Pearson Edexcel

Mark Scheme (Results)

November 2021

Pearson Edexcel GCE
In Physics (9PH0)
Paper 2: Advanced Physics II

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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 schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate.

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 means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be 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 mean that one mark will not be awarded. (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 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.

1. **Quality of Written Communication**

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

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

2. **Graphs**

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

2.2 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.

2.3 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.

2.4 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	The only correct answer is A because detail is improved by both decreasing pulse length and decreasing wavelength B increasing wavelength decrease detail C increasing pulse length decrease detail D increasing pulse length and increasing wavelength both decrease detail	**1**
2	The only correct answer is C because 10 cm is more than the focal length from a converging lens A diverging lenses do not form real images from real objects B diverging lenses do not form real images from real objects D an object at less than the focal length from a converging lens will form a virtual image	**1**
3	The only correct answer is A because the extension is doubled and the force for each spring is the same and $k = F/x$	**1**
4	The only correct answer is C because each spring is extended by the same amount so each stores the same energy so the total is doubled	**1**
5	The only correct answer is B because $x = Fl/EA$ where $F = mg$ so $x = mgl/EA = \frac{24 \times 9.81 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$	**1**
6	The only correct answer is D because there is relative motion of the objects away from each other so the wavelength is increased by the Doppler effect so the observed frequency is decreased A there is relative motion of the objects towards each other so the wavelength is decreased by the Doppler effect so the observed frequency is increased B there is no relative motion for the objects so there is no observed change in wavelength or frequency C there is relative motion of the objects towards each other so the wavelength is decreased by the Doppler effect so the observed frequency is increased	**1**
7	The only correct answer is C because wave nature would predict a greater emission rate with a greater incident power A because instantaneous emission is only predicted by particle nature B because dependence of maximum kinetic energy on frequency is only predicted by particle nature D because minimum frequency for emission is only predicted by particle nature	**1**
8	The only correct answer is B because $mg = GMm/r^2$ so acceleration of free fall is proportional to mass / diameter^2 = $g(M/9)/(D/2)^2 = \frac{9.81 \times 4}{9}$	**1**
9	The only correct answer is B because acceleration is proportional to force, so the acceleration graph would have the shape of the force graph. The acceleration at the start is zero, so the velocity graph must have an initial gradient of zero. For the acceleration to be positive in the first quarter cycle the velocity must be increasing. This graph has an initial gradient of zero and increasing velocity.	**1**

	A the initial gradient is not zero C the initial gradient is not zero D the velocity in the first quarter cycle is decreasing	
10	The only correct answer is C because decreasing the mass on the hanger decreases the tension in the string and, since $v = \sqrt{\frac{T}{\mu}}$, decreases the speed of waves on the string. $\lambda = v/f$ so the wavelength is shorter and a whole wavelength could fit in the original length A the wavelength at the original frequency is unchanged, so decreasing the length will not allow a whole wavelength B decreasing the frequency will increase the wavelength, since wave speed is unchanged, so this will not allow a whole wavelength D since $v = \sqrt{\frac{T}{\mu}}$, decreasing the mass per unit length will increase the wave speed, increasing the wavelength at the original frequency, so this will not allow a whole wavelength	**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
11	• Use of $T = 2\pi\sqrt{(l/g)}$ **(1)** • Apply factor of 2 correctly for 2 half cycles **(1)** • Use of $f = 1/T$ **(1)** • $f = 0.68$ Hz **(1)**	<u>Example of calculation</u> $T = 2\pi\sqrt{(l/g)}$ $T = 2\pi\sqrt{(0.43 / 9.81)}$ = 1.32 s $T = 2\pi\sqrt{(0.67 / 9.81)}$ = 1.64 s T = (1.32 s + 1.64 s) / 2 = 1.48 s f = 1 / 1.48 s = 0.68 Hz	**4**

(Total for Question 11 = 4 marks)

Question Number	Acceptable answers		Additional guidance	Mark
12	• Use ofincrease in thermal energy of milk = latent heat energy released by steam + decrease in thermal energy of condensed steam • Use of $\Delta Q = mc\Delta\theta$ • Use of $\Delta Q = L\Delta m$ • m = 0.15 kg (150 g)	**(1)** **(1)** **(1)** **(1)**	Example of calculation $(mc\Delta\theta)_{\text{milk}} = (mc\Delta\theta)_{\text{water}} + L\Delta m_{steam}$ $m \times 3900\ \text{J kg}^{-1}\ \text{K}^{-1} \times (65.0\ °\text{C} - 4.00\ °\text{C})$ $= (0.015\ \text{kg} \times 4200\ \text{J kg}^{-1}\ \text{K}^{-1} \times (100\ °\text{C} - 65.0\ °\text{C}))$ $+ (2.3 \times 10^{6}\ \text{J kg}^{-1} \times 0.015\ \text{kg})$ m = 0.15 kg	**4**

