OCR ADVANCED SUBSIDIARY GCE
PHYSICS B (Advancing Physics) (3888)

OCR ADVANCED GCE
PHYSICS B (Advancing Physics) (7888)

Specimen Question Papers and Mark Schemes

These specimen assessment materials are designed to accompany the OCR Advanced Subsidiary and Advanced GCE specifications in Physics B (Advancing Physics) for teaching from September 2000.

Centres are permitted to copy material from this booklet for their own internal use.

The GCE awarding bodies have prepared new specifications to incorporate the range of features required by new GCE and subject criteria. The specimen assessment material accompanying the new specifications is provided to give centres a reasonable idea of the general shape and character of the planned question papers in advance of the first operational examination.

CONTENTS

Advanced Subsidiary GCE

A2

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

Physics B (Advancing Physics)
PHYSICS IN ACTION **2860**

Specimen Paper

Question number	For examiner's use only
1	
2	
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7	
8	
9	
10	
11	
12	
13	
WC	
TOTAL	

Candidates answer on the question paper.

Additional materials:
Advancing Physics Reference Booklet

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

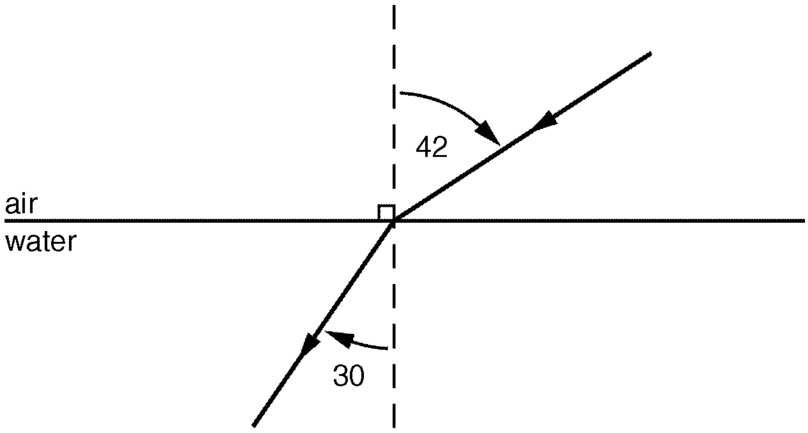
- Write your name, Centre number, Candidate number and Centre name in the spaces at the top of this page.
- Answer **all** the questions.
- Write your answers, in ink, in the spaces provided on the question paper. Extra paper should not be used.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

The values of standard physical constants are given in the Reference booklet. Any additional data required will be given in the appropriate question.
The approximate number of marks for each part question and the total for each question is given in brackets [ ].
You are reminded of the need for good English and clear presentation of your answers.
There are 4 marks for Quality of Written Communication on this paper

SECTION A

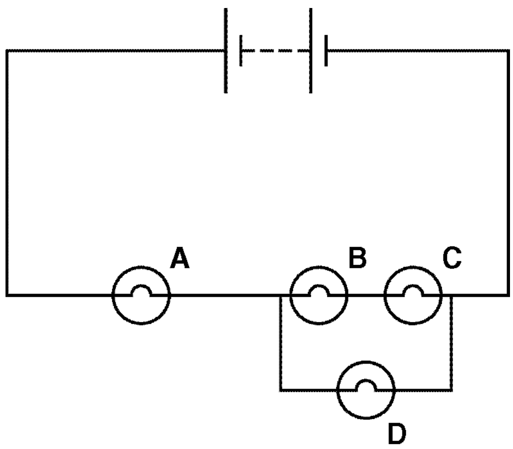
1 The diagram shows a ray of light crossing an air-water surface.



Calculate the refractive index of water.

refractive index = ___________ [3]

2 The circuit shows an arrangement of four identical lamps.



(a) Two of the lamps **A, B, C, D** have the **same** brightness. Name them.

______________ and ________________ [1]

(b) Which lamp will have the greatest current passing through it? ________________ [1]

Total: [2]

3 The lamp of a spotlight is rated at 230 V 1500 W. When the lamp is operating normally:

(a) show that the current is about 6.5A,

[1]

(b) calculate the resistance of the filament at this current.

Resistance =__________ ? [2]

Total: [3]

4 A local FM radio station broadcasts at 90 MHz.
Calculate the wavelength of the signal.

Wavelength = _________ m [3]

5 **(a)** Which of the following is the best estimate of the diameter of an atom?

10^{-14} m 10^{-10} m 10^{-7} m 10^{-3} m

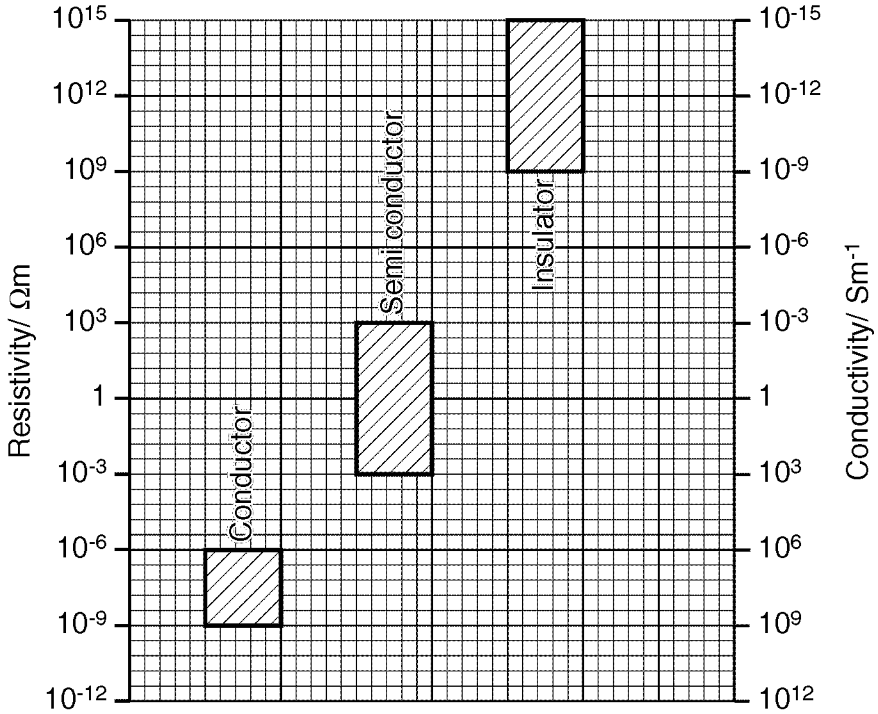
diameter of atom = _________ m [1]

(b) The width of conductors in microchips can be as small as 0.1 μm.
Calculate the number of atoms across this width.

