New Specification

Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2017

Physics

Assessment Unit AS 2

assessing

Module 2: Waves, Photons and Astronomy

[SPH21]

THURSDAY 8 JUNE, AFTERNOON

MARK SCHEME

Subject-specific Instructions

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 and unit, if obtained from a valid starting-point, gets full credit, even if all the intermediate steps are not shown. It is not necessary to quote correct units for intermediate numerical quantities.

Note that this “correct answer” rule does not apply for formal proofs and derivations, which must be valid in all stages to obtain full credit.

Do not reward wrong physics. No credit is given for consistent substitution of numerical data, or subsequent arithmetic, **in a physically incorrect equation**. However, answers to subsequent stages of questions that are consistent with an earlier incorrect numerical answer, and are based on a physically correct equation, must gain full credit. Designate this by writing **ECF** (Error Carried Forward) by your text marks.

The normal penalty for an arithmetical and/or unit error is to lose the mark(s) for the answer/unit line. Substitution errors lose both the substitution and answer marks, but 10^n errors (e.g. writing 550 nm as 550×10^{-6} m) count only as arithmetical slips and lose the answer mark.

						AVAILABLE MARKS
1	**(a)**	**(i)**	Separation between observer and source increasing/separation increasing/space expanding/galaxy moving away		[1]	
		(ii)	(Frequency or wavelength change as a result of) the source or observer moving in Doppler redshift;	[1]		
			the space (between source and observer) expanding	[1]	[2]	
	(b)	**(i)**	$z = \frac{(398.3 - 396.9)}{396.9}$ subs	[1]		
			$z = 3.527 \times 10^{-3}$ (at least 3 s.f. in ans line)	[1]	[2]	
			([–1] penalty for unit)			
		(ii)	$v = zc = 3.527 \times 10^{-3} \times 3.00 \times 10^{8}$ subs ECF (z)	[1]		
			$v = 1.06 \times 10^{6}$ (m s^{-1})	[1]	[2]	
		(iii)	$d = \frac{v}{H_0} = \frac{1.06 \times 10^{6}}{2.40 \times 10^{-18}}$ subs ECF (v)	[1]		
			$d = 4.42 \times 10^{23}$ m	[1]		
			d = 47 Mly ECF (d/m)	[1]	[3]	
	(c)		age = $\frac{1}{H_0} = \frac{1}{2.4 \times 10^{-18}}$ Eqn or subs	[1]		
			age = 4.2×10^{17} (s)	[1]		
			age = 13(.2) (billion years) (ecf from their age in s)	[1]	[3]	13
2	**(a)**		Conversion to joules: 2.29 eV = 3.66×10^{-19} J	[1]		
			$E = \frac{hc}{\lambda}$ or $f_o = 5.5 \times 10^{14}$ eqn	[1]		
			$3.66 \times 10^{-19} = \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{\lambda}$ subs ECF (E)	[1]		
			$\lambda = 5.43 \times 10^{-7}$ (m) ans	[1]	[4]	
	(b)		Substituting $hf_0 = 3.66 \times 10^{-19}$ J into Einstein's eqn ECF **(a)**	[1]		
			Substituting $hf = 8.69 \times 10^{-19}$ J into Einstein's eqn	[1]		
			Electron KE = 5.03×10^{-19} J	[1]		
			$v = 1.05 \times 10^{6}$ (m s^{-1})	[1]	[4]	
	(c)		(Work function) is the minimum energy required to remove an electron, or equivalent description of energy loss	[1]		
			if more has to be used removing it then there is less kinetic energy	[1]	[2]	10

						AVAILABLE MARKS
3	(a)	(i)	Wave theory cannot explain the threshold frequency/ frequency dependence	[1]		
			Can't explain immediate release (from a weak source) E_k max is not intensity dependent	[1]	[2]	
		(ii)	Successful as: It can explain why the number of emitted photoelectrons increases as the intensity of incident radiation increases		[1]	
		(b)	Indicative content:			
			Apparatus: Hot cathode/filament	[1]		
			anode/potential difference and acceleration ("electron gun" [1]/[2])	[1]		
			Graphite (powder) target/nickel	[1]		
			Fluorescent screen	[1]		
			Evacuated tube	[1]		
			Results: Series of (light and dark) rings	[1]		
			Concentric	[1]		
			Significance: Particles are exhibiting wave behaviour	[1]	[8]	
	(c)		Correct electron mass selected	[1]		
			$\lambda = \dfrac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31}(2.50 \times 10^{6}))}$ subs	[1]		
			$\lambda = 2.91 \times 10^{-10}$ (m)	[1]		
			$\lambda = 0.291$ (nm) ECF (λ/m)	[1]	[4]	15

					AVAILABLE MARKS
4	**(a)**	(Trace) incident and emergent rays/exit point	[1]		
		Construct the passage of a ray through the glass block	[1]		
		Measure the angle i and corresponding angle r/sin i and sin r calculated	[1]		
		Repeat until >4 pairs of results are obtained	[1]	[4]	

(b) (i) $n = \frac{\sin i}{\sin r}$ or $\frac{1}{\text{gradient}}$ — eqn or subs [1]

$n = 1.57$ (1.54–1.60) [1] [2]

(ii) $\sin c = \frac{1}{n}$ — eqn [1]

$\sin c = \frac{1}{1.57}$ ECF — subs [1]