(Total for Question 12 = 4 marks)

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*13</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>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th><th>Max linkage mark available</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>
</td>
<td>
The following table shows how the marks should be
<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>
awarded for structure and lines of reasoning.
Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).
</td>
<td>6</td>
</tr>
</table>

	Indicative content: • Requires a (very) high temperature • Nuclei all have positive charge leading to a large repulsive force between nuclei • At high temperature nuclei have high kinetic energy, sufficient to overcome repulsion • Nuclei must get close enough to fuse (accept reference to close enough for strong force) • Requires (very) high density • Collision rate must be high enough to sustain fusion		

(Total for Question 13 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14 (a)	• Use of $\rho = m/V$ **(1)** • Use of relationship upthrust = weight of liquid **(1)** • Use of $F = 6\pi\eta rv$ **(1)** • $\eta = 3.97 \times 10^{-2}$ (Pa s) so it is sunflower oil **(1)**	<u>Example of calculation</u> mass of oil displaced $= 9.20 \times 10^{2}$ kg m$^{-3} \times 1.41 \times 10^{-8}$ m^{3} $= 1.30 \times 10^{-5}$ kg upthrust $= 1.30 \times 10^{-5}$ kg $\times$ 9.81 m s^{-2} $= 1.27 \times 10^{-4}$ N weight of sphere $= 1.10 \times 10^{-4}$ kg $\times$ 9.81 m s^{-2} $= 1.08 \times 10^{-3}$ N weight = upthrust + drag 1.08×10^{-3} N = $(6\pi \times \eta \times 1.5 \times 10^{-3}$ m $\times$ 0.849 m s$^{-1}) + 1.27 \times 10^{-4}$ N $\eta = 3.97 \times 10^{-2}$ Pa s	**4**
14 (b)	An explanation that makes reference to the following points: • at a lower temperature viscosity is increased **(1)** • there would be a lower maximum speed **Or** one of the other oils could have been identified **(1)**		**2**

Question Number	Acceptable answers		Additional guidance	Mark
15 (a)	• Use of $L = 4\pi r^2 \sigma T^4$ • With 270 000 or 1420 • T = 3494 K which is smaller than the temperature of the Sun, so it is not correct • **Or** $T = 0.605\ T_{Sun}$ which is smaller than the temperature of the Sun, so it is not correct	(1) (1) (1)	Example of calculation 3.85×10^{26} W × 270 000 = 4 × π × 5.67×10^{-8} × (1420 × 6.96×10^{8} m)^2 × T^4 T = 3494 K	**3**
15 (b)	• Use of $\lambda_{max} T = 2.898 \times 10^{-3}$ m K • $\lambda_{max} = 8.29 \times 10^{-7}$ m (ecf for T from (a))	(1) (1)	Example of calculation λ_{max} × 3494 K = 2.898×10^{-3} m K $\lambda_{max} = 8.29 \times 10^{-7}$ m	**2**
15 (c)	• Add to top right • Red giant/supergiant	(1) (1)	Consistent with the answer from (a) for both marking points Accept hypergiant	**2**

(Total for Question 15 = 7 marks)

Question Number	Acceptable answers	Additional guidance	Mark
16 (a)	• Substitute eV for ½ mv^2_{max} in $hf = \phi + ½\, mv^2_{max}$ **(1)** • Rearranges to identify gradient = h/e **(1)** • Attempt to find gradient using large triangle **(1)** • $h = 7.6 \times 10^{-34}$ J s **(1)** (range: 7.5×10^{-34} J s to 7.7×10^{-34} J s)	<u>Example of calculation</u> $hf = \phi + ½\, mv^2_{max}$ $hf = \phi + eV$ $eV = hf - \phi$ $V = hf/e - \phi/e$ gradient = h/e gradient = (2.40 V – 1.00 V) ÷ (6.975×10^{14} Hz – 4.025×10^{14} Hz) gradient = 4.72×10^{-34} V s $h = 4.72 \times 10^{-34}$ V s × 1.6×10^{-19} C $h = 7.58 \times 10^{-34}$ J s	**4**
16 (b)	• (Faint and difficult to see, so may not be seen at the correct p.d. and) recorded p.d. could be too high **(1)** • (Range of frequencies could mean light is seen before the light at the stated frequency and) recorded p.d. could be too low **(1)** • Discussion of these points, e.g. opposite effects, could cancel or could be systematic errors and not affect gradient **(1)**		**3**