Number of atoms =____________ [1]

Total: [2]

6 The chart shows the approximate range of resistivity and conductivity values for three classes of materials.



(a) Write down the **minimum** resistivity of a semiconductor

minimum resistivity = _________ Ω m [1]

(b) What would be the electrical properties of a material with a conductivity of $10^{-12}Sm^{-1}$?

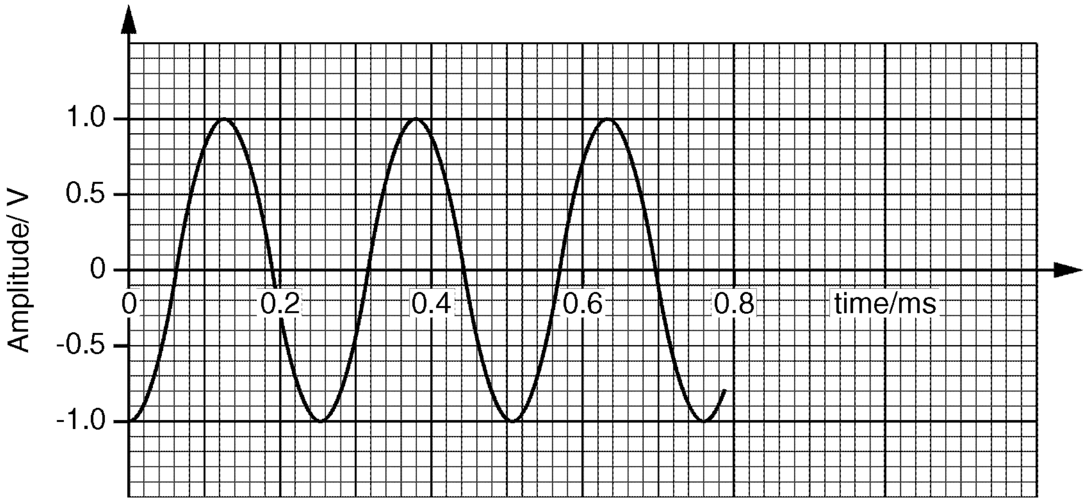
[1]

(c) Suggest why metals have much higher conductivities than insulators.

[2]

Total: [4]

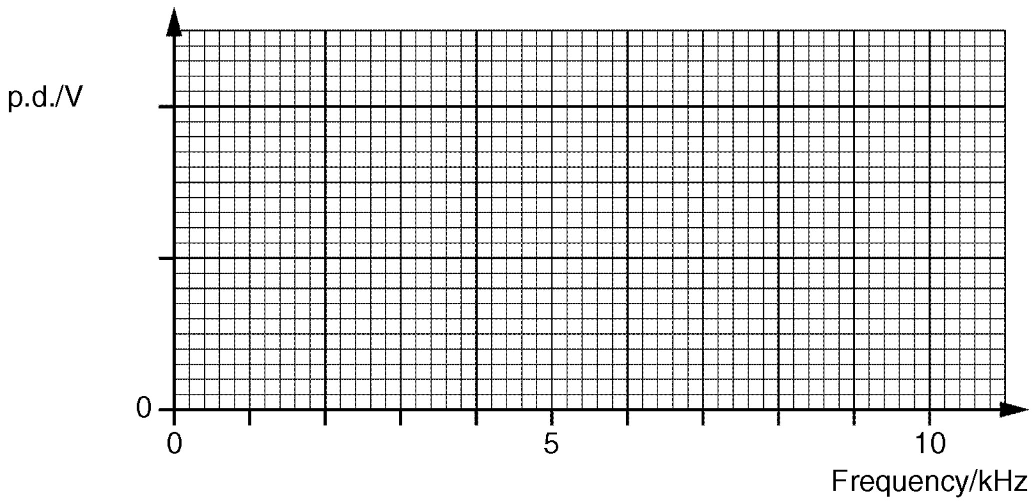
7 The diagram shows a signal in the form of a pure sine wave.



(a) Explain what is meant by the **frequency spectrum** of a signal.

[1]

(b) Sketch the frequency spectrum of the signal.



[2]

Total: [3]

SECTION B

8 This question is about testing a new material.
You are provided with samples of a new brittle material which is claimed to have a fracture stress of about 5 MN m^{-2}.

Samples are available as strips roughly 1 to 2 mm thick and 5 to 10 mm wide, in any length up to 1 m.

(a) Explain what is meant by the word brittle.

[1]

(b) Describe in outline what you would do to check on the claimed value of the fracture stress (details of experimental procedure are not required). State what you would measure and how you would calculate your result.

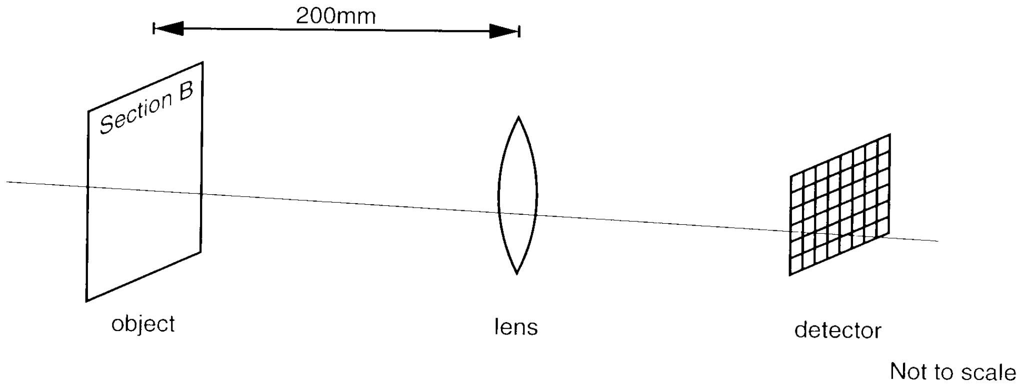
[6]

(c) Will it be possible to provide the required breaking force using ordinary laboratory equipment? Use the data above to justify your answer.

