations should increase. B is not correct because the resistance should increase. C is not correct because the lattice vibrations should increase.	1
6	**D is the correct answer** A is not correct because the current should increase and the potential difference should increase. B is not correct because the current should increase. C is not correct because the potential difference should increase.	1
7	**B is the correct answer** A is not correct because the de Broglie wavelength would be 4λ. C is not correct because the de Broglie wavelength would be 0.5λ. D is not correct because the de Broglie wavelength would be 0.125λ.	1
8	**C is the correct answer** A is not correct because the resistance of the 7 Ω and 18 Ω resistors in parallel is not correct. B is not correct because the resistance of the 7 Ω and 18 Ω resistors in parallel is not correct and there is a short circuit around the 4 Ω resistor. D is not correct because there is a short circuit around the 4 Ω resistor.	1

9	**C is the correct answer** A is not correct because this would describe the motion if it was a stationary wave. B is not correct because in a complete time period F and G would then reverse direction again. D is not correct because the wave is travelling to the right, not to the left.	**1**
10	**C is the correct answer** A is not correct because this gives the current. B is not correct because this gives the potential difference across the 20 Ω resistor. D is not correct because this gives 1/power.	**1**

Question Number	Answer		Mark
11	Electrons can behave as waves	**(1)**	
	Because the rings show diffraction / interference	**(1)**	**2**
	Total for question 11		**2**

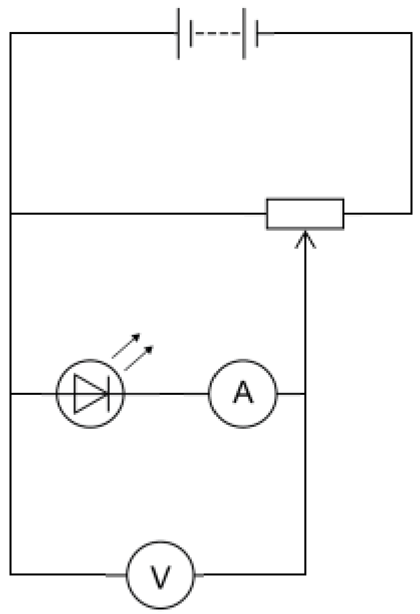
Question Number	Answer	Mark
12	The current in each wire is the same **(1)** The (cross-sectional) area of each wire is the same **(1)** Because $I = nqvA$ the (average) velocity of electrons (in the copper wires) is less (than that in the nichrome wire) **(1)**	**3**
	Total for question 12	**3**

Question Number	Answer		Mark
13(a)	Oscillations / vibrations are perpendicular to the direction of energy transfer of the wave **Or** Oscillations / vibrations are perpendicular to the direction of wave travel / propagation	**(1)**	**1**
13(b)	The paths are different lengths / distances **Or** There is a path difference	**(1)**	
	If the path difference is a whole number of wavelengths **Or** path difference = $n\lambda$ where n is an integer	**(1)**	
	Waves are in phase (so constructive interference occurs) **Or** there is a phase difference of 0 (so constructive interference occurs) **Or** there is a phase difference of $2\pi n$ where n is an integer	**(1)**	**3**
	Total for question 13		**4**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>14(a)</td><td>LED, power supply and ammeter, in series
(allow diode for LED)

Method to vary the potential difference across the LED

LED connected in forward bias and voltmeter connected in parallel with LED

<u>Example circuit</u>

</td><td>(1)

(1)

(1)</td><td>3</td></tr>
<tr><td>14(b)</td><td>Current = 37 (mA) read from graph
(allow range 36 to 38 mA)

Use of $P = VI$

Power of LED = 0.0814 W
(allow range 0.079 to 0.084 W)

<u>Example calculation</u>
$P = 2.2 \text{ V} \times 37 \times 10^{-3} \text{ A} = 0.0814 \text{ W}$</td><td>(1)

(1)

(1)</td><td>3</td></tr>
<tr><td>14(c)</td><td>Between 0 V and 1.6 V the resistance of the LED was (almost) infinite

(As p.d. increased) above 1.6 V, the resistance of the LED decreased

Max 1 mark for statement that resistance is initially (almost) infinite and then decreases</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td></td><td>Total for question 14</td><td></td><td>8</td></tr>
</table>