(Total for Question 16 = 7 marks)

Question Number	Acceptable answers	Additional guidance	Mark
17 (a)	Use of $F = mv^2 / r$ with $F = Gm_1 m_2 / r^2$ **(1)** Use of $v = 2\pi r / T$ **(1)** $T = 6.64 \times 10^8$ s (= 21 years) **(1)** **Or** Use of $F = m\omega^2 r$ with $F = Gm_1 m_2 / r^2$ Use of $\omega = 2\pi / T$ $T = 6.64 \times 10^8$ s (= 21 years)	Example of calculation $F = Gm_1 m_2 / r^2 = m_2 v^2 / r = (2\pi r)^2 m_2 / rT^2$ $T^2 = 4\pi^2 r^3 / G m_1$ $= 4\pi^2 \times (1.9 \times 10^{14}$ m$)^3$ / $(6.67 \times 10^{-11}$ N m^2 kg$^{-2} \times 9.2 \times 10^{36}$ kg) $T = 6.64 \times 10^8$ s (= 21 years)	3
17 (b)(i)	• Use of $V = -Gm / r$ **(1)** • Change in $V = 3.18 \times 10^{13}$ (J kg^{-1}) **(1)**	Example of calculation $\Delta V = -Gm (1/r_2 - 1/r_1)$ $= -6.67 \times 10^{-11}$ N m^2 kg$^{-2} \times 9.2 \times 10^{36}$ kg $\times$ $((1/2.7 \times 10^{14}$ m $- 1/1.8 \times 10^{13}$ m) $= 3.18 \times 10^{13}$ J kg^{-1}	2
17 (b)(ii)	• Equate change in gravitational potential energy to change in kinetic energy **Or** use of $E_p = mV$ **(1)** • Use of $E_k = ½ mv^2$ **(1)** • $v = 1.4 \times 10^6$ m s^{-1} **(1)**	Example of calculation $m \times 3.18 \times 10^{13}$ J kg^{-1} $= (0.5 \times m \times (8.10 \times 10^6$ m s$^{-1})^2) - (0.5 \times m\, v_2^2)$ $v_2 = 1.4 \times 10^6$ m s^{-1}	3
17(c)	An explanation that makes reference to the following points: • Hubble is for cosmological distances **(1)** • is not suitable since S2 is in our galaxy **(1)** • trigonometrical parallax is suitable for local stars because the parallax angles produced are large enough to measure accurately **(1)**	e.g. to distant galaxies	3
			(Total for Question 17 = 11 marks)

Question Number	Acceptable answers		Additional guidance	Mark
18 (a)	• Use of $p = F/A$ • Cylinder pressure = calculated pressure + atmospheric pressure • $p = 2.0 \times 10^5$ Pa	**(1)** **(1)** **(1)**	<u>Example of calculation</u> $p = 8.8$ N / 9.2×10^{-5} m^2 $= 9.57 \times 10^4$ Pa Total $p = 9.57 \times 10^4$ Pa + 1.0×10^5 Pa = 1.957×10^5 Pa	**3**
18 (b)	• Use of $pV = NkT$ • = 349 K (= 76 °C) (ecf from (a))	**(1)** **(1)**	<u>Example of calculation</u> pV/T = constant $T = 1.957 \times 10^5$ Pa $\times 6.7 \times 10^{-6}$ m^3 $\times$ 292 K / 1.0×10^5 Pa $\times 1.1 \times 10^{-5}$ m^3 = 349 K = 76 °C	**2**
18 (c)	• Equate $pV = NkT$ and $$pV = \frac{1}{3}Nm < c^2 >$$ • Suitable algebra			**2**
18 (d)	• Use of $\frac{1}{2} m <c^2> = 3/2\ kT$ • $\sqrt{<c^2>} = 500$ m s^{-1}	**(1)** **(1)**	<u>Example of calculation</u> $\frac{1}{2} m <c^2> = 3/2\ kT$ $\frac{1}{2} \times 4.8 \times 10^{-26}$ kg $\times <c^2> = 3/2 \times 1.38 \times 10^{-23}$ J K^{-1} $\times$ 292 K $<c^2> = 2.52 \times 10^5$ m^2 s^{-2} $\sqrt{<c^2>} = 502$ m s^{-1}	**2**
			(Total for Question 18 = 9 marks)	

