Oxford Cambridge and RSA Examinations

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

AS 3888

PHYSICS B (ADVANCING PHYSICS)

AS

MARK SCHEME FOR THE UNITS

JUNE 2001

3888/MS/01

Advanced Subsidiary GCE Physics B 3888
June 2001 Assessment Session

Unit Threshold Marks

Unit		Maximum Mark	a	b	c	d	e	u
2860	Raw	90	66	58	50	43	36	0
	UMS	100	80	70	60	50	40	0
2861	Raw	90	62	53	45	37	29	0
	UMS	110	88	77	66	55	44	0
2862	Raw	120	96	84	72	60	48	0
	UMS	90	72	63	54	45	36	0

Syllabus Aggregation Results

Overall threshold marks in UMS (i.e. after conversion of raw marks to uniform marks)

	Maximum Mark	A	B	C	D	E	U
3816	300	240	210	180	150	120	0

The cumulative percentage of candidates awarded each grade was as follows:

	A	B	C	D	E	U	Total Number of Candidates
3816	25.14	47.42	69.7	85.66	95.3	100	6234

ADVICE TO EXAMINERS ON THE ANNOTATION OF SCRIPTS

1. Please ensure that you use the **final** version of the Mark Scheme. You are advised to destroy all draft versions.

2. Please mark all post-standardisation scripts in red ink. A tick (✓) should be used for each answer judged worthy of a mark. Ticks should be placed as close as possible to the point in the answer where the mark has been awarded. The number of ticks should be the same as the number of marks awarded. If two (or more) responses are required for one mark, use only one tick. Half marks (½) should never be used.

3. The following annotations may be used when marking. No comments should be written on scripts unless they relate directly to the mark scheme. Remember that scripts may be returned to Centres.

X	=	incorrect response (errors may also be underlined)
^	=	omission mark
bod	=	benefit of the doubt (where professional judgement has been used)
ecf	=	error carried forward (in consequential marking)
con	=	contradiction (in cases where candidates contradict themselves in the same response)
sf	=	error in the number of significant figures

4. The marks awarded for each part question should be indicated in the margin provided on the right hand side of the page. The mark total for each question should be ringed at the end of the question, on the right hand side. These totals should be added up to give the final total on the front of the paper.

5. In cases where candidates are required to give specific number of answers, (e.g. 'give three reasons'), mark the first answer(s) given up to the total number required. Strike through the remainder. In specific cases where this rule cannot be applied, the exact procedure to be used is given in the mark scheme.

6. Correct answers to calculations should gain full credit even if no working is shown, unless otherwise indicated in the mark scheme. (An instruction on the paper to 'Show your working' is to help candidates, who may then gain partial credit even if their final answer is not correct.)

7. Strike through all blank spaces and/or pages in order to give a clear indication that the whole of the script has been considered.

8. An element of professional judgement is required in the marking of any written paper, and candidates may not use the exact words that appear in the mark scheme. If the science is correct and answers the question, then the mark(s) should normally be credited. If you are in doubt about the validity of any answer, contact your Team Leader/Principal Examiner for guidance.

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 themethod, 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 forward*: the candidate's own previous result is taken as correct for the subsequent calculation.
- Inappropriate number of significant figures in a final answer are penalised by the loss of a mark, generally one 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.

Section C

The outline mark schemes given here will be given more clarity by the papers seen when the examination is taken. Some of these scripts will be used as case law to establish the quality of answer required to gain the marks available.
It is not possible to write a mark scheme that anticipates every example which students have studied.

For some of the longer descriptive questions three marks will be used (in scheme called the 1/2/3 style).

1 will indicate an attempt has been made
2 will indicate the description is satisfactorily, but contains errors
3 will indicate the description is essentially correct

Abbreviations, annotations and conventions used in the Mark Scheme		
	/	= alternative and acceptable answers for the same marking point
	;	= separates marking points
	NOT	= answers which are not worthy of credit
	( )	= words which are not essential to gain credit
	___	= (underlining) key word which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

1. (a) Light(er) / grey background NOT white ✓; with one dark(er) / black central pixel ✓ 2

(b) Any pixel value = 116 ✓; all pixel values equal ✓ 2

2. Metals – have electrons free to move ✓;
Semiconductors – much smaller charge carrier density /
Fewer free electrons AW ✓ NOT have no free electrons
(Metals have more free electrons gets both marks) 2

