Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2023

Physics

Assessment Unit AS 2

assessing

Module 2: Waves, Photons and Astronomy

[SPH21]

WEDNESDAY 24 MAY, AFTERNOON

MARK SCHEME

Physics Subject Specific Instructions

It is essential that, before using the mark scheme, markers familiarise themselves with the following guidance.

General

To ensure that all candidates receive the same treatment, the mark scheme must be applied consistently.

The mark scheme for each question shows typical intermediate steps, the answer expected and the marks available for each part of the question.

In cases where a candidate has responded with a seemingly correct response which has not been anticipated in the mark scheme, the marker must make a professional judgement of the correct physics/validity of the response when awarding marks.

Brackets (...) are used to indicate information which is not essential for the mark to be awarded. Alternative answers are indicated by 'or', or the symbol for or, '/'.

Multiple/Cancelled Responses

If a candidate provides multiple responses, the general principle to be followed is that 'right + wrong = wrong'.

Responses considered to be neutral are not penalised. For example, if additional irrelevant information is given in an explanation that does not contradict the correct information given, the mark(s) can be awarded.

In a numerical problem if two different solutions are presented without a definitive answer on the answer line, credit should not be given. If an answer is given on the answer line, then the solution that has led to the answer given should be marked according to the mark scheme.

If a candidate clearly cancels their working by scoring it out, then this should not be marked. It is not the role of the marker to select from the candidate's response what should or should not be marked.

Marking Numerical Problems

In numerical problems, the marks for the intermediate steps shown in the mark scheme are for the benefit of candidates who do not obtain the final correct answer.

A correct answer, if obtained from a valid starting point, gets full credit, even if all the intermediate steps are not shown.

This “correct answer” rule does not apply in situations where candidates have been asked to ‘show your working’ or ‘show that’. These answers must be valid in all stages to obtain full credit.

The answer to a ‘show that’ question should be quoted to one more significant figure than that given in the question.

Do not reward wrong physics. No credit is given for consistent substitution of numerical data, or subsequent arithmetic, in a physically incorrect equation.

The normal penalty for an arithmetical error is to lose the mark(s) for the answer/unit line. An arithmetic error should be penalised for one mark only. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value of a quantity given in a question.

10^n errors count as arithmetical slips and incur a penalty of one mark.

If a candidate rounds a value incorrectly this should be penalised one mark. However, care must be taken not to penalise a candidate for rounding correctly in parts leading up to their final answer in an unstructured numerical problem.

Answers should be given in decimal form. Fractional answers will not be credited with the answer mark.

Error Carried Forward

An ECF can occur between parts of a question or, in more unstructured numerical problems, within a part.

When an incorrect answer is carried forward from one question to the next, full credit should be awarded in the part where the incorrect answer is used, provided all the working is correct.

Within a part, ECF is applied where a candidate does an incorrect calculation, for example calculates a value for R incorrectly using V/I and then goes on to use their calculated value for R to calculate a resistivity value. The penalty is applied in the V/I calculation but then the value of R can be carried forward so that the remainder of the marks are available to the candidate provided all the remainder of their working is correct.

The ECF within a part will only apply in numerical problems where more than one calculation is required in a part.

Significant Figures

Candidates should show an awareness of using a sensible number of significant figures in their answers, based on the values given in the question. In SPH11, SPH21, APH11 and APH21, unless specifically asked for in the question, candidates will not be penalised for incorrect significant figures.

In SPH31, SPH32, APH31 and APH32, all answers should be given to a suitable number of significant figures and penalties will be applied in these papers unless otherwise stated in the mark schemes.

Units
In the majority of questions, the unit will be stated on the answer line.

When the unit is omitted, candidates will be clearly asked to state an appropriate unit and this will be credited in the mark scheme.

Where there is a final calculation required to get from the unit of the answer calculated to the unit on the answer line the required unit will be stated in the question. For example, if wavelength was calculated and the answer line was in nm a statement ‘Give your answer in nanometres’ would be included.

