Pearson Edexcel

Mark Scheme (Results)

June 2022

Pearson Edexcel International Advanced 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 table top

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]

Example of answer: **3**

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.

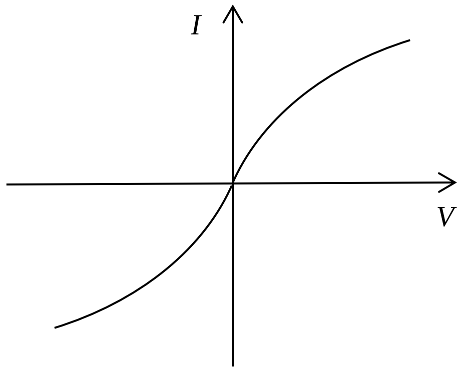
For a line mark there must be a thin continuous line which is the best-fit line for the candidate's results.

Question Number	Answer	Mark
1	**A is the correct answer as, for total internal reflection to take place, the angle of incidence should be greater than the critical angle, when travelling from a substance with a higher refractive index towards a substance with a lower refractive index.** B is not the correct answer as total internal reflection cannot take place if the light travels towards a boundary beyond which the refractive index increases. C is not the correct answer as total internal reflection cannot take place if the angle of incidence is less than the critical angle. D is not the correct answer as total internal reflection cannot take place if the angle of incidence is less than the critical angle.	**(1)**
2	**D is the correct answer as wavelength cannot be determined from a graph of displacement against time (only displacement against distance graphs)** A is not the correct answer as amplitude is the maximum displacement from the equilibrium position for a wave. B is not the correct answer as the frequency can be calculated from $1/T$ C is not the correct answer as T is the time between two peaks on a displacement against time graph.	**(1)**
3	**B is the correct answer as Power = Intensity × Area where area = $4\pi r^2$.** A is not the correct answer as the area in this equation is not πr^2. C is not the correct answer as Power is not Intensity/Area D is not the correct answer as Power is not Intensity/Area	**(1)**
4	**D is the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter.** A is not the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter. B is not the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter. C is not the correct answer as the intensity transmitted by a single polarising filter is independent of the angle of rotation of the filter.	**(1)**
5	**D is the correct answer as, for a first order maximum, $\lambda = d \sin\theta$, where d is $\frac{1}{\text{number of lines per m}}$ and $\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$ or $\frac{(0.378)}{(2.035)}$** A is not the correct answer as the distance between adjacent slits is not 300,000m. B is not the correct answer as the distance between adjacent slits is not 300,000m. C is not the correct answer as $\sin\theta$ is not $\frac{(0.378)}{(2.000)}$	**(1)**
6	**D is the correct answer as $Q = It$ where t is time in seconds.** A is not the correct answer as $Q = It$ where t is time in seconds. B is not the correct answer as $Q = It$ where t is time in seconds. C is not the correct answer as $Q = It$ where t is time in seconds.	**(1)**

7	**A is the correct answer as a photon cannot be partially absorbed by an atom.** B is not the correct answer as a photon of 10.2eV would use all of its energy to transfer an electron from the −13.6eV level to the −3.4eV level. C is not the correct answer as an electron of 13.6eV would use 10.2eV to transfer the electron and retain 3.4eV as its own kinetic energy. D is not the correct answer as an electron of 10.2eV could give all its energy to transfer an electron from the −13.6eV level to the −3.4eV level.	**(1)**
8	**B is the correct answer as the potential across the 0.25m section of PQ is 1.0V, and the potential across the 0.25m section of RS is also 1.0V, leaving 2.0V of p.d. to make the sum of the p.d.s equal to the sum of the e.m.f.s on that loop of the circuit passing through the voltmeter.** A is not the correct answer as a p.d. of 1.0V would require an e.m.f. of 3.0V C is not the correct answer as a p.d. of 3.0V would require an e.m.f. of 5.0V D is not the correct answer as a p.d. of 4.0V would require an e.m.f. of 6.0V	**(1)**
9	**C is the correct answer as semiconductors such as LDRs release more electrons when energy is absorbed.** A is not the correct answer as the number of conduction electrons increases. B is not the correct answer as the increase in lattice vibrations is not related to the reason why more conduction electrons are released. D is not the correct answer as the number of conduction electrons increases.	**(1)**
10	**B is the correct answer as diffraction is a wave property** A is not the correct answer as diffraction is not a particle property. C is not the correct answer as diffraction is not a particle property. D is not the correct answer as diffraction is a wave property.	**(1)**

