G492 – Understanding Processes, Experimentation and Data Handling

Physics B (Advancing Physics) mark schemes – an introduction

Just as the philosophy of the *Advancing Physics* course develops the student's understanding of Physics, so the philosophy of the examination rewards the candidate for showing that understanding. These mark schemes must be viewed in that light, for in practice the examiners' standardisation meeting is of at least equal importance.

The following points need to be borne in mind when reading the published mark schemes:

- Alternative approaches to a question are rewarded equally with that given in the scheme, provided that the physics is sound. As an example, when a candidate is required to "Show that..." followed by a numerical value, it is always possible to work back from the required value to the data.
- Open questions, such as the questions in section C permit a very wide variety of approaches, and the candidate's own approach must be rewarded according to the degree to which it has been successful. Real examples of differing approaches are discussed in standardisation meetings, and specimen answers produced by candidates are used as 'case law' for examiners when marking scripts.
- Final and intermediate calculated values in the schemes are given to assist the examiners in spotting whether candidates are proceeding correctly. Mark schemes frequently give calculated values to degrees of precision greater than those warranted by the data, to show values that one might expect to see in candidates' working.
- Where a calculation is worth two marks, one mark is generally given for the method, and the other for the evaluation of the quantity to be calculated.
- If part of a question uses a value calculated earlier, any error in the former result is not penalised further, being counted as *error carried forwar*d: the candidate's own previous result is taken as correct for the subsequent calculation.
- Inappropriate numbers of significant figures in a final answer are penalised by the loss of a mark, generally once per examination paper. The maximum number of significant figures deemed to be permissible is one more than that given in the data; two more significant figures would be excessive. This does not apply in questions where candidates are required to show that a given value is correct.
- Where units are not provided in the question or answer line the candidate is expected to give the units used in the answer.
- Quality of written communication will be assessed where there are opportunities to write extended prose.

Question		Expected Answers	Marks	Additional guidance
1 (a) (b)		power (1); force (1); velocity (1)	1 2	Both correct and no others (2); Two correct and one other (1); 1 correct and one or no other: (1); No other combination gains marks
2		(n)$\lambda = d \sin \theta$ $\lambda = 2.0 \times 10^{-6} \times \sin(17°)$ (1) m & s; $= 5.8 \times 10^{-7}$ m (1) e	2	First mark is for choice of correct equation and substituting values. Bare answer gets (2).
3		$E = ½mv^2 = 0.5 \times 120 \times 10^{-6} \times 3^2$ (1) m & s $= 5.4 \times 10^{-4}$ J (1) e	2	First mark is for choice of correct equation and substituting values even if m incorrectly converted
4 (a) (b)		$s = ½gt^2 \Rightarrow t = \sqrt{(2s/g)} = \sqrt{(36/9.8)}$ (1) m & s $= \sqrt{3.67} = 1.92$ s ≈ 2 s (1) e $s = u\,t = 5 \times 1.92 = 9.6$ m (1)	2 1	Needs evidence of calculation, viz. 1.9 s. Allow g=10 m s-2 Allow 2 s $\Rightarrow$ 10.0 m Ecf possible from (a)
5 (a) (b)		Use/reference to 'tip to tail' adding/use of Pythagoras (1); Calc./measurement of hypotenuse=$\sqrt{5}$ =2.2±0.1 units (1) $P \propto (A_{res})^2$ (1)	2 1	Scale drawing OK. May need to use scoris ruler to measure. If triangle drawn, must show clearly that 2<hypotenuse<3 Allow A for Ares. Allow P = (Ares)2
6 (a) (b)		Four parallel wavefronts, either spreading out or curved more at ends than centre(1); constant λ similar to approaching λ (1) Diffracted through larger angle owtte (1)	2 1	judge λ by eye between wavefronts added eg. 'spreads more', 'more curved'

Question	Expected Answers	Marks	Additional guidance
7 (a)	$f = v/\lambda$ = 0.08/500 000 = 1.6×10^{-7} (Hz) (1)m (1)e	2	1.6×10^{-7} gets (2); calc. with one incorrect conversion gets (1)
(b)	Very low amplitude (1); very slow moving (1); very long wavelength/few waves to see across ocean (1); very long period (1); lots of other waves present/background noise hard to distinguish from random wave motion (1)	2	Any two distinct points with their relevance clear.
	Section A total:	**20**	