[3]

Total: [10]

9 This question is about a digital camera.



The lens of the camera is 200 mm away from the object. The lens has a focal of length 5.00 mm. It produces a sharp image on the detector.

(a) Calculate the power of the 5.00 mm lens.

power = _________ D [2]

(b) Calculate the distance from the lens to the detector.

distance = ________ mm [2]

(c) The detector has an array of 10^6 discrete light-sensitive elements in a square of side 2.5 mm.

(i) Show that the width of each element is 2.5 μm.

(ii) Calculate the distance this width corresponds to on the object.

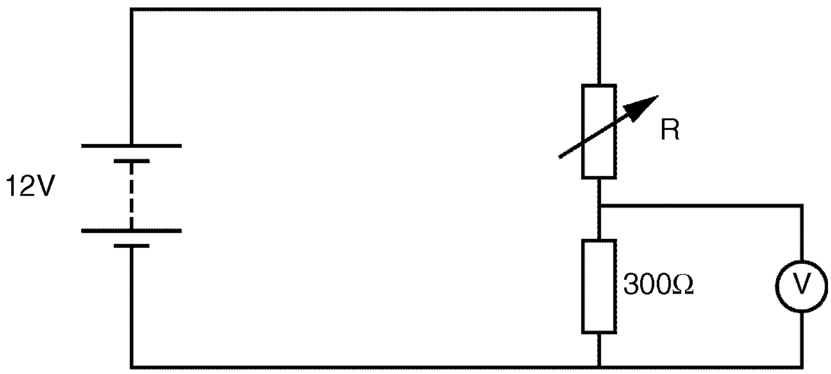
distance = ________ mm [3]

(d) The object being imaged is this page. Comment on the quality of image that would be produced by this camera.

[2]

Total: [9]

10 This question is about a potential divider circuit.



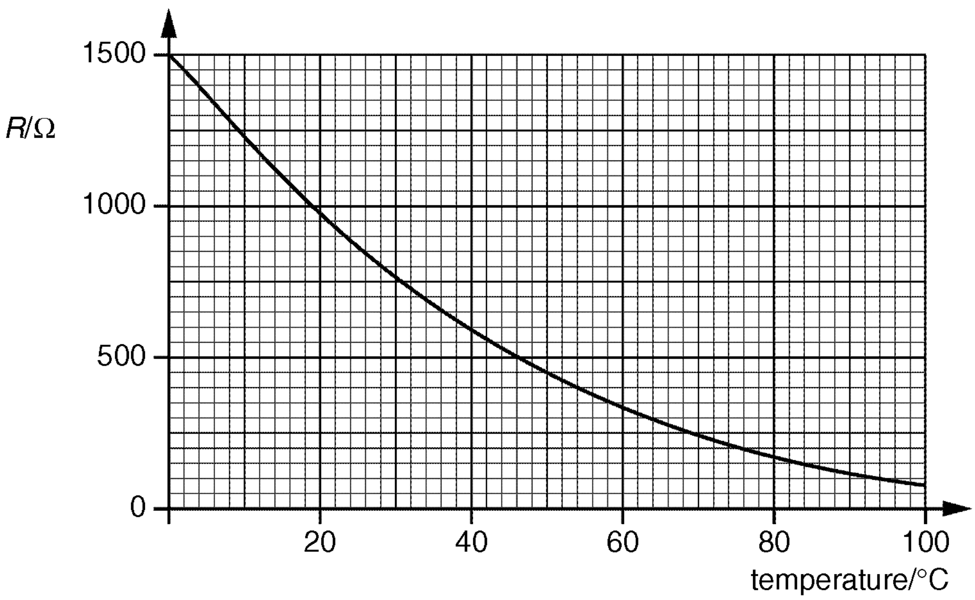
The circuit diagram shows a 12 V battery connected across a variable resistor and a 300 Ω resistor. When a high resistance voltmeter is connected across the 300 Ω resistor the p.d. registered by the voltmeter changes as the resistance of the variable resistor, ***R*****,** changes.

(a) Describe what happens to the voltmeter reading as *R* decreases.

[1]

The variable resistor is replaced by a thermistor .

The graph shows how the resistance of the thermistor varies with temperature.



(b) **(i)** Use the graph to find the resistance *R* of the thermistor at 0°C and 100 °C.

Resistance *R* of thermistor at 0°C = ____________ Ω

Resistance *R* of thermistor at 100°C = ____________ Ω

(ii) Calculate the current in the circuit when the thermistor is at 0°C.

current = _______________ A

(iii) Hence calculate the voltmeter reading when the thermistor is at 0°C.

voltmeter reading = _______________ V

(iv) Show that the voltmeter reading at 100 °C is approximately 10 V.