Question Number	Answer		Mark
15(a)	Use of cross-sectional area = width × thickness	**(1)**	
	Use of factor of 6 to determine total length of metal strips **Or** Use a factor of 6 to determine the resistance of one strip	**(1)**	
	Use of $R = \frac{\rho l}{A}$	**(1)**	
	$\rho = 4.8 \times 10^{-7} \Omega$ m	**(1)**	**4**
	<u>Example calculation</u> $A = 1.40 \times 10^{-3}$ m $\times 0.23 \times 10^{-3}$ m $= 3.22 \times 10^{-7}$ m^2 $l_{\text{total}} = 6 \times 18 \times 10^{-3}$ m $= 0.108$ m $\rho = \frac{0.16\ \Omega \times 3.22 \times 10^{-7}\ \text{m}^2}{0.108\ \text{m}} = 4.77 \times 10^{-7} \Omega$ m		
15(b)	The cross-sectional area of each metal strip is $\frac{\text{volume}}{l}$	**(1)**	
	So the resistance of each strip is $\frac{\rho l^2}{\text{volume}}$	**(1)**	
	So resistance is proportional to l^2 (which gives a straight line through the origin)	**(1)**	**3**
	Total for question 15		**7**

Question Number	Answer	Mark
16(a)	Direct the laser away from people's eyes Stand behind the laser Avoid directing the laser at reflective surfaces **(1)**	**1**
16(b)	The distance from the central maximum to any other maximum **(1)** **or** the distance between two maxima of the same order The (perpendicular) distance between the diffraction grating and the screen **(1)**	**2**
16(c)(i)	$\theta = 9°$ **(1)** Calculates d **(1)** Use of $n\lambda = d\sin\theta$ **(1)** $\lambda = 630$ (nm) **(1)** <u>Example calculation</u> $\theta = \frac{18°}{2} = 9°$ $d = \frac{10^{-3}\text{ m}}{250} = 4 \times 10^{-6}\text{ m}$ $\lambda = 4 \times 10^{-6}\text{ m} \times \sin(9°) = 626\text{ nm}$	**4**
16(c)(ii)	Use of $n\lambda = d\sin\theta$ with $\theta = 90°$ **(1)** $n_{max} = 6$ **(1)** (ecf from (c)(i)) <u>Example calculation</u> $n_{max} = \frac{4 \times 10^{-6}}{630 \times 10^{-9}} = 6.3$	**2**
	Total for question 16	**9**

Question Number	Answer	Mark
17(a)	Use of $n = \frac{c}{v}$ **(1)** $v = 2.26 \times 10^8$ m s^{-1} **(1)** <u>Example calculation</u> $v = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{1.33} = 2.256 \times 10^8 \text{ m s}^{-1}$	**2**
*17(b)	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.	

IC points	IC mark	Max linkage mark	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

Indicative content

IC1 The speed of light is less in water (than air)
Or The refractive index of water is greater than the refractive index of air
Or Water is more (optically) dense than air

IC2 So ray A refracts towards the normal (and is incident on the person's eyes)

IC3 The angle (of incidence) of ray B at the water surface is greater than the critical angle

IC4 So ray B is totally internally reflected (and is incident on the person's eyes)

IC5 The angle (of incidence) of ray C at the water surface is less than the critical angle

IC6 So (most) light from ray C is transmitted / refracted (into the air so is not incident on the person's eyes)

6

	Total for question 17	8

Question Number	Answer	Mark
18(a)	Oscillations / waves <u>reflect</u> from (each) end of the cable **(1)** The (reflected) waves interfere / superpose **(1)** A node forms where there is destructive interference **Or** An antinode forms where there is constructive interference **(1)**	**3**
18(b)	Point X has a large / maximum amplitude **(1)** At point X the displacement varies (between maximum displacement and zero displacement) **(1)** At point Y the cable always has zero displacement **(1)** **Or** At point Y the cable is stationary	**3**