Question	Expected Answers	Marks	Additional guidance
8 (a)	(i) N at one end/both ends and A in the centre (1) (ii) waves travelling in opposite directions (1); waves in phase (1); superpose constructively /interfere constructively (1); displacement varies from negative to positive (1)	1 2	 Any two points. Reflect…meet = waves in opposite directions 'add up' = superpose
(b)	(i) 3.8 m (1) (ii) μ = 0.008 kg (1); $T = 4L^2f^2\mu$ = 118 N ≈ 120 N (1)m (1)e	1 3	 Allow wrong μ in calculation, eg. 8 gives 118 000N (2) Ora from μ = 0.008 kg gives f =32.2 Hz
(c)	(i) three loops similar size(1) (ii) node where finger touches (1); pattern symmetry about centre/ example of higher harmonic pattern (1)	1 2	 eg. touching ¼ way down is same as touching ¾ way down
	Total:	**10**	

Question	Expected Answers	Marks	Additional guidance
9 (a)	(i) $f = 3 \times 10^8 / 470 \times 10^{-9} = 6.4 \times 10^{14}$ Hz (1); $E = hf = 6.6 \times 10^{-34} \times 6.4 \times 10^{14}$ $= 4.2 \times 10^{-19}$ J $\approx 4 \times 10^{-19}$ J (1) (ii) Blue photons are (higher frequency and hence) higher energy than red ones (1); larger voltage $\Rightarrow$ more energy (per electron) (1) (iii) $20 \times 10^{-3}/1.6 \times 10^{-19} = 1.25 \times 10^{17}$ (1); (iv) $P = 1.3 \times 10^{17} \times 4.2 \times 10^{-19} = 0.054$ W (1)m (1)e	2 2 1 2	or $E = hc/\lambda$ (1)m (1)e Needs calculator value 4.2×10^{-19} J for 'show that'. One mark is links λ ($\Rightarrow f$) $\Rightarrow E$; one mark links $V \Rightarrow E$ QWC is 'clear organisation' which applies when both marks have been earned. Photon energy must be 4×10^{-19} J or 4.2×10^{-19} J 4×10^{-19} J gives 0.05 W. Allow 0.1 W
(b)	(i) Ring around 470 nm peak (1) (ii) Has (significant light intensity over) range of visible light/ contains all of the wavelengths (of visible light) (1). (iii) blue photons have more energy than red ones (1); cannot emit photon if there's not enough energy (1)	1 1 2	Ring must enclose the maximum and should not include the peak to the right.
	Total:	**11**	

Question		Expected Answers	Marks	Additional guidance
10	(a)	(i) Takes more time for P→ER than for ER→ M (1) (ii) method of detecting change of direction (1); explains how this method distinguishes them (1) (iii) Easier to read/ easier to use/clearer presentation / aesthetically more satisfactory/used to this format (1).	1 2 1	 eg. feel motion, use compass, observe next carriage
	(b)	(i) sin(1°) or cos(89°)= 0.017 ≈ 1/50 or 0.02 (1) Parallel component of W = W sin(1°) (1); (ii) Will decelerate/slow down as it approaches (1); and accelerate/speed up as it leaves station (1). (iii) Energy argument here (any two points) • flat track involves braking and loss of energy (1); • climbing into station increases gravitational PE (1); • gravitational PE → KE as train leaves station (1)	 2 2 2	Or vector triangle with identified forces (1); ratio of 1:50 (1) (something) × sin(1°) or (something) × cos(89°) is enough to identify component of that something. NOT tan(1°). Not just force arguments. Doing work to climb = gaining GPE
		Total:	**10**	