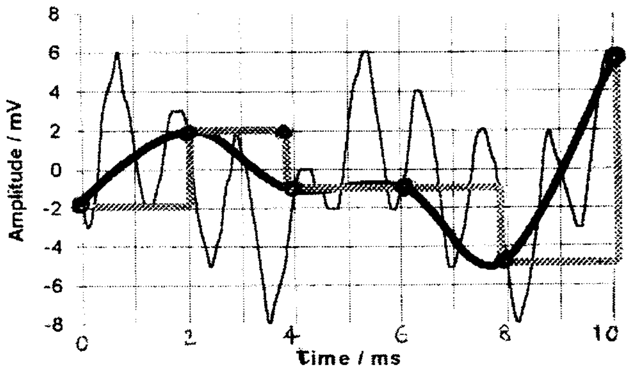
3. (a) (1 / 0.25 – 1 / 1) ✓ ; = 3.0 D ✓ ignore sign 2

(b) Power of reading lenses = 3.0 D ecf on (a) ✓ NOT negative value 1

4. (a) Resistor (heats) melts / burns / blow or better AW ✓ NOT safety / overload 1

(b) $V = \sqrt{(P \times R)}$ ✓ ; = $\sqrt{(0.25 \times 470)}$ ✓ ; = 11 V (10.8 V) ✓ 3
OR $I = \sqrt{(P / R)}$ ✓ ; = 0.02(3) A ✓ ; V = 11 V (accept 9.4 V method clear) ✓

5. (a) 5 or 6 correct points sampled ✓; attempt best fit waveform curved / rectangular ✓ ecf 2

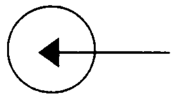


(b) Higher frequencies missing / fewer waves / amplitude less / less information /
Spurious low frequencies / other correct difference ✓ AW 1

6. (a) A ✓ 1

(b) Resistances are equal ✓ ; because same value of $R = V / I$ 2
same V and I but resistance of B is rising ✓ 19

7. (a) 0.6 V ✓ 1

(b)(i) Loop drawn around  wiper ✓ NOT around whole pot 1

(ii) A complete explanation with **two** correct points:
R needed to: drop some (2) Volts / prevent output becoming too large ✓ AW; 1
to achieve the required sensitivity / ✓ AW 1
OR lower quality answers:
to make a potential divider / current limiter / protective R AW
one mark max

(iii) evidence of a correct **method** e.g.

$R \propto V$ / $V_{out} = V_{in}\,(R_{pot}/(R_{pot} + R_f))$ / $I = V / R_{pot}$ then $R_f = V / I$ ✓ ; 1
Evidence of a correct **substitution** e.g.
$R / 2 = 1$ kΩ / 3 / 3 = 5 x 1k / (1+R)k / = 3V / 1k then R_f = 2V/3mA ✓ 1
(give credit here for calculations based at the 0.6 V output position) ;
evaluation R_f = 670 Ω ✓ **SF** penalty any answer not 2 or 3 SF 1

(c) Change in output consistent with change in p.d. ✓ ; 1
change in p.d. consistent with their stated change in R ✓; R_f is less 2

8. (a)(i) 400 ✓ 1

(ii) 1 ✓ 1

(iii) 400 / same as (a)(i)x(a)(ii) ecf ✓ 1

(b)(i) 8 ✓ 1

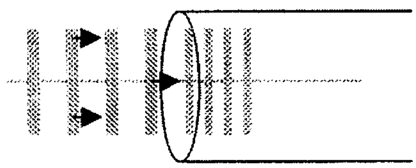
(ii) 256 / 2^8 NOT 255 ✓ ecf on 2 raised to the power (b)(i) 1

(c) e-mail is more compressed / efficient ✓ ; 1
detail or qualification on coding e.g. valid numerical comparison ecf /
effect of pictorial characters / images / diagrams (as benefit of fax) AW ✓ 1

(d) 2 correct points e.g.
There is no colour/grey scale / only black and white ✓ ; contrast is changed ✓;
photo has small pixels ✓; resolution / fine detail is lost AW ✓ max 2

9. (a)(i) (v = c / n) = 3 x 10^8 / 1.5 ✓ ; = 2 x 10^8 ✓ ; m s^{-1} ✓ unit mark 3

(ii) 4 Wavefronts normal ✓; constant new λ x 2/3 i.e. 1.5 cm <3λ <2.5 cm ✓ 2
any position in fibre ecf on no. of wavefronts