Question Number	Answer		Mark
11a	Angle of incidence measured from diagram in range 54-56(°) Use of $n_1\sin\theta_1 = n_2\sin\theta_2$ with their measured angle of incidence θ_2 = 30-32(°) Normal line drawn correctly at point of incidence Ray refracted towards normal <u>Example of calculation</u> Angle of incidence measured as 55° $n_1\sin\theta_1 = n_2\sin\theta_2$ so $1.00 \times \sin 55° = 1.58 \times \sin\theta_2$ $\theta_2 = \sin^{-1}\left(\frac{1.00 \times \sin 55°}{1.58}\right) = 31.2°$	(1) (1) (1) (1) (1)	**5**
11b	Use of $n = c/v$ with $c = 3.00 \times 10^8\ \mathrm{m\,s^{-1}}$ Use of $\sin C = 1/n$ $C = 41°$ <u>Example of calculation</u> $n = \frac{c}{v} = \frac{3.00 \times 10^8 \mathrm{ms^{-1}}}{1.96 \times 10^8 \mathrm{ms^{-1}}} = 1.53$ $\sin^{-1}(C) = \frac{1}{1.53}$ so $C = 40.8°$	(1) (1) (1)	**3**
	Total for question 11		**8**

Question Number	Answer		Mark
12(a)	**Either** Resistance at 54°C = 0.95 - 1.0 (kΩ) Use of resistors in parallel formula Use of $V = IR$ Milliammeter reading = 9.0 (mA) (MP2 can only be awarded if the thermistor resistance is added to 3.0 kΩ prior to using the formula). **Or** Resistance at 54°C = 0.95 - 1.0 (kΩ) Use of $V = IR$ to calculate current in 2.0 kΩ resistor Use of resistors in series formula and $V = IR$ Milliammeter reading = 9.0 (mA) <u>Example of calculation</u> At 54°C, resistance of thermistor (read from graph) = 1.0 kΩ. $\frac{1}{R_T} = \frac{1}{2000\ \Omega} + \frac{1}{(3000+1000)\Omega}$, so $R_T = 1333\ \Omega$ $I = \frac{V}{R} = \frac{12\text{ V}}{1333\ \Omega} = 9.0\text{ mA}$	(1) (1) (1) (1) (1) (1) (1) (1)	**4**
12(b(i)	Resistance (of thermistor) increases (Thermistor takes a larger share of the pd) so voltmeter reading increases (MP2 dependent on MP1 being awarded)	(1) (1)	**2**
12(b)(ii)	**Either** Potential difference (across 2.0 kΩ resistor) is constant Power dissipated (by 2.0 kΩ resistor) remains the same because $P = V^2/R$ **Or** Current (in 2.0 kΩ resistor) is constant Power dissipated (by 2.0 kΩ resistor) remains the same because $P = I^2R$ **Or** Potential difference and current (for 2.0 kΩ resistor) are both constant Power dissipated (by 2.0 kΩ resistor) remains the same because $P = VI$	(1) (1) (1) (1) (1) (1)	**2**
	Total for question 12		**8**

Question Number	Answer		Mark
13a	Correct shape of graph for positive quadrant Correct symmetry in negative quadrant  	(1) (1)	**2**
13bi	Use of $A = \pi r^2$ Use of $I = nqvA$ $v = 1.3 \times 10^{-2}\ \mathrm{m\,s^{-1}}$ <u>Example of calculation</u> $A = \pi r^2 = \pi \times (0.023 \times 10^{-3}\ \mathrm{m})^2 = 1.66 \times 10^{-9}\ \mathrm{m^2}$ $v = \frac{I}{nAq} = \frac{0.44\ \mathrm{A}}{(1.26 \times 10^{29}\mathrm{m^{-3}})\ (1.66 \times 10^{-9}\ \mathrm{m^2})(1.60 \times 10^{-19}\mathrm{C})} = 0.0131\ \mathrm{m\,s^{-1}}$	(1) (1) (1)	**3**
13bii	Use of $R = V/I$ Use of $R = \rho l/A$ $\rho = 9.1 \times 10^{-7}$ (Ω m), so approximately 2700°C (MP2 e.c.f. for A value from part b(i)) <u>Example of calculation</u> $R = \frac{140\ \mathrm{V}}{0.44\ \mathrm{A}} = 318\ \Omega$ $\rho = \frac{RA}{l} = \frac{(318\ \Omega)(1.66 \times 10^{-9}\mathrm{m^2})}{0.580\ \mathrm{m}} = 9.1 \times 10^{-7}\ \Omega\,\mathrm{m}$, so this most closely matches the resistivity value at 2700°C.	(1) (1) (1)	**3**
	Total for question 13		**8**

