Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2018

Physics

Assessment Unit AS 2

assessing

Module 2: Waves, Photons and Astronomy

[SPH21]

FRIDAY 18 MAY, MORNING

MARK SCHEME

Subject-specific Instructions

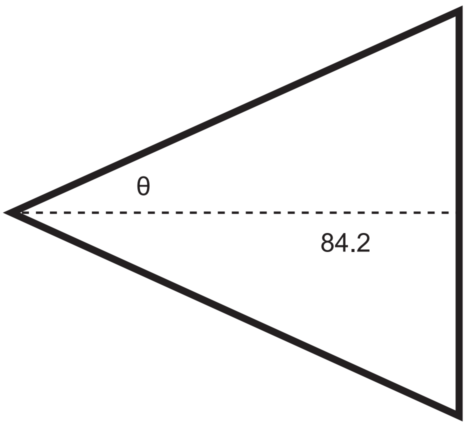
In numerical problems, the marks for the intermediate steps shown in the mark scheme are for the benefit of candidates who do not obtain the final correct answer. A correct answer and unit, if obtained from a valid starting-point, gets full credit, even if all the intermediate steps are not shown. It 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)		Electrons exist in (fixed) energy levels	[1]		
			ΔE **different** between levels	[1]	[2]	
	(b)	(i)	Recognises ground state is (–)13.6 eV		[1]	
		(ii)	ΔE = hf or c = fλ	[1]		
			$\lambda = \frac{hc}{\Delta E}$	[1]		
			c = speed of light, h = Planck's constant	[1]	[3]	
		(iii)	ΔE = 2.56	[1]		
			conv to J 4.1×10^{-19} (ecf ΔE)	[1]		
			$\lambda = 4.85 \times 10^{-7}$ (ecf J)	[1]	[3]	
		(iv)	Yes as the visible light spectrum is 400–700 nm		[1]	
	(c)		Electrons are excited to a metastable state where they stay for a longer time	[1]		
			Population inversion as there are more electrons in excited than ground state/lower state	[1]		
			Stimulated emission is when electrons fall (to ground state)	[1]		
			when stimulated by a photon of the **same** energy/frequency	[1]	[4]	14
2	(a)		The spreading of waves through a gap or opening		[1]	
	(b)		*diagram 1*			
			plane waves on RHS of diagram with slight curved edges	[1]		
			diagram 2			
			curved wavefronts	[1]		
			same size wavelength in both	[1]	[3]	
	(c)	(i)	$\tan\theta = \frac{30.3}{84.2}$	[1]		
			$\theta = 19.8$	[1]	[2]	

