Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2016

Physics

Assessment Unit AS 2

assessing

Module 2: Waves, Photons and Medical Physics

[AY121]

TUESDAY 28 JUNE, 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.

1 (a)

Typical frequency/Hz	**Region**	**Typical wavelength/m**
10^3	Radio	$\approx 10^5$
10^{22}	Gamma	$\approx 10^{-14}$

Radio λ_{radio} ~10^5 m $10^{-1} - 10^8$ m
Gamma λ_{gamma} ~10^{-14} m $10^{-10} - 10^{-16}$ m [2]
[1] [1]

(b) (i) The fraction of a cycle by which one wave leads/lags the other. [1]
or in terms of time
or in terms of angle
or the fraction of a cycle by which a point in a wave leads/lags another

(ii) $\Delta t = 4$ (ms) [1]
Fraction of cycle = 4/20 = 0.2 ecf Δt or 18^0 ms^{-1} [1]
Phase difference = 0.2 × 360 = 72 degrees [1] [3] 6
ecf for Δt

AVAILABLE MARKS

AVAILABLE MARKS

2 (a) Diagram

Diagram to include a (glass (or Perspex)) block and **ray** box + labels. [1]

or if using TIR method
semicircular (glass (or Perspex)) block and **ray** box + labels.

Procedure

– (Remove block and) join the incident and emergent rays to show the refracted ray. [1]
– Repeat for various angles of incidence. [1]

or if using TIR method:
– Direct the incident ray towards **centre** of flat side of semicircular block. [1]
– Rotate block/move ray until emergent ray is refracted at an angle of 90° to normal in air/lies along the straight edge of the semicircular block. Mark incident, ((emergent) and reflected rays). [1]

Measurements

– Calculate sin i and sin r. [1]
– Plot a graph of sin i (*y*-axis) against sin r (*x*-axis) and calculate gradient. [1]

or plot sin r (*y*-axis) against sin i (*x*-axis) and calculate 1/gradient.
Assume 1st mentioned is in *y*-axis
Calculations and average cannot get 2nd mark

or if using TIR method
– Measure angle between incident ray and reflected ray using a protractor = 2C.
– n = 1/sinC

both points needed for [1]

Quality of written communication

2 marks

The candidate expresses ideas clearly and fluently, through well-linked sentences and paragraphs. Arguments are generally relevant and well structured. There are few errors of grammar, punctuation and spelling.

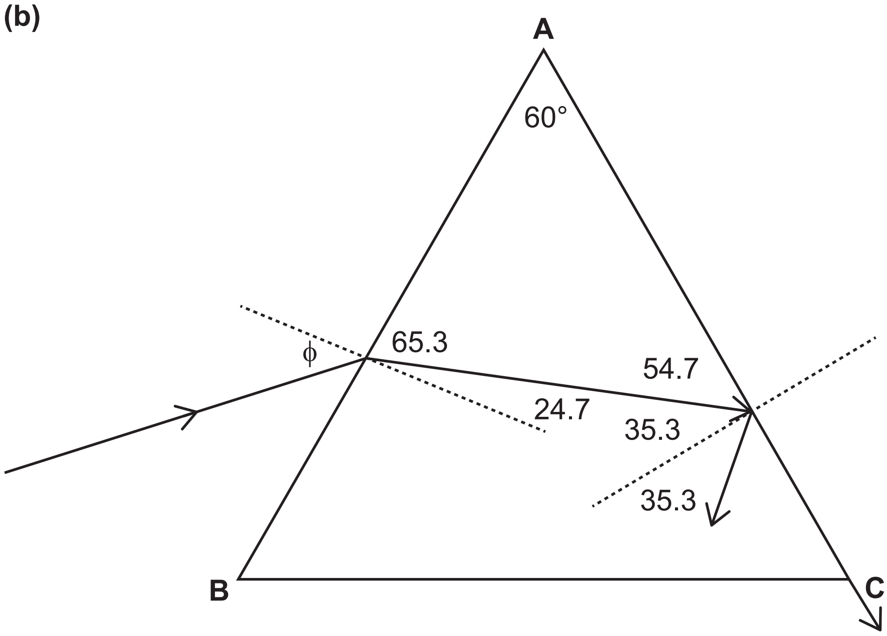
1 mark

The candidate expresses ideas clearly, if not always fluently. Arguments may sometimes stray from the point. There are some errors in grammar, punctuation and spelling, but not such as to suggest a weakness in these areas.