The unit on the answer line will generally be the SI unit but may in some cases be a more appropriate unit. For example, if values of mass in g and momentum in g cm s^{-1} were given, the unit on the answer line for speed could reasonably be cm s^{-1} without prompt.

						AVAILABLE MARKS
1	**(a)**	**(i)**	Any e.m. wave, wave on a rope, other correct answer		[1]	
		(ii)	sound wave or other correct answer		[1]	
		(iii)	oscillations/vibrations	[1]		
			transverse wave vibrations/oscillations are perpendicular to wave direction or energy transfer direction	[1]		
			and longitudinal are parallel	[1]	[3]	
	(b)	**(i)**	amplitude correct in any position		[1]	
		(ii)	three waves in 2.0 (s)	[1]		
			Period = 0.67 s = 6.7×10^{-1} s	[1]	[2]	
		(iii)	f = 1/T or f = 1.5 Hz	[1]		
			λ = v / f	[1]		
			λ = 3.5 / 1.5 = 2.33 m	[1]	[3]	
		(iv)	wave correctly drawn $\lambda/4$ out of phase	[1]		
			same amplitude and period	[1]	[2]	13
2	**(a)**		Sketch to include lens (in holder), screen, illuminated object, metre-rule [$\frac{1}{2}$] each correct label, round down		[2]	
	(b)		Lens-object distance/u correctly identified	[1]		
			Lens-screen distance/v correctly identified	[1]		
			At least 5 sets	[1]	[3]	
	(c)		Graph of 1/v against 1/u or correct alternative		[1]	
	(d)		f = (intercept)$^{-1}$ consistent with **(c)**	[1]		
			Ave 2 values	[1]	[2]	8
3	**(a)**		Doppler shift depends on the relative motion of the source and observer	[1]		
			Cosmological depends on the expansion of the space between the two	[1]	[2]	
	(b)	**(i)**	$\Delta\lambda$ = 5.3 nm or z=0.0135	[1]		
			subs into $\Delta\lambda / \lambda$ = v/c, v = 3×10^8 (5.3/393.3)	[1]		
			v = 4.04×10^6 m s^{-1}	[1]	[3]	
		(ii)	d = v / H_o = $4.04 \times 10^6 / 2.4 \times 10^{-18}$ e.c.f. v	[1]		
			1.7×10^{24} m	[1]	[2]	
		(iii)	because H_o is an estimate		[1]	8

					AVAILABLE MARKS
4	**(a)**	In phase	[1]		
	(b)	30.5 mm / 5 = 6.1 (mm) for y	[1]		
		mm conversions correct	[1]		
		subs into formula λ = ay/d = $0.27 \times 10^{-3} \times 6.1 \times 10^{-3} / 2.5$ e.c.f. for y	[1]		
		$\lambda = 6.6 \times 10^{-7}$ (m)	[1]	[4]	5
		S.E. 5.49×10^{-7} [3] for /6 rather than /5			
		S.E. 3.3×10^{-6} [3] for no division by 5			
5	**(a)**	**(i)** $f = (\text{power})^{-1}$	[1]		
		1/2.0 = 0.50 m = 50 cm	[1]	[2]	
		(ii) virtual	[1]		
		upright	[1]		
		magnified	[1]	[3]	
		(iii) near point without lenses = 50 cm	[1]		
		1/50 = 1/25 + 1/v (to locate where virtual image is created with glasses)	[1]		
		far point with lenses = 50 cm	[1]	[3]	
	(b)	ray parallel to the principal axis and refracted as if from F	[1]		
		ray through optical centre	[1]		
		image located between O and lens and labelled upright arrow	[1]		
		dashed lines for virtual rays	[1]		
		eye position	[1]	[5]	13
		(penalty [–1] arrows missing)			
6	**(a)**	Photons or e.m. radatiation incident on metal	[1]		
		with energy greater than the work function/freq greater than threshold	[1]		
		will cause ejection of (photo-)electrons	[1]	[3]	
	(b)	**(i)** $\varphi = hf_o$	[1]		
		$6.63 \times 10^{-34} \times 1.04 \times 10^{15}$	[1]		
		6.89×10^{-19} J	[1]		
		4.31 eV conversion J=>eV independent mark	[1]	[4]	
		(ii) different electron position within metal/ proximity to the surface	[1]		
		Some energy required to reach surface, reducing E_k of emitted electron	[1]	[2]	9