[8]

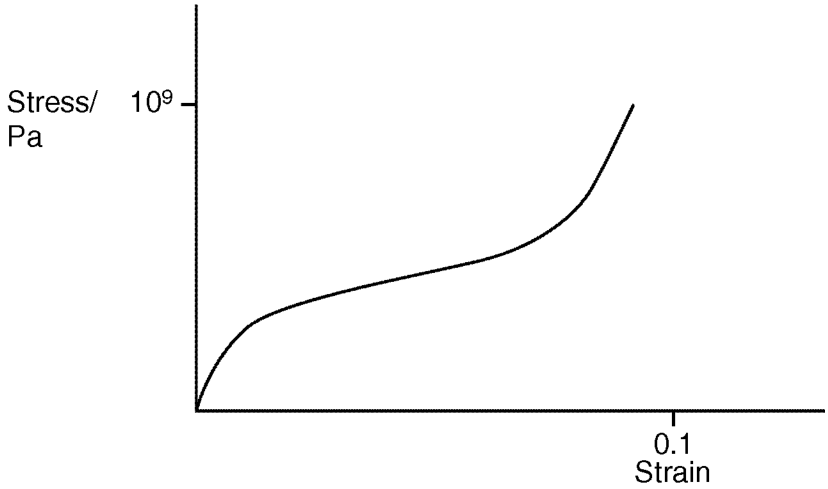
(c) Some instruments have a linear response, others are non-linear. Using the graph, discuss the response of this thermistor.

[2]

Total: [11]

11 This question is about the properties of climbing ropes.

The graph shows the relationship between stress and strain for a climbing rope.



(a) Explain the significance of the gradient of the graph

[2]

(b) Using appropriate scientific terms, describe how the material behaves as it is stretched until it breaks.

[3]

(c) A particular nylon rope breaks when the tension is 120 kN. Using information from the graph, calculate the cross-sectional area of this rope on breaking.

Area = _________ m^2 [3]

(d) In the event of a fall, the climber will first fall under gravity as the rope straightens and then be brought to rest as the rope stretches. Suggest why a nylon rope would be particularly suitable for absorbing the energy of the falling climber without causing injury.

[2]

Total: [10]

SECTION C

In this section of the paper you have the opportunity to write about some of the physics you have studied independently**.**
Use diagrams to help your explanations and take particular care with your written English. Up to four marks will be awarded in this section for the quality of communication.

12 This question is about choosing a material for a particular application, and the properties the material must have in order to be suitable for its purpose.

(a) Describe, briefly, an application for which a material must be carefully chosen to have the appropriate properties.

[-]

(b) **(i)** State **two** properties that the material must have for it to be suitable for this application.

(ii) Why must the material have these properties?

[4]

(c) **(i)** Choose an appropriate material to be used in this application, and discuss the reasons for your choice.

(ii) Explain how the structure of the material chosen gives it **one** of the required properties.

[6]

(d) Comment on how **one** of the factors – availability; cost; aesthetics; or culture and tradition – influence the choice of material in this case.

[3]

Total: [13]

13 This question is about choosing an electrical or electronic sensor for a particular application.

(a) (i) Describe, briefly, an application in which a sensor is required.

(ii) Describe the purpose of the sensor, and explain the importance of the measurement in this application.

(iii) Suggest a suitable sensor for this purpose.

[4]

(b) (i) Draw a circuit or block diagram showing how the output from the sensor can be obtained as a suitable electrical signal which can provide values of the quantity to be measured.

(ii) Describe how the circuit works.

[6]

(c) Write down one characteristic of the sensor which makes it a good choice in this application. Justify your answer.

[3]

Total: [13]

Quality of written communication [4]

Oxford Cambridge and RSA Examinations

Advanced Subsidiary GCE

Physics B (Advancing Physics)
PHYSICS IN ACTION **2860**

Mark Scheme

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 the method, 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 numbers of significant figures in a final answer are penalised by the loss of a mark, generally once 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. Missing or incorrect units in a final answer are penalised by the loss of a mark, generally once per examination paper.
- Quality of written communication will be assessed in Section C where there are more opportunities to write extended prose.

Within the marks scheme the following notation is adopted

m	– method mark
s	– substitution mark
e	– evaluation mark
;	–separates individual marking points
/	– separates alternative answers
= 0	– common answers which should not be given credit
ecf	– error carried forward
owtte	– or words to that effect
( )	– material in brackets not needed for mark
vv	– vice versa

Qn		level	Expected answers	Marks	Additional guidance
SECTION A					
1		E	sin42 / sin30 ✓ = 0.67 / 0.5 n = 1.34✓	3 **3**	equation✓ substitution✓ evaluation✓
2	**(a)**	E	B & C ✓	1	
	(b)	E	A ✓	1 **2**	
3	**(a)**	E	I=P/V=1500/230=6.52A✓	1	
	(b)	E	$1500 = 230^{2} / R$ ✓ $R = 35.3$ ✓ (Ω)	2 **3**	m✓ e✓ or equivalent calculation
4		E	v = fλ ; λ = 3✓ x 10^8/90 x 10^6 = 3.33m ✓✓	**3**	m✓ e✓
5	**(a)**	E	10^{-10} m✓	1	
	(b)	E	0.1μm / 10^{-10} m = 1000 atoms✓	1 **2**	allow ecf
6	**(a)**	E	10^{-3} Ω m✓	1	
	(b)	E	Insulator✓	1	
	(c)	C/D	metals have more✓ more mobile✓ electrons than insulators owtte	2 **4**	
7	**(a)**	C/D	The spectrum of frequencies **required to synthesise the signal**✓	1	
	(b)	B/A	Single line✓; at 4.0 kHz✓	2 **3**	
			Section A total	**20**	