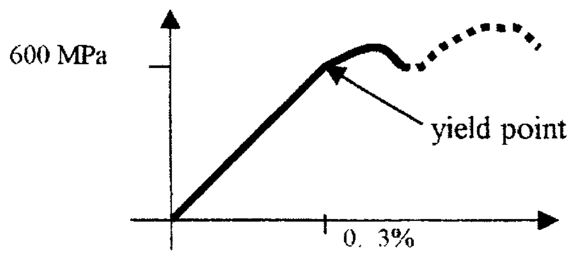
(b)(i) sin r = sini / n (formula / numerical) ✓ ; sin r = 0.644 ; 2
= 40 ± 0.5° ✓ 1

(ii) Correct argument consistent with (b)(i) ecf
e.g. Ray incident at i = (90 – 40)° = 50° ✓ ; i > C ecf on angle i ✓ ; 2
Diagram consistent with their value of i ✓ i.e. 2 marks max for i incorrect 1

10\. (a)(i) 10 400 N (10.4 kN) ✓ 1

(ii) Strain = stress / E ✓ (words / numbers) ; = $6 \times 10^8 / 2 \times 10^{11}$ ✓ ; 2
= 0.0030 / 0.3% ✓ three marks for correct answer without working 1

(iii) Linear graph through origin ✓ ; to yield point indicated by label / value ✓ ; 2
plastic region beyond ✓ 1
(accept any shape with decreased or negative gradient)



(b) x = strain x L (words / numbers) ✓ ; = (0.003 x 80✓;) / 4 ✓ ecf on (a)(ii); 3
= 0.06 m ✓ ecf 1
(award marks for a part attempt e.g. using x = (FL / EA) ; correct use of ¼)
41

Section C

11\. (a)(i) Clear choice of **image** e.g. surface of planet Venus ✓ ; 1
appropriate wave or radiation stated e.g. using microwave radar ✓ 1
some relevant detail e.g. showing surface features / λ = 3 cm ✓ ; 1

(ii) Credit may be found in (a)(i), but no double counting
Relevant explanations of: **emission** – wave energy related to its source
e.g. microwave transmitter on orbiting satellite emits microwave pulses ✓ ;
transmission – wave energy propagates through medium
e.g. radar pulse travels through Venus dense atmosphere ✓ ;
absorption – wave energy lost to warming the medium
e.g. radar waves may be absorbed by atoms in the atmosphere / surface ✓ ;
reflection – wave energy bouncing off layers of different density and returning to detector e.g solid surface of Venus reflects microwaves strongly ✓ ;
timing of echo reflected pulses e.g. distance from (c x Δt) / 2 ✓ ;
detection of return signal strength e.g. reflected amplitude measured and given digital / false colour code ✓ up to max. 4
Give credit for any other relevant physics points made
A clearly annotated diagram is OK for full marks

(b) Any enhancement technique ✓✓✓ 1/2/3 style OR manipulation **mentioned** e.g. smoothing / rank filtering / edge detection / false colour / contrast adj. etc. AW ✓ 1

description e.g. colours are added to bands of pixel values visualising contours ✓ 1

Explanation of enhancement: A 3-d image of Venus surface can be created / hidden detail can be made apparent AW / emphasis of surface detail etc. ✓ 1

(c) Use of image clearly stated e.g.
make clear invisible surface features on another planet ;
more detail e.g. to decide if Venus is shaped by volcanic activity ;
One reason for human benefit / scientific interest e.g.
to understand tectonic / other forces shaping planets ✓✓✓ 1/2/3 style 3

12. (a) Choice of material e.g. copper ✓ ; 1
linked to suitable application e.g. electrical wiring (in a flexible extension lead ✓) 1

(b) Qualified relevant property stated e.g. high electrical conductivity ✓ ; 1
Explanation of relevance of property
e.g. without good conductivity, it would offer higher resistance to the flow of electrical current and drop the voltage at the device connected to the lead. It would also dissipate heat by Joule heating and if wound up might overheat causing a fire risk. ✓✓✓ 1/2/3 style 3

(c)(i) Numerical scale of structure clear e.g. atomic spacing about 0.1 nm ✓ ; 1
Description of structure and labelled diagram
e.g. diagram showing close packed planes / + ions and free electrons
✓✓✓ 1/2/3 3

(ii) Link between structure and a property required by (a) e.g. copper wire needs to be flexible so that the lead can bend plastically. This involves slip of the close packed planes over each other by dislocations.
A few bonds are stretched and broken at a time. ✓✓✓ 1/2/3 style 3

Quality of written communication 4

30

Marking quality of written communication

The appropriate mark (0-4) should be awarded based on the candidate's quality of written communication in Section C of the paper.