Question	Expected Answers	Marks	Additional guidance
11 (a)	(i) Radius of orbit = 7.7×10^{6} m (1) Circumference of orbit = $2\pi \times 7.7\times10^{6}$ m = 4.8×10^{7} m (1) Speed = 4.8×10^{7} m /6800s = 7100 m s^{-1}(1) (ii) time = $(2\times1.3\times10^{6}$m)/ 3.0×10^{8} m s^{-1} = 8.7×10^{-3} s; (1) distance = 7100 m $s^{-1}\times8.7\times10^{-3}$ s= 62 m (1)	3 2	Or diameter =1.54×10^{7} m Ecf throughout part (i). *R* = 6.4×10^{6} m ⇒ circumf = 4.0×10^{7} m⇒*v* = 5910 m s^{-1} =(2) If time = 4.3 ms, correct evaluation of next stage gives a mark of (1), other times get (0) for (ii) Allow ecf for speed of satellite from (i). 7000 m s^{-1} gives 61 m; 5900 m s^{-1} gives 51 m. Look for half echo distance; 4.3 ms ⇒ 30 m or 26 m from 7000 m s^{-1} and 5900 m s^{-1} respectively

<table>
<tr><th>Question</th><th colspan="2">Expected Answers</th><th>Marks</th><th>Additional guidance</th></tr>
<tr><td rowspan="9">11 (b)</td><td colspan="2">Advantage:</td><td rowspan="9">4</td><td rowspan="9">Same feature may feature as advantage and disadvantage as separate attributes are explained.
May have mark for either factor or explanation or both.

QWC: first mark is conditional on no more than 1 mis-spelling per 15 words and no gross errors in punctuation.</td></tr>
<tr><td>Factor:
• larger area of wavefront striking sea</td><td>Explanation:
• Averages out different bits of sea/smoothes out waves
• Data taken from more ocean surface (per second)</td></tr>
<tr><td>• larger area of wavefront reaching Jason’s orbital path</td><td>• More likely to receive reflected information</td></tr>
<tr><td colspan="2">Disadvantage:</td></tr>
<tr><td>Factor:
• larger area of wavefront striking sea</td><td>Explanation:
• Poorer resolution in terms of area of sea surface
• More noise due to waves etc.</td></tr>
<tr><td>• larger area of wavefront reaching Jason’s orbital path</td><td>• Weaker signal
• Signal/noise ratio worse</td></tr>
<tr><td>• different possible paths</td><td>• Distance calculated would not be accurate/consistent
• Interference between different parts of signal
• Separate pulses overlap
• Low pulse frequency needed</td></tr>
<tr><td>• Part of wavefront misses Jason</td><td>• Some information lost</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td></td><td colspan="2">Total:</td><td>9</td><td></td></tr>
<tr><td></td><td colspan="2">Section B total:</td><td>40</td><td></td></tr>
</table>

Question		Expected Answers	Marks	Additional guidance
12	(a)	(i) 1.4 (1); ± 0.2 (1) m (ii) 1.8 not > 2 × spread from mean (1)	2 1	Allow 3 sf for mean; allow 2 sf for spread if mean has 3 sf Must apply this rule: '1.4 + 2 × 0.2 = 1.8' is enough
	(b)	(50%) increase in one value makes a small contribution to the mean when compared with 11 others (1); Presence of this single high reading has increased the range by 0.2 / spread by 0.1/ made spread or range 50% larger (1)	1 1	Mean: must state/imply that it is just one reading in many, eg. ref. to 'all the data'; Spread: should refer to highest and lowest data Can recalculate: mean = 1.4(4) (1) spread = 0.3 (1)
	(c)	factor correctly identified (1) direction of change stated (1);	1 1	eg. compression of spring, angle of launch, friction in tube, mass of marble. eg. spring compressed too much, angle decreased/nearer 45°, mechanism for reduced friction suggested, marble has smaller mass.
		Total:	**7**	