SECTION B

8	**(a)**	E	brittle – little extension before fracture	1	
	(b)	E	Clamp strip at both ends, and pull it ✓with force increasing gradually in steps until it fractures ✓. Note force F at fracture ✓.	6	
		D/C	Measure thickness t and width w✓ Calculate cross section t w ✓. Fracture stress is F/t w. ✓		
	(c)	A/B	If strip is 1 mm x 10 mm cross section is 10 mm^2 or 10^{-5} m^2 ✓ If fracture stress is 5 MN m^{-2} then strip fractures at force 50 N ✓, or about 5 kg weight. Not difficult to provide, with weights for example ✓.	3	
				10	
9	**(a)**	E	+200 D ✓✓	2	m✓ e✓
	(b)	D/C	$({}^{1}/_{200} - {}^{1}/_{5}) = {}^{1}/_{u}$;✓ 5.13✓ mm	2	m✓ e✓(or equivalent calc)
	(c)(i)	E	$2.5 \times 10^{-3} / 10^{3} = 2.5 \times 10^{-6}$ ✓m	1	
	(ii)	B/A	magnification approximately (200 mm/5 mm) = 40;✓ distance on object = 40 x 2.5 µm = 0.1 mm ✓	2	
	(d)	B/A	line width on page approx. equivalent to 1 pixel - so detail reasonable;✓ image would be 10^{3} × 0.1 mm square = 10 cm - so whole page not visible;✓	2	or other valid points
				9	
10	**(a)**	C/D	as R decreases V increases✓	1	
	(b) (i)	E	R_0 = 1500 Ω ✓ R_{100} = 75 Ω ✓	2	
	(ii)	E	*I* = 12 / (1500 +300) ✓ = 0.66 A✓	2	m✓ e✓ allow ecf
	(iii)	E	V = 0.66 x 300 = 2 A✓✓	2	m✓ e✓
	(iv)	E	V = 12 / (75 + 300) x 300 = 9.6 V ✓✓	2	m✓ e✓ allow ecf
	(c)	B/A	graph shows non-linear✓ discussion about value of V for (say) 50°C✓	2	
				11	
11	**(a)**	E	Gradient = Young modulus ✓ Measure of stiffness of material ✓	2	
	(b)	E	stiff ......✓ less stiff .... ✓stiff✓	3	
	(c)	B/A	breaking stress = 10^{9} ✓Pa $10^{9} = 1.2 \times 10^{5}$ / A;✓ $A = 1.2 \times 10^{-4}$ ✓m^2	3	
	(d)	C/D	climber brought to rest over longer distance ✓.... smaller force ...✓ less danger✓ OR energy absorbed as rope stretches✓ ... force increases gradually ✓.. reducing shock✓	2	Any 2 points
				10	
			Section B total	**40**	

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 satisfactory, but contains errors
3 will indicate the description is essentially correct

12	**(a)**		Clear choice of application		
	(b)(i)	E	two properties	2	
	(ii)	C/D	+ reasons	2	
	(c)(i)	C/D	material ✓+ reasons ✓✓	3	1/2/3 style
	(ii)	A/B	property clearly linked to structure ✓✓✓	3	1/2/3 style
	(d)	C/D	clearly identified and described factor✓ + influence✓	3	1/2/3 style
				13	
13	**(a)(i)**	E	Clear application chosen and described	1	
	(ii)	E	Purpose ✓ + importance ✓	2	
	(iii)	E	Suitable sensor ✓	1	
	(b) (i)	D/C B/A	Circuit or block diagram attempted, some correct elements;✓ circuit mostly correct✓ good circuit✓	3	1/2/3 style
	(ii)	D/C B/A	Some effort to describe✓ Description attempted, some correct elements ✓ description essentially correct✓	3	1/2/3 style
	(c)	B/A	Relevant characteristic such as sensitivity, resolution, response time, absence of systematic error or drift, absence of noise or random variation, is given✓ Explanation of the term given✓ Reason why important in this application✓	3	
				13	
			Quality of written communication	**4**	
			Section C total	**30**	

QoWC	Marking quality of written communication The appropriate mark (0-4) should be awarded based on the candidates quality of written communication in Section B of the paper.	**4** max
4	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 candidates meaning uncertain.	

Specification grid for OCR Physics B *Advancing Physics* | Specimen paper

Name of paper Unit 2860 Physics in Action | Component number: - | Page 1 of 1

Question number	Syllabus reference	Assessment objectives: Knowledge with understanding AS (60%) A2 (40%)	Assessment objectives: Application, synthesis and evaluation AS (40%) A2 (40%)	Assessment objectives: Synthesis – A2 (20%)	Total mark for paper 100%	Level of demand of question: E 35-45%	Level of demand of question: D-C 25-35%	Level of demand of question: B-A 25-35%	QoWC (4 marks)	
1	5.1.3	1	1		2	2				
2	5.1.2	2			2	2				
3	5.1.2	3			3	3				
4	5.1.1	2			2	2				
5	5.1.1	2			2	2				
6	5.1.3	3			3	1	2			
7	5.1.1		3		3		1	2		
8	5.1.1	2	1		3		1	2		
9	5.1.3	7	3		10	2	5	3		
10	5.1.1	3	6		9	3	2	4		
11	5.1.2	7	4		11	6	3	2		
12	5.1.2	2	8		10	5	3	2		
13	5.1.3	10	3		13	2	8	3		
14	5.1.2	5	8		13	4	4	5		
QoWC		4			4				4	
		53	37		90	34	29	23	4	

Oxford Cambridge and RSA Examinations

OCR
RECOGNISING ACHIEVEMENT

Advanced Subsidiary GCE

Physics B (Advancing Physics)
UNDERSTANDING PROCESSES **2861**

Specimen Paper

Additional materials:
Advancing Physics Reference booklet

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

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Question number	For examiner's use only
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13	
WC	
TOTAL	

SECTION A

1 For each of these astronomical distances, choose the quantity from the list nearest to it in size:

Increasing
distance

(a) Earth to Moon ______________ [1]

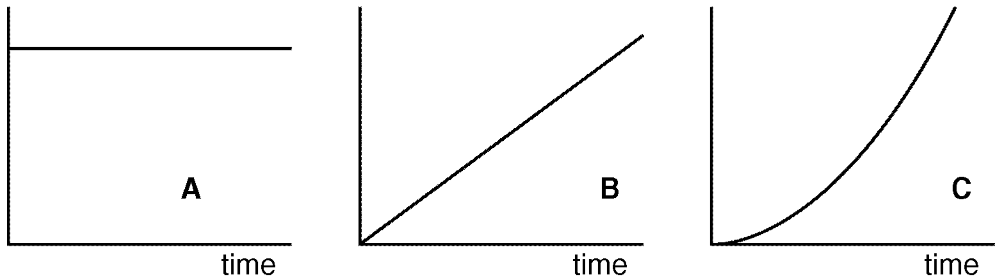
(b) Earth to Arcturus (a nearby star) ______________ [1]

(c) Diameter of the Universe ______________ [1]

1 light second 10^6 light years 10^{10} light years 10^{11} m 10^{18} m

Total: [3]

2 A car moves with uniform acceleration from rest. The graphs show three different quantities plotted against time during the period when the car has a uniform acceleration.