4 max The candidate will express complex ideas extremely clearly and fluently. Answers are structured logically and concisely, so that the candidate communicates effectively.
Information is presented in the most appropriate form (which may include graphs, diagrams or charts where their use would enhance communication). The candidate spells, punctuates and uses the rules of grammar with almost faultless accuracy, deploying a wide range of grammatical constructions and specialist terms.

3 The candidate will express moderately complex ideas clearly and reasonably fluently. Answers are structured logically and concisely, so that the candidate generally communicates effectively. Information is not always presented in the most appropriate form. The candidate spells, punctuates and uses the rules of grammar with reasonable accuracy; a range of specialist terms are used appropriately.

2 The candidate will express moderately complex ideas fairly clearly but not always fluently. Answers may not be structured clearly. The candidate spells, punctuates and uses the rules of grammar with some errors; a limited range of specialist terms are used appropriately.

1 The candidate will express simple ideas clearly, but may be imprecise and awkward in dealing with complex or subtle concepts. Arguments may be of doubtful relevance or obscurely presented. Errors in grammar, punctuation and spelling may be noticeable and intrusive, suggesting weakness in these areas.

0 The candidate is unable to express simple ideas clearly; there are severe shortcomings in the organisation and presentation of the answer, leading to a failure to communicate knowledge and ideas. There are significant errors in the use of language which makes the candidate's meaning uncertain.

Abbreviations, annotations and conventions used in the Mark Scheme	m	= method mark
	s	= substitution mark
	e	= evaluation mark
	/	= alternative and acceptable answers for the same marking point
	;	= separates marking points
	NOT	= answers which are not wortyh of credit
	( )	= words which are not essential to gain credit
	___	= (underlining) key words which **must** be used to gain credit
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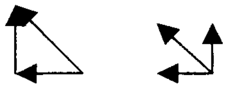
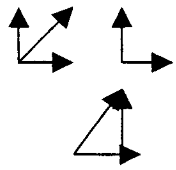
Question			**Expected answers**	**Marks**	**Additional guidance**
1	(a) (b)		3 m, ✓ 30 μm ✓	2	
2	(a) & (b)		Correct vector diagram ✓ Direction 321°, 39° W of N, 51° N of W ✓ Speed calc M✓ , 38 m s^{-1} ✓	4	
3	(a)		(A leads by B) by 90° / π/2 / ¼ period / 270° ✓	1	Allow ¼ wave(length)
	(b)		A ↓ ✓ B ← ✓	2	
4	(a)		ΔGPE = $mg\Delta h$ ✓ = 706 J ✓ sfe penalty for > 3 sf	2	g=10 → 720 J g=9.81 → 706 J
	(b)		**ANY 2** *g* perpendicular to Earth's surface ✓ same mass ✓ same *g* ✓ independent of route ✓ gravitational potential energy depends on (Δ*h*) ✓	2	
5			Use $s = vt$ ✓ Distance = 5.1 m ✓ Since it is an echo wall is 2.6 m away ✓	3	M ✓ E ✓ X ½
6	(a)		→ → → (all 3 same length ✓ and in same direction ✓)	2	
	(b)	(i)	→ ✓	2	
		(ii)	ratio = 3:1 ✓		Allow 1:3
			Total for section A	**20**	
7	(a)	(i)	Use $F = ma$ ✓ a = 4.2 m s^{-2} ✓	2	Allow use of 10 kN or 20 kN
		(ii)	Use $v = at$ ✓ t = 2.4 x ✓ (ecf)	2	
	(b)	(i)	Use $P = Fv$ ✓ F = 2500 N ✓	2	
		(ii)	F = 5 kN to 10 m s^{-1} ; ✓ Decreasing line passing through F = 2500 N, 20 m s^{-1} (ecf) ✓ Concave shape drawn ✓ Explanation of curve e.g. Fv = constant or calc of more points ✓	4 10	