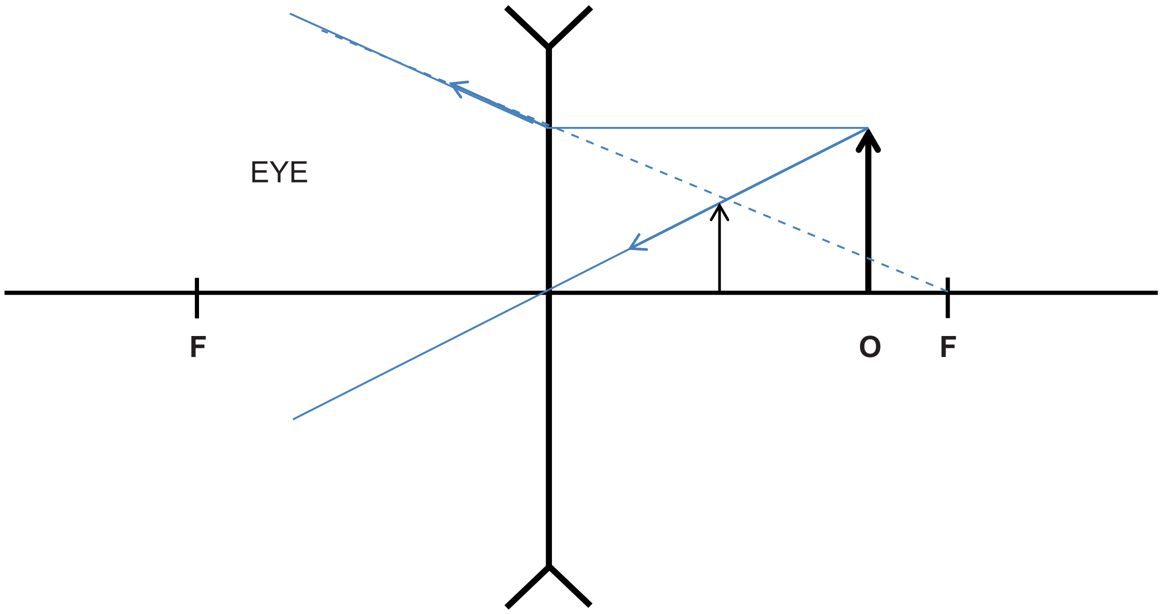


		(ii)	$d = \frac{1 \times 10^{-3}}{200} = 5 \times 10^{-6}$ m	[1]		
			$n\lambda = d\sin\theta$			
			$3\lambda = 5 \times 10^{-6} \sin 19.8$	[1]		
			$\lambda = 5.65 \times 10^{-7}$ m	[1]		
			λ = 565 nm	[1]	[4]	10
			(20°, λ = 570 nm)			

						AVAILABLE MARKS
3	**(a)**		$eV = \frac{1}{2}mv^2$	[1]		
			$v = \sqrt{\frac{2eV}{m}}$	[1]		
			$K = \sqrt{\frac{2e}{m}}$	[1]	[3]	
	(b)	**(i)**	$v^2 = \frac{1.55 \times 10^{-15} \times 2}{9.11 \times 10^{-31}}$ or $\frac{1}{2} \times 9.11 \times 10^{-31}\ v^2 = 1.55 \times 10^{-15}$	[1]		
			$v = 5.83 \times 10^7$	[1]		
			$mv = 5.31 \times 10^{-23}$ kg m s^{-1} (ecf v)	[1]	[3]	
		(ii)	$\lambda = \frac{6.63 \times 10^{-34}}{5.31 \times 10^{-23}}$	[1]		
			$\lambda = 1.25 \times 10^{-11}\ m$ (ecf **(i)**)	[1]	[2]	
	(c)	**(i)**	concentric circles		[1]	
		(ii)	Diameter decreases/smaller spacing		[1]	10
4	**(a)**	**(i)**	Begin at zero/lowest frequency and (slowly) increase the frequency	[1]		
			Until the (1st) loud**est** sound is heard	[1]	[2]	
		(ii)	$\frac{1}{4}$ of a wave drawn	[1]		
			Correct placing of N and A	[1]	[2]	
	(b)	**(i)**	$\lambda = 4 \times 1.2 = 4.8$ m	[1]		
			$v = f\lambda = 70 \times 4.8 = 336$ m s^{-1} (ecf λ)	[1]	[2]	
		(ii)	$f_1 = 210$ Hz	[1]		
			$f_2 = 350$ Hz	[1]	[2]	
	(c)		new l = 0.9	[1]		
			new wavelength = 0.9 × 4 = 3.6 m (ecf new l)	[1]		
			f = 336/3.6 = 93 (ecf λ)	[1]		
			$\Delta f = 23$ Hz (ecf f)	[1]	[4]	12