18(c)(i)	Calculates mass per unit length μ = 24.1 (kg m^{-1}) <u>Example calculation</u> $\mu = \frac{2.10 \times 10^3 \text{ kg}}{87.0 \text{ m}}$ μ = 24.14 kg m^{-1}	**(1)** **(1)**	**2**
18(c)(ii)	Use of $W = mg$ Use of $T = \frac{W}{\text{number of cables}}$ Use of $v = \sqrt{\frac{T}{\mu}}$ Use of $v = f\lambda$ with λ = 320 m **or** λ = 7 m **Or** Use of $v = f\lambda$ with f = 280 Hz Lowest possible frequency produced by standing wave on longest cable = 1.1 Hz **Or** Lowest possible frequency produced by standing wave on shortest cable = 48 Hz **Or** Length of cable needed to give lowest frequency of 280 Hz = 0.60 m Lowest frequency waves produced < 280 Hz so humming is not produced by standing waves on the suspending cables **Or** length of cable is not within range 3.5 to 160 m so humming is not produced by standing waves on the suspending cables <u>Example calculation</u> $W = 140 \times 10^6 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 1.37 \times 10^9 \text{ N}$ $T = \frac{1.37 \times 10^9 \text{N}}{500} = 2.74 \times 10^6 \text{ N}$ $v = \sqrt{\frac{2.74 \times 10^6 \text{ N}}{24 \text{ kg m}^{-1}}} = 338 \text{ m s}^{-1}$ $f = \frac{338 \text{ m s}^{-1}}{320} = 1.06$ Hz **or** $f = \frac{338 \text{ m s}^{-1}}{7} = 48.3$ Hz Lowest frequency waves produced < 280 Hz so humming is not produced by standing waves on the suspending cables	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
	Total for question 18		**14**

Question Number	Answer		Mark
19(a)	A photon (incident on a surface) is absorbed by an atom / electron **Or** A photon (incident on a surface) collides with an atom / electron An electron gains energy and is emitted (from the surface)	**(1)** **(1)**	 **2**
19(b)	(To cause the photoelectric effect) the energy (of a photon) must be greater than the work function (of the photocathode) **Or** (to cause the photoelectric effect) the frequency (of a photon) must be greater than the threshold frequency (of the photocathode) Photon energy is proportional to frequency, so photons below a certain frequency / energy cannot cause the photoelectric effect	**(1)** **(1)**	 **2**
19(c)	Use of 1 eV = 1.6×10^{-19} J Use of $E = hf$ Use of $v = f\lambda$ Comparison of 840 nm with 700 nm and conclusion all wavelengths of visible light can be detected **Or** Comparison of 2.85×10^{-19} J with 2.37×10^{-19} J and conclusion all wavelengths of visible light can be detected **Or** Comparison of 1.78 eV with 1.48 eV and conclusion all wavelengths of visible light can be detected **Or** Comparison of 3.57×10^{14} Hz with 4.29×10^{14} Hz Example calculation $E = 1.48 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 2.37 \times 10^{-19}$ J $f_{\text{threshold}} = \frac{2.37 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ Js}} = 3.57 \times 10^{14}$ Hz $\lambda_{\text{threshold}} = \frac{3 \times 10^{8} \text{ m s}^{-1}}{3.57 \times 10^{14} \text{ Hz}} = 840 \times 10^{-9}$ m 700 nm < 840 nm so all wavelengths of visible light can be detected	**(1)** **(1)** **(1)** **(1)**	 **4**

19(d)	Use of $E_k = \frac{1}{2} mv^2$ Use of $V = \frac{W}{Q}$ Final kinetic energy = 1.81×10^{-17} (J) <u>Example calculation</u> Initial $E_k = 0.5 \times 9.11 \times 10^{-31}$ kg $\times (1.35 \times 10^6$ m s$^{-1})^2 = 8.30 \times 10^{-19}$ J W = 108 V × 1.6 × 10^{-19} C = 1.73 × 10^{-17} J Final kinetic energy (= 1.73 × 10^{-17} J + 8.30 × 10^{-19} J) = 1.81 × 10^{-17} J	**(1)** **(1)** **(1)**	**3**
19(e)	**EITHER** Use of $V = IR$ to calculate current in circuit Calculates total p.d across resistors A to D Use of sum of e.m.f. = sum of p.d Internal resistance = 1.20 MΩ **OR** Calculates total p.d. across resistors A to D Uses ratio of resistance = ratio of p.d. Correct values substituted into ratio equation Internal resistance = 1.20 MΩ <u>Example calculation</u> $I = \frac{108 \text{ V}}{85 \times 10^3 \ \Omega} = 1.27 \times 10^{-3}$ A $V = 1960 - 4 \times 108 = 1530$ V $r = \frac{1530 \text{ V}}{1.27 \times 10^{-3} \text{A}} = 1.20 \times 10^6 \ \Omega$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 19		**15**

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