0 marks

The candidate expresses ideas satisfactorily, but without precision. Arguments may be of doubtful relevance or obscurely presented. Errors in grammar, punctuation and spelling are sufficiently intrusive to disrupt the understanding of the passage. [2] [7]

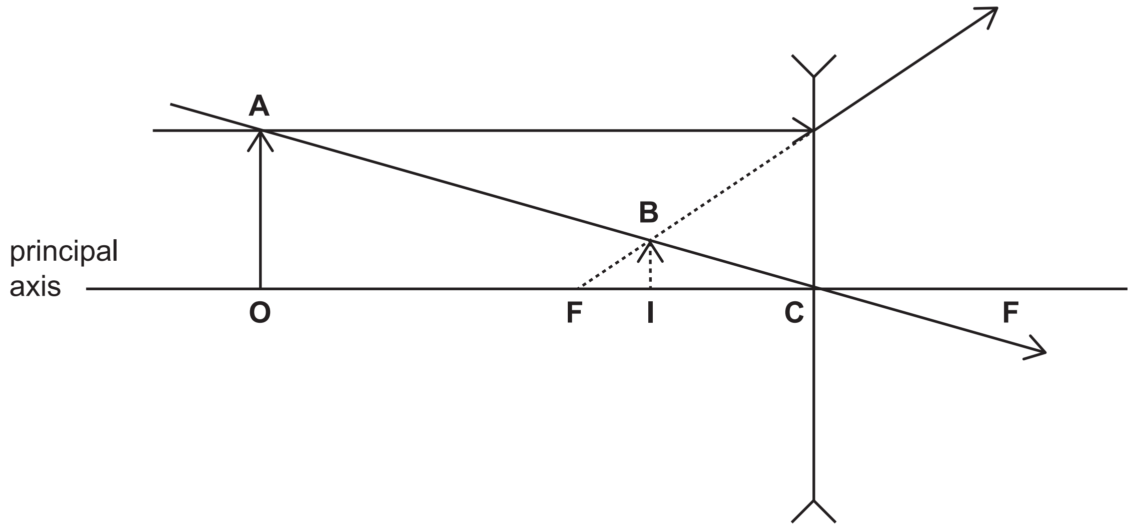
(b)



– Calculation of critical angle = $\sin^{-1}(1/1.73) = 35.3°$	[1]		
– Calculation of angle of refraction at surface AB = 24.7° ecf **(c)**	[1]		
– **Use** of $n = \sin i/\sin r$	[1]		
– Substitution to calculate $\phi = 46.3°$	[1]	[4]	11
S.E. 88.6° [2]/[4]			

AVAILABLE MARKS

3 **(a)** Concave/diverging lens marked [1]
Two correct rays [2]
Image labelled (IB) and dotted or labelled to indicate it is virtual [1] [4]



[–1] if virtual ray not dotted
[–1] if no arrows, once only

(b) **(i)** Illuminated object, lens and screen in order. [1]
Metre rule/optical bench [1]
u and v correctly identified [1] [3]
Penalty [–1] for missing label

(ii) [Algebra with $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ or y = mx + c [1]]
f = 1/gradient [2]

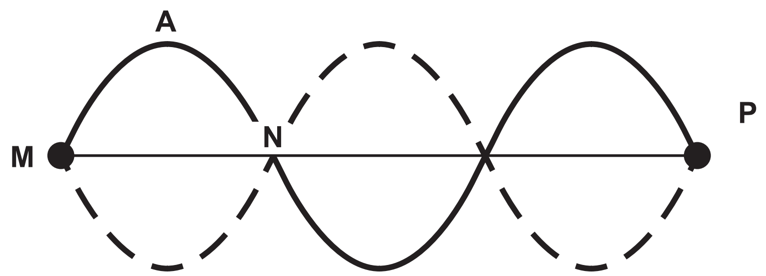
AVAILABLE MARKS: 9

4 **(a)** The principle of superposition states that when two waves meet or (and) combine, [1]
the total displacement at any point is the **vector** sum of individual displacements at that point. [1] [2]

b) Correct overall shape [1]
Accurately drawn [1] [2]

(c) **(i)** $\boldsymbol{\lambda}$ = v/f = 106.4/56 = **1.90** m [1]
L = λ/2 = 1.90/2 = 0.95 m ECF ($\boldsymbol{\lambda}$) [1] [2]