(a) Which of the graphs, **A**, **B**, **C** best represents the speed of the car plotted against time?

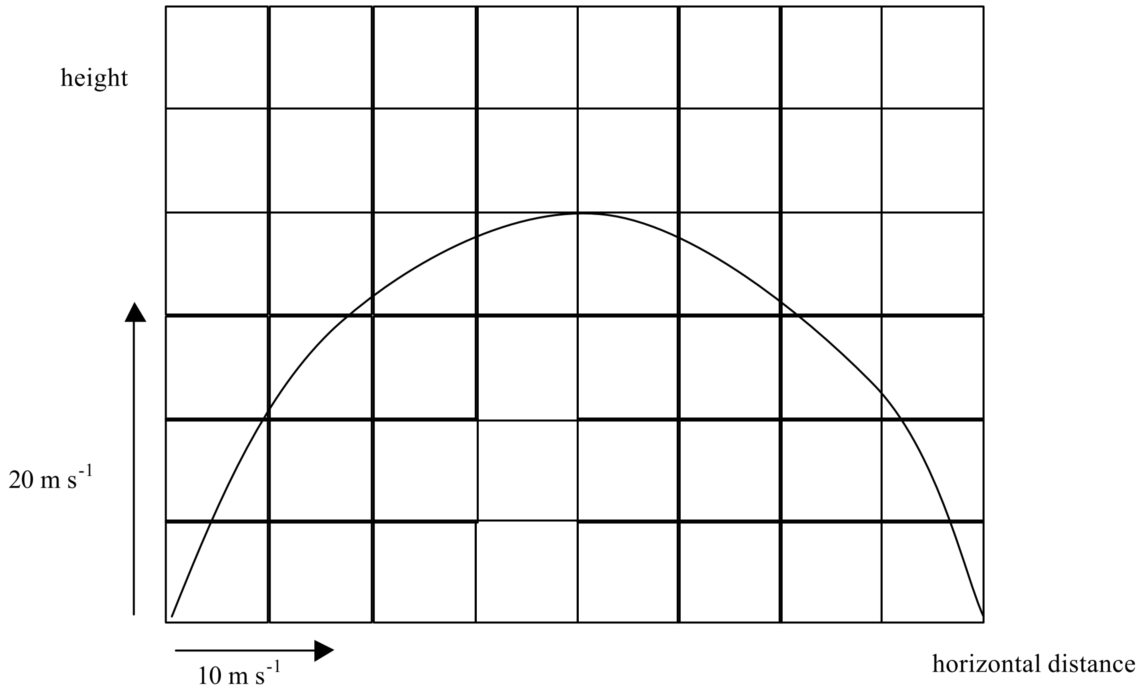
Graph __________ [1]

(b) Which of the graphs, **A**, **B**, **C** best represents the distance covered by the car plotted against time?

Graph __________ [1]

Total: [2]

3 A ball is lobbed in a tennis match as shown. The initial horizontal and vertical components of the velocity are shown on the diagram.



What is the ratio $\frac{\text{magnitude of vertical component}}{\text{magnitude of horizontal component}}$ after 0.5 s?

[2]

4 The Global Positioning System (GPS) allows a hand-held receiver to pick up radio signals from satellites and combine them to fix its position .

(a) One satellite is directly overhead in an orbit 2.656×10^7m above the Earth's surface.

Calculate how long the signal takes to reach the receiver from the satellite.

[2]

(b) The receiver can calculate its position to within 30m.
Discuss what this implies about the precision of the timing devices in the system.

[2]
Total: [4]

5 A laser pointer is directed at a diffraction grating so that the beam is at right angles to the grating surface. The grating has 6.0×10^5 slits per metre. The first order diffraction angle is measured as 22.6°.

(a) Show that the wavelength of the radiation is about 640 nm.

[2]

(b) Calculate the quantum energy of the photons being emitted by the laser.

[2]

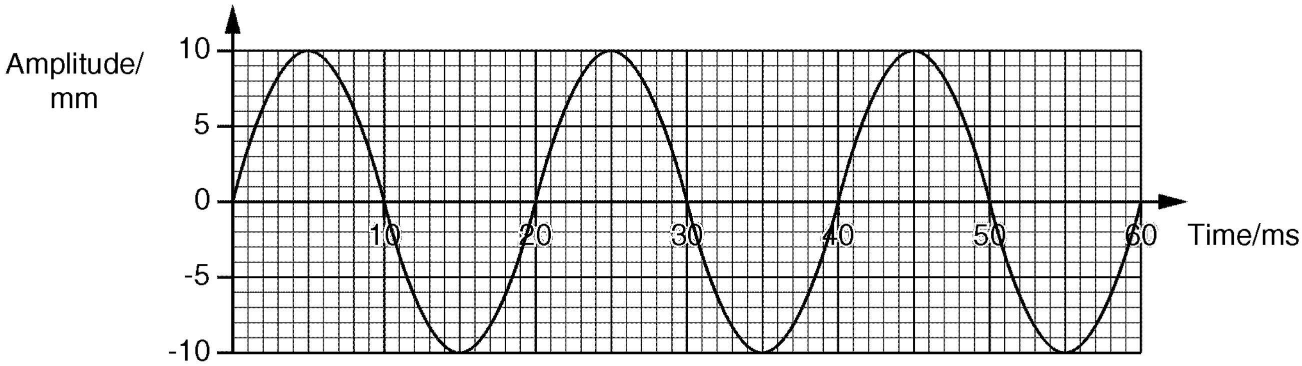
Total: [4]

6 When Apollo 11 travelled to the moon the crew turned the rocket motors off beyond a certain distance from the Earth and the spacecraft coasted towards its destination. The velocity component away from the Earth fell from 5500 m s^{-1} to 5454 m s^{-1} in two minutes. The mass of the spacecraft was 5×10^4 kg.