Question Number	Acceptable answers		Additional guidance	Mark
19 (a)(i)	• Use of $P = 1/f$ • $f = 8.47$ (mm)	(1) (1)	<u>Example of calculation</u> $f = 1 / 118$ D = 8.47 mm	2
19 (a)(ii)	• Use of $1/v + 1/u = 1/f$ (allow u and v reversed, but not f) • $u = 14.8$ mm (ecf for f from 19(a)(i))	(1) (1)	<u>Example of calculation</u> $1/20$ mm + $1/u = 1/8.5$ mm $u = 14.8$ mm	2
19 (a)(iii)	• (Freshwater has a lower refractive index than seawater, so) there will be greater refraction of light on entering the lens • This means that the power of the lens is greater in freshwater **Or** this means that the focal length is less in freshwater • This means that the shortest distance will be decreased	(1) (1) (1)		3
19 (a)(iv)	• Use of $n = c/v$ • $v = 2.2 \times 10^8$ m s^{-1}	(1) (1)	<u>Example of calculation</u> $1.37 = 3.00 \times 10^8$ m s^{-1} / v $v = 2.2 \times 10^8$ m s^{-1}	2

19(b)	**Either** • Polarised light is light where the oscillations are in a single plane **(1)** • Which includes the direction of propagation **(1)** **Or** • Polarised light is light where the oscillations are in a single direction **(1)** • Which is perpendicular to the direction of propagation **(1)**		**2**

(Total for Question 19 = 11 marks)

Question Number	Acceptable answers	Additional guidance	Mark
20 (a)(i)	• Use of $\ln 2 = \lambda t_{1/2}$ **(1)** • $\lambda = 4.92 \times 10^{-18}$ (s^{-1}) **(1)**	Example of calculation $\lambda = \ln 2 / 1.41 \times 10^{17}$ s $= 4.92 \times 10^{-18}\ s^{-1}$	**2**
20 (a)(ii)	• Calculate rate = counts / time **(1)** • Subtract background radiation **(1)** • Use of $A = -\lambda N$ **(1)** • Calculates N × atomic mass **(1)** • Calculates percentage by mass **(1)** • Answer = 0.17 % (ecf for λ from (a)(i)) **(1)**	Example of calculation background rate = 525 / (10 × 60) s = 0.875 s^{-1} vase count rate = 3623 / (5 × 60) s = 12.077 s^{-1} corrected rate = 11.2 s^{-1} for whole vase = 11.2 s^{-1} × 0.0177 m^2 / 6.36×10^{-5} m^2 = 3117 s^{-1} $N = 3117 / 4.91 \times 10^{-18}\ s^{-1} = 6.348 \times 10^{20}$ Mass = $6.348 \times 10^{20} \times 238 \times 1.66 \times 10^{-27}$ kg = 2.51×10^{-4} kg Percentage = 2.51×10^{-4} kg × 100 / 0.149 = 0.17 %	**6**

20 (a)(iii)	**Max 2** from: • Alpha particles could have been absorbed by the glass **(1)** • Alpha particles will be emitted in all directions, not just towards the detector **(1)** • Some alpha particles could have been detected from other parts of the vase **(1)** • The count could include radiation from decay products **(1)** • Some alpha particles could be absorbed by the GM tube window **(1)**		**2**
20 (b)	• Calculates change in mass **(1)** • Converts from u to kg **(1)** • Use of $\Delta E = c^2 \Delta m$ **(1)** • Use of $E_k = \frac{1}{2} mv^2$ **(1)** • $v = 1.4 \times 10^7$ m s^{-1} **(1)**	<u>Example of calculation</u> $\Delta m = 238.0003u - (233.9942 + 4.0015)u$ $= 0.00463 \times 1.66 \times 10^{-27}$ kg $= 7.636 \times 10^{-30}$ kg $\Delta E = (3.00 \times 10^8 \text{ m s}^{-1})^2 \times 7.636 \times 10^{-30}$ kg $= 6.872 \times 10^{-13}$ J 6.872×10^{-13} J $= \frac{1}{2} (4.0015\ u)\ v^2$ $v = 1.4 \times 10^7$ m s^{-1}	**5**

(Total for Question 20 = 15 marks)

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