Question Number	Answer	Mark
14ai	Use of $v_p = \sqrt{\frac{K+\frac{4}{3}G}{\rho}}$ (1) Use of $v_s = \sqrt{\frac{G}{\rho}}$ (1) $v_p = 6400\ \text{m s}^{-1}$ (1) $v_s = 3100\ \text{m s}^{-1}$ (Only one unit error applied across both answers) (1) <u>Example of calculation</u> $v_p = \sqrt{\frac{K+\frac{4}{3}G}{\rho}} = \sqrt{\frac{(7.55\times10^{10}\text{Pa})+\frac{4}{3}(2.61\times10^{10}\text{Pa})}{(2700\ \text{kg m}^{-3})}} = 6392\ \text{m s}^{-1}$ $v_s = \sqrt{\frac{G}{\rho}} = \sqrt{\frac{(2.61\times10^{10}\text{Pa})}{(2700\ \text{kg m}^{-3})}} = 3109\ \text{m s}^{-1}$	**4**
14aii	(When $G = 0$), $v_s = 0\ (\text{m s}^{-1})$ (1) S-waves cannot travel through liquids (1) (MP2 dependent on MP1 being awarded)	**2**
14bi	Same frequency (1) Constant phase difference/relationship (1)	**2**
14bii	There is a path difference (for waves travelling from the two sources to A) (1) This causes a phase difference of π radians / 180° (at A) **Or** waves are in antiphase (at A) (1) Destructive interference/superposition (at A) (1)	**3**
	Total for question 14	**11**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>*15a</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

Current is the rate of flow of charge
Current is the same at all points in a series circuit
Or current in C = current in cell.
total current going into a junction = total current out of junction
Or current in C/cell = current in A + current in B
Or current splits (equally) between A and B
p.d. is energy transferred per unit charge
p.d is shared between components in series
Or p.d. across C + p.d. across A = e.m.f. of cell
Or p.d. across C + p.d. across B = e.m.f. of cell
Or p.d. across C + p.d. across A/B combination = e.m.f. of cell
p.d. is the same across components in parallel
Or p.d. across A is the same as that across B

</td><td>6</td></tr>
</table>

15bi	Use of resistors in parallel formula Use of resistors in series formula Total resistance = 18.8 Ω (Allow MP1 for use of R^2 / 2R) <u>Example of calculation</u> For parallel section, $\frac{1}{R_P} = \frac{1}{12.5\Omega} + \frac{1}{12.5\Omega}$ so R_P = 6.25Ω R_{total} = 6.25Ω + 12.5Ω = 18.75Ω.	(1) (1) (1)	**3**
15bii	Equation for sum of p.d. = sum of e.m.f. seen e.g. $\varepsilon = IR + Ir$ Rearranged to make r the subject of the formula e.g. $r = \frac{\varepsilon}{I} - R$ Ammeter labelled anywhere on series part of circuit **Or** Terminal p.d. calculated using IR Subtract from ε and divide by ammeter reading Ammeter labelled anywhere on series part of circuit **Or** ε divided by ammeter reading Subtract answer for (b)(i) from this value Ammeter labelled anywhere on series part of circuit	(1) (1) (1) (1) (1) (1) (1) (1) (1)	**3**
	Total for question 15		**12**