Calculate the average force towards the Earth on the craft at this time.

[3]

7 The graph shows a time trace for an oscillator. Add a second trace to the graph for an oscillator with half the amplitude and which is out of phase by 90° ($\pi/2$) with the first.



[2]

SECTION B

8 This question is about a famous video showing an astronaut dropping a feather and a hammer on the moon. They fell together.

The video was analysed to obtain values of the speed over the first 0.8 seconds of the drop. The data are shown in the table.

time / s	speed / m s^{-1}
0.00	0.00
0.20	0.32
0.40	0.64
0.60	0.96
0.80	1.28

(a) Discuss how the video might have been analysed to obtain values of the speed.

[2]

(b) Calculate the acceleration of free fall on the moon.

[2]

(c) **(i)** Sketch a speed-time graph for the hammer falling on the moon.

(ii) Describe and explain how the speed-time graph would be different if the hammer were dropped in a laboratory on Earth.

(iii) Comment on the motion of the feather in the laboratory on Earth.

[6]

Total: [10]

9 This is a question about measuring speeds and accelerations .

(a) 'A speed in miles per hour can roughly be converted to metres per second by halving the value'
Discuss this statement including a calculation.
(1 mile is about 1600 metres)

[2]

(b) Describe in outline what you would do to measure the speed of a car as it travels along a road at about 30 miles per hour.
State what you would measure and how you would calculate your results.

[3]

(c) Suggest possible sources of uncertainty in your measurement and make a reasoned estimate of the maximum error this causes in the final speed.

[3]

(d) If the car was accelerating at a uniform rate, describe how you could develop your method to estimate the acceleration of the car.

[2]

Total: [10]

10 This question is about a chest X-ray where a photographic film receives photons which have travelled through flesh and bone from a source.

(a) Explain why, although photons strike a particular place on the film 'randomly', a clear picture is built up

[2]

(b) The x-ray photons are produced by accelerated electrons colliding with a target.

Show that to produce an x-ray quantum energy of 10^{-15} J electrons must be accelerated through a potential difference of about 6 kV.

[2]

(c) Suppose that on average 10 x-ray photons fall on each grain of the photographic film, and the grains are about 1 μm across.

(i) Estimate the area of a film which covers the chest of a patient.

area = _______________ m^2

(ii) Use your estimate to estimate the total x-ray energy falling on the film.

total energy = __________ J [4]

(d) When all possible photon paths are summed, the amplitude for paths travelling through flesh is four times the size of the amplitude for paths travelling through bone.

Calculate the ratio $\dfrac{\text{Probability of arrival though flesh}}{\text{Probability of arrival through bone}}$

[2]

Total: [10]

11 This question is about a swan swimming in a river. When swimming in still water, it has a top speed of $2\ \mathrm{m\ s^{-1}}$
The swan is swimming in a straight river whose waters are flowing at a uniform speed of $5\ \mathrm{m\ s^{-1}}$

(a) Calculate the swan's speed relative to the bank if it swims at top speed
(i) downstream.

(ii) upstream.

[2]

(b) **(i)** Calculate the swan's velocity if it swims at top speed directly across the river.

(ii) The river is 10 metres wide.
Calculate how far downstream the swan will have travelled when it reaches the other side.

[5]

(c) The situation is actually more complex than this. One complication is that the river will flow more quickly at the centre than the edge. Discuss how this affects the swan's journey.

[3]

Total: [10]

SECTION C

In this section of the paper you have the opportunity to write about some of the physics you have studied independently.
Use diagrams to help your explanations and take particular care with your written English. Up to four marks will be awarded in this section for the quality of communication.

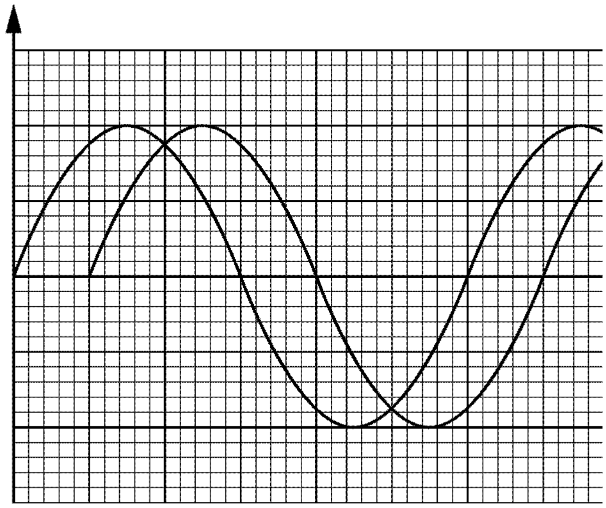
12 All around you at this very moment are sounds from many sources. The air at your ear vibrates in a complicated pattern made up of all these sounds. This is **wave superposition**.

(a) The graph shows two oscillations at a point, having the same amplitude and frequency but differing in phase.

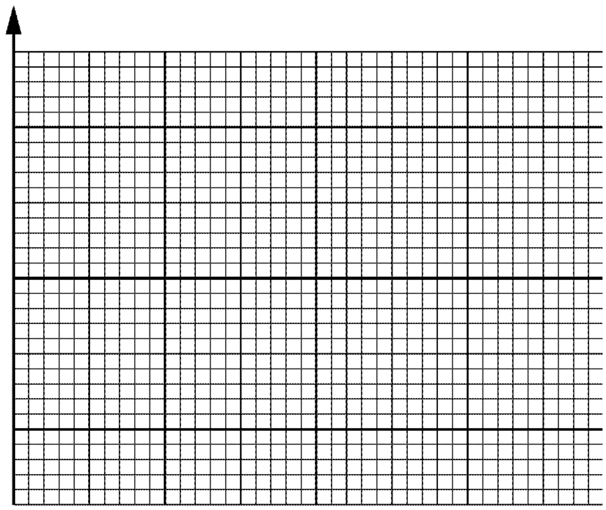
Use the blank grid to sketch a graph of the combined (superposed) effect of these two oscillations.