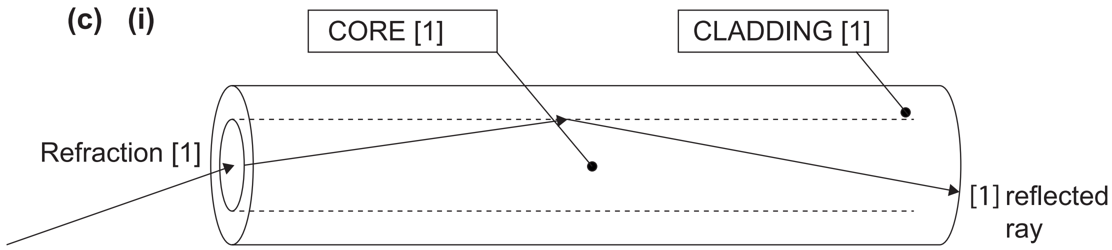
$c = 39.6°$ (38.7–40.5) — ans [1] [3]

(iii) $n = \frac{c_1}{c_2}$ — eqn [1]

$1.57 = \frac{3.00 \times 10^8}{c_2}$ — subs [1]

$c_2 = 1.91 \times 10^8$ (m s^{-1}) [1] [3]

(c) (i)



[4]

(ii) Non-coherent and coherent bunch of fibres [1]

Non-coherent for illumination [1]

Coherent for image transmission [1] [3] 19

						AVAILABLE MARKS
5	(a)	(i)	Ray through optical centre does not refract	[1]		
			Image position identified on 2 cm line	[1]		
			Ray parallel to PA refracts downwards	[1]		
			through PF	[1]		
			(or Ray incident through PF refracts parallel to PA)			
			Principal focus correctly identified or dist to f measured (2.4 cm)	[1]		
			(ecf) f = 120 (cm)	[1]	[6]	
		(ii)	mag = $\frac{v}{u} = \frac{I}{O} = \left(\frac{200}{300} = \frac{2}{3}\right)$	[1]		
			mag = 0.67 (0.7)	[1]	[2]	
			(ecf from their v)			
	(b)	(i)	v = 2.2 u	[1]		
			negative for virtual image	[1]		
			$\frac{1}{u} + \frac{1}{(-2.2u)} = \frac{1}{16}$ subs (ecf v)	[1]		
			u = 8.7 (cm)	[1]	[4]	
			(SE 23.3 gets 3/4)			
		(ii)	P = $\frac{1}{f}$	[1]		
			P = 6.3 (D) must be positive	[1]	[2]	
	(c)	(i)	Myopia (short sight)		[1]	
		(ii)	eyeball too long/lens too strong ecf } from long sight		[1]	
		(iii)	far point too close/close objects in focus ecf } from long sight can't see distant objects clearly		[1]	
		(iv)	diverges the rays		[1]	18

				AVAILABLE MARKS
6	**(a)** Two waves travelling in opposite directions **meet** they have the same frequency/wavelength/are coherent (Reflection at closed end [1])	[1] [1]	 [2]	

(b)

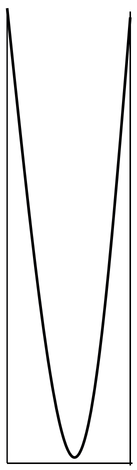


Fig. 6.1

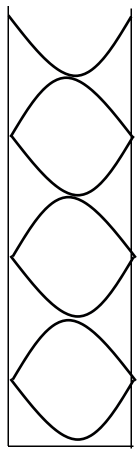


Fig. 6.2

(i) node at closed end, antinode at open end [1]
as **Fig 6.1** above or inverted [1] [2]

(ii) as **Fig 6.2** above or inverted [1]

(c) Nodes – positions of minimum displacement/zero displacement [1]
Antinodes – positions of maximum amplitude/**periodic** maximum displacement [1] [2]

(d) Wavelength (1st mode) = 2.72 m ecf **(b)** [1]

Frequency = $\frac{v}{\lambda}\left(= \frac{330}{2.72}\right)$ Eqn [1]

f(1st mode) = 121 (Hz) ECF* (λ) [1]

f(4th mode) = 7 × 121 = 849 (Hz) ECF **(b)(ii)** [1] [4] 11

SE $\frac{0.68}{4} \rightarrow$ f = 1941 gets 2 of 1st 3 marks

						AVAILABLE MARKS
7	(a)	Constant phase relationship		[1]		
		$S_1f - S_2f = P.D.$ or equivalent		[1]		
		P.D. related to wavelength for reinforcement ($PD = n\lambda$)		[1]	[3]	
	(b)	(i)	a = 1.24 (mm)	[1]		
			y = 1.86 (mm)	[1]		
			d = 3.64 (m)	[1]	[3]	
		(ii)	6.33×10^{-7} m ecf **(b)(i)**		[1]	
	(c)	(i)	$d = \frac{1}{(300 \times 10^3)} = 3.33 \times 10^{-6}$	[1]		
			$\theta = \frac{40.2}{2} = 20.1°$	[1]		
			$2\lambda = 3.33 \times 10^{-6} \sin\left(\frac{40.2}{2}\right)$ ECF d and θ subs	[1]		
			$\lambda = 5.72 \times 10^{-7}$m	[1]	[4]	
		(ii)	$n_{max} = \frac{d}{\lambda}$	[1]		
			$n_{max} = 5.8$	[1]		
			$n_{max} = 5$	[1]	[3]	14
					Total	**100**