8	(a)	(i) (ii)	Correct vector diagram ✓ labelling components (words or values) ✓ 42 cos 30° = 36(.4) m s^{-1} ✓ 42 sin 30° = 21 m s^{-1} ✓ horizontal v = 36 m s^{-1} ✓ ecf vertical v = zero ✓	2 2 2	
	(b)	(i)	Use $v = at$ ✓ or 0 = 21 t – ½ 9.8 t^2 ✓ or $\frac{\Delta v}{\Delta t} = a$ t = 2.1 s ✓ t = 4.3 s ✓✓ $\frac{-42}{\Delta t}$ = -9.81 2t = 4.3 s ✓ Δt = 4.3 s **must** be Δv ✓✓✓ use $s = vt$ s = 160 m (156 m) ✓ (ecf)	3 1 10	M✓ E✓ (watch for use of u or v = 42 m s^{-1} x) x 2 ✓
9	(a)		$d \sin \theta = n\lambda$ ✓	1	allow $d \sin \theta = \lambda$ give mark if seen below
	(b)	(i) (ii)	use n = 2, d = 2.5 μm ✓ and substitute correctly ✓ θ_1 = 28.11° ✓ θ_2 = 28.14° ✓ spacing = d (tan θ_2 – tan θ_1) ✓ spacing = 3.0 (tan 28.14° - tan 28.11°) ✓ = 2.1 x 10^{-3} m✓ sin $\theta \to$ 1.4 x 10^{-3} m r Δ $\theta \to$ 1.6 c 10^{-3} m $n \lambda = d$ x l / $L \to$ 1.4 x 10^{-3} m	4 3	if n = 1 → 13.626° and 13.641° 2 max if only 3 sf then 2 max method ✓ subst✓ eval✓ (ecf from (i)
	(c)		difference in wavelengths = 0.6 nm ✓ in approx 600 nm = 1/1000 = 0.1% ✓	2 10	
10	(a)	(i) (ii) (iii)	$E = hc\lambda$ ✓ = 3.6 x 10^{-19} J ✓ 180 x 3.6 x 10^{-19} J = 6.5 x 10^{-17} J ✓ 180 in 3600 s ✓ gives prob/s = 0.050 s^{-1} ✓	2 1 2	Method ✓ evaluation ✓ ecf
	(b)	(i) (ii)	**Continuous curved** wavefronts concance to rhs✓ Converge on focus / same spacing ✓ **ANY 3** Many paths to focus ✓ Photon 'tries all paths' ✓ Paths take equal times ✓ (mirror curved) to make paths of equal length ✓ phasors along all paths 'line up' / arrive in phase✓ 'lining up' gives large resultant amplitude ✓ probability related to (resultant amplitude)^2 ✓ 'least time principle' ✓	2 **3 max** 10	Shape ✓ Quality (need shape mark first)✓ More photons reflected on to the detector x Photons hitting mirror x
			Total for Section B	**40**	

Section C

See also guidance through examples on separate sheet

11	(a)		Flash seen instantaneously, estimate distance from distance covered by sound in 5.0 s ✓ Distance = 1700 m ✓	2	
	(b)	(i) (ii) (iii)	Suitable example ✓ Relevant physics principle for measurement ✓✓ Procedure / suitable set of measurements / further details described ✓✓ Appropriate formulae ✓ to give value for distance ✓ Two uncertainties stated ✓✓ Correctly linked to effect on value for distance ✓✓	1 2 2 2 2 2 13	
12	(a) (b)	 (i) (ii) (iii)	Same spacing as before the gap ✓ Straight centre section ✓ and curved edges ✓ Sensible practical situation ✓ Description/ diagrams of apparatus ✓✓✓ Sensible dimensions ✓✓ Angular spread depends on width of gap ✓ Use of formula to back up prediction ✓ Easier to observe with monochromatic waves ✓ Strong central maximum Aware of subsidiary maxima ✓ Observe spread into 'shadow region' ✓ Appropriate measurements ✓ Leading to calculation ✓ Other sensible physics up to max 4	 3 1 5 **4 max** 13	(✓✓ for correctly spaced semicircles) source, aperture, detection observations of appropriate diffraction effects can be credited even if the method described in (ii) is not feasible
			QoWC (see separate guidance and exemplar material)	**4**	
			Total for section C	**30**	
			Total for paper	**90**	