Question	Expected Answers	Marks	Additional guidance
13 (a)	$\frac{1}{100}$ mm = 10^{-5} m or 10^{-4} m = 1/10 mm (1); quantitative comparison of the two values obtained (1)	**2**	Can calculate eg. percentage uncertainty 10% for (2) Uncertainty of + - half a scale division is OK, giving 5%
(b)	$V = Ax = \pi r^2 x$ (1); $\rho = m/V$ and substituting above (1)	**2**	Needs to have explicit volume and density definitions. Dimensional analysis gets no marks.
(c)	(i) Substituting values correctly (1); Correct calc. / rearranging $\Rightarrow r = 4.0976 \times 10^{-5}$ m (1) (ii) least accurate datum /Δx (or E) recognised (1); 2 s.f. indicated by uncertainty of data (1); (iii) x is already very accurate / should tackle the least accurate measurement / most accurate measurement is the least significant source of uncertainly (1) (iv) Recalculation with Δx = 2.5 cm (4.18×10^{-5} m) **or** 2.7 cm (4.02×10^{-5} m) (1)m (1)e Percentage uncertainty = 100 × (difference in r) / r (1); (Δx = 2.5 cm $\Rightarrow$2.0%, Δx = 2.7 cm $\Rightarrow$1.9%) Rounding answer to 1 s.f. (2%) (1)	2 2 1 4	If Δx and/or x not correct in metres, no marks. No ecf allowed. $\sqrt{1.679 \times 10^{-9}}$ is evidence of calculation 4.0976×10^{-5} m gets (2) even if substitution not clear. Not 'all the data' or 'the data' Idea of constraint due to uncertainty of data needed for this mark. Any point. First mark is using extreme value(s) of Δx, second is evaluation. Allow attempts using combination of uncertainties: Percentage uncertainty in Δx = 3.8% (1)m(1)e Percentage uncertainty in Δr =½ that in Δx = 1.9% (1) = 2% (1) Treat all consideration of uncertainties in F and x as neutral.

Question	Expected Answers	Marks	Additional guidance
(d)	(i) Identifying Δx and *m* as the main contributors to uncertainty in method 1 and method 2 respectively (1); Conclusion: method 2 is less uncertain justified in terms of fractional/percentage uncertainties(1)	2	Needs quantitative comparison: m: 1/72 =1.4% = 1% uncertain Allow attempt using combination of uncertainties: Treat all consideration of other uncertainties as neutral, but adding percentage uncertainties gives 1.7% for method 2 (1); and 4.7% for method 1 so method 2 is better (1)
	(ii) Method 1: produces (proportionately) bigger Δx /most uncertain measurement greatly improved (1); any reasonably comment on practicality (1) Method 2: produces (proportionately) bigger *m* / most uncertain measurement greatly improved (1); any reasonably comment on practicality (1)	2	If method 1, must comment on Δx. if method 2, must comment on *m*
	Total:	**17**	

Question	Expected Answers	Marks	Additional guidance
14 (a)	No clocks accurate enough (1); accurate rulers easy to make (1)	2	Must state or imply comparison in precision of instruments
(b)	(i) $E_p = mgh = 0.025 \times 9.8 \times 1.0 = 0.245$ J (1); (ii) $E_k = ½mv^2$ $\Rightarrow v = \sqrt{(2 \times 0.25/0.025)} = 4.47$ m s^{-1}(>4 m s^{-1}) (1) (iii) $v = \sqrt{(10 \times 0.25/[7 \times 0.025])} = 3.8$ (1)m (1)e; units of m s^{-1} or m/s given (1) (iv) friction (1); bigger area in contact on flat mass / explaining why friction reduces v in terms of energy dissipation or reduced accelerating force (1)	1 1 3 2	NOT 0.025×9.8=0.245J Ora from 4 m s-1 and shows energy = 0.2 J < 0.25J E = 0.245 J gives v = 4.43 m s-1 0.245 J gives 3.7 m s-1; reverse calc. from 4 m s-1 not allowed. Unit mark is free-standing.
(c)	(i) 1.37 (3 s.f.) and 0.64 or 0.640 (2 or 3 s.f.) (1) (ii) points (0.30,0.64) and (0.65,1.37) correctly plotted (1); Best-fit straight line (1); Straight line (almost) through origin so $D^2 \propto H$ / Straight line not through origin so D^2 not $\propto H$ (1) [ecf from their line which must go back to axes]. (iii) gradient 2.3 (± 0.2) (1)m (1)e; [check for construction on graph if gradient outside this range] $Y = 7 \times 2.3/20 = 0.81 \approx 0.8$ m (1)	1 3 3	Overlay shows point positions; points should be within one small square of correct positions; line should be centred on all points plotted. Move overlay so that red square coincides with outside of graph grid to check points and line.
	Total:	**16**	
	Section C total:	**40**	