						AVAILABLE MARKS
7	**(a)**	Energy must be supplied		[1]		
		In order to remove an electron from the atom, to reach zero energy		[1]	[2]	
	(b)	**(i)**	652×10^{-9} m	[1]		
			E = hc / λ subs	[1]		
			$E = 3.05 \times 10^{-19}$ J	[1]		
			C to B	[1]		
			Direction correct	[1]	[5]	
		(ii)	no transition	[1]		
			this is not exactly a difference in energy levels	[1]	[2]	
	(c)	**(i)**	Computed Tomography		[1]	
		(ii)	X-ray images are 2-D, CT scans are 3-D or 'slice' through body CT requires rotating X-ray tube conventional images do not CT imaging processes multiple images rather than one image CT better than X-ray at imaging soft tissue higher dose of radiation from CT than X-ray Any 3, [1] each		[3]	13
8	**(a)**	**(i)**	subs into λ = h / p	[1]		
			$p = 2.1 \times 10^{-23}$	[1]	[2]	
		(ii)	p = mv	[1]		
			$v = 2.3 \times 10^{7}$ ecf from p	[1]	[2]	
	(b)	when wavelength of the wave is equal to aperture width			[1]	
	(c)	**(i)**	radius of <u>circles/rings</u> decreases	[1]		
			Electrons given greater velocity	[1]	[2]	
		(ii)	subs into d sinθ = n λ	[1]		
			$d = 9.86 \times 10^{-11}$ m	[1]		
			no lines $m^{-1} = d^{-1}$, 1×10^{10}	[1]		
			1×10^{7} lines mm^{-1}	[1]	[4]	
			S.E. 2 x 10^{7} for n=1			11
9	**(a)**	For a pair of given media		[1]		
		The ratio of sin i to sin r is a constant		[1]	[2]	
	(b)	n = sin i / sin r		[1]		
		sin 60 / sin 35 = 1.51		[1]	[2]	
	(c)	**(i)**	$n = \frac{C_1}{C_2}$	[1]		
			speed in core = $3 \times 10^{8}/1.51$	[1]		
			1.99×10^{8} m s^{-1}	[1]	[3]	
		(ii)	$\frac{1}{n_{co}} \times n_{cl}$ or $\frac{\text{speed in core}}{\text{speed in cladding}}$	[1]		
			1.45 / 1.51 or $1.99 \times 10^{8}/2.07 \times 10^{8}$	[1]		
			0.96	[1]	[3]	10

					AVAILABLE MARKS
10	**(a)**	(driver) frequency of signal	[1]		
		matches/equals natural frequency of air in tube	[1]	[2]	
		or			
		constructive interference/superposition (between incident and reflected waves)	[1]		
		results in a standing wave	[1]		
	(b)	**(i)** A labelled at open end of tube and N labelled at base of tube		[1]	
		(ii) particles not vibrating (no e.c.f.)	[1]		
		particles vibrate with max amplitude at open end (no e.c.f. from diagram)	[1]	[2]	
		(iii) $\lambda = L \times 4$	[1]		
		wavelength = 3"	[1]		
		$v = 342 \text{ m s}^{-1}$	[1]	[3]	
		(iv) $L = \frac{3}{4}\lambda$ or similar, maybe shown on sketch	[1]		
		$f = 3 \times f_o = 342$ Hz	[1]	[2]	10
			Total		**100**