Question Number	Answer		Mark
16a	Wave <u>reflected</u> at the pulley Superposition/interference (takes place)	(1) (1) (1)	**3**
16b	Use of $W = mg$ Use of $v = \sqrt{(T/\mu)}$ Use of $v = f\lambda$ to find λ $\lambda = 1.2$ (m) node to node distance = $\lambda/2$, so there is a node at R **Or** See $\lambda/2 = 0.6$m, so there is a node at R (MP4 requires evidence of calculation) <u>Example of calculation</u> Tension in string = $W = mg = (0.300 \text{ kg})(9.81 \text{ N kg}^{-1}) = 2.94\text{N}$ $v = \sqrt{(T/\mu)} = \sqrt{\frac{2.94 \text{ N}}{2.27 \times 10^{-3} \text{ kg m}^{-1}}} = 36.0 \text{ m s}^{-1}$ $\lambda = \frac{v}{f} = \frac{(36.0 \text{ m s}^{-1})}{(30 \text{ Hz})} = 1.20 \text{ m}$ node to node distance = $\lambda/2$, so node to node distance = 0.60 m.	(1) (1) (1) (1) (1)	**5**
16ci	S and T are in antiphase **Or** 180° out of phase **Or** π radians out of phase S and T are in adjacent node-to-node regions **Or** S and T are in adjacent loops	(1) (1)	**2**
16cii	S has a greater amplitude than T S is at an antinode **and** T is between a node and antinode **Or** S is at an antinode **and** T is not **Or** T is closer to a node than S (MP2 dependent on MP1)	(1) (1)	**2**
	Total for question 16		**12**

Question Number	Answer	Mark
17a	Minimum energy (required to release electrons from the surface of a metal) (1)	**1**
17b	Use of $\lambda = h/p$ with $\lambda = 1.50 \times 10^{-9}$ m (1) Use of $p = mv$ with $m = 9.11 \times 10^{-31}$ kg (1) Converts work function from eV into J (1) Use of $hf = \Phi + ½mv^2_{max}$ to find hf (1) Use of $E = hf$ **and** $v = f\lambda$ to find λ (1) λ = 250 nm, so UVC (1) <u>Example of calculation</u> $\lambda = h/p$ so $p = h/\lambda = \frac{(6.63 \times 10^{-34}\ \text{Js})}{(1.50 \times 10^{-9}\ \text{m})} = 4.42 \times 10^{-25}$ kg m s^{-1} so $v = \frac{p}{m} = \frac{(4.42 \times 10^{-25}\ \text{kg m s}^{-1})}{(9.11 \times 10^{-31}\ \text{kg})} = 4.85 \times 10^{5}$ ms^{-1} KE = $½mv^2 = ½\,(9.11 \times 10^{-31}\ \text{kg})\,(4.85 \times 10^{5}\ \text{ms}^{-1})^2 = 1.07 \times 10^{-19}$ J $\Phi = (4.30\ \text{eV})(1.60 \times 10^{-19}\ \text{J eV}^{-1}) = 6.88 \times 10^{-19}$ J $E = hf = \Phi + ½mv^2_{max} = 6.88 \times 10^{-19}\ \text{J} + 1.07 \times 10^{-19}\ \text{J} = 7.95 \times 10^{-19}$ J $f = \frac{E}{h} = \frac{(7.95 \times 10^{-19}\ \text{J})}{(6.63 \times 10^{-34}\ \text{Js})} = 1.20 \times 10^{15}$ Hz $\lambda = \frac{v}{f} = \frac{(3.00 \times 10^{8}\ \text{ms}^{-1})}{(1.20 \times 10^{15}\text{Hz})} = 2.50 \times 10^{-7}$ m (250nm) UVC	**6**
17c	**MAX 2 for work function** y-intercept of graph should be (negative) work function (1) y-intercept is approximately (-) 10.0 eV (so cannot be zinc) (1) **Or MAX 2 for threshold frequency** Threshold frequency is the x-intercept / 7.5×10^{14} Hz (1) threshold frequency should be 1.0×10^{15} Hz, (so cannot be zinc) (1) **Or MAX 2 for Planck constant** Gradient of graph should be the Planck constant (allow “gradient = h”) (1) Calculates that gradient of the graph is approx. 2.1×10^{-33} (Js) (so not correct) (1) (Alternative for work function pair of marks: hf_0 should be the work function **Or** calculate work function from hf_0(1) hf_0 from graph = 3.1eV (so cannot be zinc) (1))	**4**
	Total for question 17	**11**