Possible marking points for Section C questions
Question 11 – Remote sensing

	Ultrasound scanning	**Underwater Sonar**	**Fault in metal**
Physical principle (2)	Ultrasound ✓ Reflected from foetus ✓	Ultrasound ✓ Reflects from seabed / wreck / shoal etc ✓	Ultrasound ✓ Reflects from fault in metal ✓
Procedure, measurements, further details (2)	Need matching gel for good contact between transmitter and skin ✓ strength of signal depends on type of tissue ✓ Bone is better reflector than soft tissue ✓	Location of transmitter and microphone ✓ consequences if not adjacent ✓ measure time between signals ✓	Transducer needs matching fluid for good contact with metal ✓ Need to consider relationship between pulse rate and transit time ✓ detail about transducer / detector ✓
Data processing (2)	Distance = speed x time ✓ Halve → depth of tissue ✓	Distance = speed x time ✓ Halve → depth of object ✓	Distance = speed x time ✓ Halve → depth of fault ✓
Uncertainty & detail of consequence (2 x 2)	Speed of wave changes with tissue ✓ → Lack of precision about distance ✓ Pulse rate important → return signals confused ✓	Something else in path of wave may reflect ✓ → wrong location of object ✓ position of ship on surface may change ✓ → error in timing and hence location ✓	Smearing of pulse ✓ → poor resolution of location ✓ identification of material essential✓ for correct wave speed calculation ✓ small faults return small signal ✓ may be missed in noise ✓

	Moon	**Aeroplane**	**Remote radio mast**
Physical principle (2)	Microwaves ✓ reflects from Moon ✓	Radio waves ✓ transmitted, reflected from plane and received ✓	Take a bearing from 2 different points (A & B) ✓ A known separation apart ✓
Procedure, measurements, further details (2)	Reflector on Moon needed ✓ Some property of detector ✓ Measure time for return trip ✓	Pulsed transmission of waves ✓ Detail about transmitter / receiver ✓	Use a compass to take bearings ✓ Measure distance AB
Data processing (2)	Distance = speed x time ✓ Halve → distance of Moon ✓	Distance = speed x time ✓ Halve → distance of plane	Use sine rule for triangulation ✓ with details ✓
Uncertainty & consequence (2 x 2)	Atmosphere changes speed of waves → error in Δt and distance ✓ Small change in position of reflector → large change in direction of reflection ✓	Something in path of wave ✓ → gives false location ✓	Error in bearing ✓ → error in distance ✓ error in measuring AB ✓ → error in distance ✓

Possible marking points for Section C questions
Question 12

	Single slit diffraction	Young's slits	Microwaves
Apparatus (3)	Source ✓ Slit / aperture ✓ Screen ✓	Source – light plus slit or coherent Source ✓ Slits ✓ Screen ✓	Source ✓ Slit(s) ✓ Detector ✓
Dimensions (2)	Slit width λ - 10λ ✓ Slit – screen distance > 1 m	Slit separation < 1 mm ✓ Slit-screen distance > 1 m ✓	Gap 3 cm ✓ Slit – detector 0.3 m – 1 m ✓
Observations (4)	Fringe pattern ✓ Light spread into 'shadow region' ✓ Strong central maximum ✓ Subsidiary maxima ✓ Width of spread depends on slit width ✓ Easier to observe with monochromatic light ✓ Different pattern with different wavelengths ✓	Fringe pattern ✓ Light spreads into 'shadow region' ✓ Easier to observe with monochromatic light ✓ Measure fringe separation ✓ hence calculate λ or D ✓ Observe fringed where 2 diffraction patterns overlap ✓	Measure intensity perpendicular to propagation ✓ Hence deduce amount of diffraction ✓ Change gap size > change in diffraction ✓ Subsidiary maxima ✓ Investigate polarisation of diffracted wave ✓ 999

	Radio waves around building	Electron diffraction	Diffraction grating
Apparatus (3)	Radio transmitter ✓ Suitable obstacle ✓ Receiver ✓	Electron tube ✓ High voltage supply ✓ Graphite target ✓	Source – light plus slit or coherent Source ✓ Grating ✓ Screen ✓
Dimensions (2)	Wavelength of radio waves 10 – 500 m ✓ size of houses / hills comparable to wavelength	Voltage 1-5 kV ✓ Diffraction target grid 10^{-10} m ✓	Slit separation < 1 mm ✓ Slit-screen distance > 1 m ✓
Observations (4)	Varying signal strength with position ✓ spreading of waves into 'shadow' of obstacle ✓ Change wave bands to observe effect of wavelength ✓ No effect with long waves ✓	Without target small spot in centre of screen ✓ Concentric rings on fluorescent screen ✓ radius of ring depends on accelerating voltage ✓ Central ring is brightest ✓ measure ring radius, V, ✓ calculate separation of atoms in graphite✓	Fringe pattern ✓ Easier to observe with monochromatic light ✓ measure fringe separation ✓ hence calculate λ or d ✓ Colour in fringes ✓ Relate colour to position ✓ Orders ✓

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