				AVAILABLE MARKS
5 **(a)** frequency is highest for train moving towards observer and lowest for train moving away from observer	[1]			
wavelength of sound when train moving away from platform $\lambda = \frac{v_{sound} + v_{train}}{f}$	[1]			
wavelength of sound when train moving towards platform $\lambda = \frac{v_{sound} - v_{train}}{f}$	[1]	[3]		
(b) **(i)** an increase in wavelength of light	[1]			
due to the expansion of space	[1]	[2]		
(ii) $z = \frac{\Delta\lambda}{\lambda}$ =2.2/550 = 0.004	[1]			
$z = \frac{v}{c}$				
$v = 4 \times 10^{-3} \times 3 \times 10^{8}$ (ecf z)	[1]			
$v = 1200\ \text{km s}^{-1}$	[1]	[3]		
(c) $T = \frac{1}{H_0} = \frac{1}{2.4 \times 10^{-18}}$	[1]			
$= 4.2 \times 10^{17}$ s	[1]			
$= 1.3 \times 10^{10}$ years (ecf s)	[1]	[3]		11
6 **(a)** Labelled diagram to include lens, illuminated object, screen, metre stick/optical bench	[2]			
([–1] for each missing piece of equipment)				
Object (u) and image (v) distance from lens clearly marked	[1]	[3]		
(b) Adjust screen/lens to obtain focused image	[1]			
Repeat for various object distances	[1]	[2]		
(c) plot $\frac{1}{u}$ vs $\frac{1}{v}$	[1]			
straight line with negative gradient	[1]	[2]		
Or plot uv vs $u + v$,				
plot straight line through the origin				
(d) Find the inverse of (both) intercepts and average them to find f		[1]		8
Or gradient is f				

7 (a) (i)



for ray through optical centre [1]
2nd ray drawn, construction line dotted, [1]
for (labelled) image [1]
eye marked on LHS of ray diagram [1]
[–1] for incorrect or no arrows [4]

(ii) Virtual, diminished, upright [1]

(b) (i) $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Identifies f is negative in substitution } within substitution [1]
Identifies v = 0.42u } within substitution [1]
Identifies v is negative } within substitution [1]

u = 20.7 cm [1]

m = $\frac{i}{o}$ [1]

i = 14 × 0.42 = 5.9 cm [1] [6]

(ii) v = 0.42u, ***v* = 8.7 cm** (ecf), u = 20.7 cm on same side of lens as object [1]
v – u (ecf) 12 cm [1] [2]

AVAILABLE MARKS: 13

						AVAILABLE MARKS
8	**(a)**	**(i)**	Vibrations parallel to direction of travel of the wave – longitudinal	[1]		
			Vibrations perpendicular to direction of travel of the wave – transverse	[1]	[2]	
		(ii)	Vibrations confined to only one plane	[1]		
			Transverse waves	[1]	[2]	
	(b)		$\frac{1}{f} = \frac{\lambda}{v}$ (substitute $T = \frac{1}{f}$)	[1]		
			Rearrange to show $v = f\lambda$	[1]	[2]	
	(c)	**(i)**	$f = \frac{1}{0.24 \times 10^{-3}}$	[1]		
			= 4167 Hz (ecf T)	[1]	[2]	
		(ii)	New wave has same time period	[1]		
			New wave has an amplitude of 0.6 cm	[1]		
			New wave is moved over 4 squares on the grid	[1]	[3]	11

9 **(a)** **(i)**

The refractive index of the cladding is larger than the refractive index of the core	
The refractive index of the cladding is the same as the refractive index of the core	
The refractive index of the cladding is smaller than the refractive index of the core	✓

[1]

(ii)	$\frac{\sin 38}{\sin r} = 1.52$ $\frac{\sin i}{\sin r}$ = n, equation or subs	[1]		
	$r = 23.9$	[1]		
	$i = 66.1°$	[1]	[3]	
(b) (i)	$n = \frac{C_1}{C_2}$	[1]		
	$v = 1.97 \times 10^8$ m s^{-1}	[1]		
	$t = \frac{3000}{1.97 \times 10^8}$	[1]		
	$= 1.52 \times 10^{-5}$ s	[1]	[4]	
(ii)	$\sin 70 = \frac{\textit{old path}}{\textit{new path}}$	[1]		
	new path = 1.064 × *old path*			
	extra distance = 0.064 × *old path*	[1]		
	Time = 6.4 % longer since distance ∝ time	[1]	[3]	11
			Total	**100**