(ii) Determination of standing wave obtained:
Mode of vibration/number of loops = 168/56 = 3 [1]
Correct sketch [1] [2]



(iii) Any node and antinode correctly marked. Both correct [1]

AVAILABLE MARKS: 9

						AVAILABLE MARKS
5	**(a)**	**(i)**	There is a **constant phase difference** between the two waves.		[1]	
		(ii)	Sources must have similar amplitudes Room must be dark Screen should be far away from slits ($\geqslant$ 1m) Same slit width Any 2		[2]	
	(b)	**(i)**	Path difference = whole odd number of half wavelengths (= $[n + \frac{1}{2}]\lambda$)		[1]	
		(ii)	Third dark fringe, therefore n = 2.	[1]		
			$(2 + \frac{1}{2})\lambda = 1.38 \times 10^{-6}$ subs	[1]		
			$\lambda = 5.52 \times 10^{-7}$ m ans	[1]	[3]	7
6	**(a)**		$\lambda_{sound} >> \lambda_{light}$	[1]		
			Diffraction at door is greatest for biggest λ/general diffraction statement	[1]		
			Thus diffraction of sound through door is much greater than for light	[1]	[3]	
	(b)		$T = 1/5000 = 2 \times 10^{-4}$ s	[1]		
			1 square corresponds to 5×10^{-5} s or $T \propto 4$ sq	[1]		
			Time base setting = 50 μs cm^{-1}	[1]	[3]	6
7	**(a)**		**Rapid deceleration** of the electrons by the **nuclei** (of the target material with the emission of photons of electromagnetic radiation with various energies).	[1]		
			Deep lying electrons in the target material being knocked out by the bombarding electrons creating a vacancy.	[1]		
			The vacancy is filled by an (outer) electron ‘falling’ into the vacancy (with the emission of a high energy photon of electromagnetic radiation)	[1]	[3]	
	(b)	**(i)**	Computed tomograph(y)		[1]	
		(ii)	In a conventional X-ray the beam and detector are stationary	[1]		
			In a CT scan the beam (and detector) are rotated (in phase)	[1]	[2]	
		(iii)	The X-ray dose in a CT scan is much higher than for a conventional X-ray or The cost of a CT scan is much higher than for a conventional X-ray or Patient preparation can be time consuming/unpleasant		[1]	7

						AVAILABLE MARKS
8	**(a)**	Photons/electromagnetic radiation must be **absorbed** by electrons within the metal	[1]			
		Photon energy must be ⩾ work function of the metal or Frequency of radiation ⩾ (minimum) threshold frequency f_0 of metal	[1]	[2]		
	(b)	$\phi = hf_0$ or $E = hf$ $= (6.63 \times 10^{-34} \times 2.5 \times 10^{15})$ eqn or subs	[1]			
		$= 1.6575 \times 10^{-18}$ J	[1]			
		$= 10.36$ eV **ecf for conversion of J to eV**	[1]	[3]		
	(c)	**(i)** No effect/KE remains the same/stays at zero		[1]		
		(ii) The number of photoelectrons emitted per second increases		[1]		7
9	**(a)**	**(i)** Population inversion	[1]			
		More (Not **all**) electrons are in the excited state (than the ground state).	[1]	[2]		
		(ii) A passing photon with **metastable** energy equal to the difference between the two energy levels involved.		[1]		
	(b)	**(i)** Energy must be supplied to the atom to ionise it	[1]			
		Energy level associated with ionisation = 0 (therefore levels have negative values) or Stationary free electrons have zero energy	[1]	[2]		
		(ii) Transition between (–)4.030 eV and (–)5.995 eV		[1]		
		(iii) Arrow down between correct levels. (Must be accurately drawn) **ecf from (b)(ii)**		[1]		7
10	**(a)**	$\lambda_{db} = h/p$ $\lambda_{db} = h/m_ev = (6.63 \times 10^{-34})/(9.11 \times 10^{-31} \times 1.22 \times 10^{7})$ subs	[1]			
		$= 5.96 \times 10^{-11}$ m ecf (v)	[1]			
		$= 0.0597$ nm ecf (λ)	[1]	[3]		
	(b)	(V has increased, thus) v increases	[1]			
		(Since $\lambda_{db} = h/mv$, then) λ_{db} decreases	[1]			
		Ring diameters decrease/rings get closer together	[1]	[3]		6
				Total		**75**