[2]

Amplitude



Amplitude



(b) Interference, diffraction and standing waves are all effects due to **wave superposition**. Choose any practical example or application of wave superposition to explain in detail.

(i) State the example or application you have chosen, discussing its practical importance or its interest in physics.

(ii) Illustrate your chosen example or application with a suitably labelled diagram that helps explain the physics of the situation.

(iii) Describe clearly what can be observed in your chosen example or application.

(iv) Say how the observations you have described can be explained. Write equations where applicable.

[11]

Total: [13]

13 Write a short account of an example of a method of measuring the distance to an object which is remote or inaccessible, so making a direct measurement with a tape-measure or ruler impossible. Choose an example which you believe to be of interest, practical value or benefit.

(a) **(i)** What example of a remote or inaccessible object have you chosen? State clearly why the distance cannot be measured directly.

(ii) Give one reason why the example you have chosen is of interest, practical value or benefit.

[3]

(b) **(i)** State the physical principles on which your method is based. Write down any relevant relationships between physical quantities

(ii) Assume that you have to specify carefully the construction of the measuring devices so that the measurement can be made as well as possible.
Explain how the method works and what the various components must do, together with the characteristics they need to have.

[9]

(c) State one factor which would limit the resolution (that is, the smallest detectable difference in distance) which could be achieved.

[1]

Total: [13]

Quality of written communication: [4]

Oxford Cambridge and RSA Examinations

RECOGNISING ACHIEVEMENT

Advanced Subsidiary GCE

PHYSICS B (Advancing Physics)

UNDERSTANDING PROCESSES **2861**

Mark Scheme

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 the method, and the other for the evaluation of the quantity to be calculated.
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- Where units are not provided in the question or answer line the candidate is expected to give the units used in the answer. Missing or incorrect units in a final answer are penalised by the loss of a mark, generally once per examination paper.
- Quality of written communication will be assessed in Section B where there are more opportunities to write extended prose.

Within the marks scheme the following notation is adopted

m	– method mark
s	– substitution mark
e	– evaluation mark
;	– separates individual marking points
/	– separates alternative answers
= 0	– common answers which should not be given credit
ecf	– error carried forward
owtte	– or words to that effect
( )	– material in brackets not needed for mark
vv	– vice versa

Qn		level	Expected answers	Marks	Additional guidance
SECTION A					
1	**(a)**	E	1 light second ✓	1	
	(b)	E	10^{18}m ✓	1	
	(c)	E	10^{10} light years ✓	1	
				3	
2	**(a)**	E	B✓	1	
	(b)	E	C✓	1	
				2	
3		C/D	after 0.5 s vertical is 15 m s^{-1}, horizontal still 10 ms^{-1} ✓ ratio 1.5✓	2	
				2	
4	**(a)**	E	2.656×10^7m ÷ 3×10^8 ms^{-1}✓ = 0.088s✓	2	
	(b)	C/D	T = 30m ÷ 3×10^8 ms^{-1} = 1×10^{-7}s✓ at least – might be better if something else is constraining position accuracy ✓	2	or other appropriate comment on value
				4	
5	**(a)**	E	$d = 1 \div 6 \times 10^5$ ✓ $\lambda = d\sin q = 1.67 \times 10^{-6} \times 0.384 = 6.4 \times 10^{-7}$m✓	2	
	(b)	E DC	E = hc÷λ ✓ $E = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{6.4 \times 10^{-7}} = 3.1 \times 10^{-19}$ J ✓	2	
				4	
6		E	(5500-5454)/120= 0.38 ms^{-2}✓ F = -0.38 ms^{-2} x 5×10^4 kg✓ = -19200N ✓	1 2 **3**	
7		E	amplitude ✓ phase✓	2 **2**	
			Section A total	**20**	

SECTION B

8	(a)	CD	Frame rate ✓ Distance measure✓	2	
	(b)	E	$a=\Delta v \div \Delta t$ ✓ $= 1.6\ ms^{-2}$ ✓	2	
	(c)(i)	BA	straight line✓ (some) values indicated✓	2	
	(ii)	AB	slope steeper✓ as this is acceleration✓	2	
	(iii)	BA	Acceleration tends to zero owtte✓ Fluid friction, drag owtte✓	2	
				10	
9	(a)	E	e.g. $30 \times 1600 \div 3600$ = about 13✓ ms^{-1} discussion / comment ✓	2	
	(b)	E	A means of measuring time ✓ and distance✓ speed = dist ÷ time✓	3	Using 1/2/3 scheme
	(c)	AB	either time or distance✓ Estimate of error✓ Effect on result✓	3	
	(d)	DC	eg time the car over two distance intervals ✓, and the time it took to get between them✓ (owtte for their technique)	2	
				10	
10	(a)	DC	The probability of arrival is known✓ , and some areas of plate have far higher probabilities of a photon striking than others (owtte) ✓	2	
	(b)	DC	Energy = eV $V = 10^{-15}\ J / 1.6\ 10^{-19}\ C$✓ $V = 6250\ V$✓	2	Must get intermediate value for ✓✓
	(c) (i)	E	area = 0.2 m x 0.3 m = $0.06\ m^2$ ✓	1	reasonable value
	(ii)	A/B	no of grains = $(6 \times 10^{-2} / 10^{-12}) = 6 \times 10^{10}$ ✓ no of photons = 6×10^{11} ✓ energy = $6 \times 10^{11} \times 10^{-15} = 6 \times 10^{-4}\ J$ ✓	3	estimate value carried forward
	(d)	A/B	implied probability of arrival proportional to square of amplitude✓ so ratio is 16 × as likely✓	2	
				10	
11	(a) (i)	E	$5+2 = 7ms^{-1}$ ✓	1	
	(ii)	E	$5-2= 3ms^{-1}$ ✓	1	
	(b)(i)	CD	by vector addition✓ $5.4ms^{-1}$ ✓at 21.8 to bank✓	3	
	(ii)	CD	journey time = 10/2 = 5s ✓at $5ms^{-1}$ so 25m✓ (or similar calc)	2	
	(c)	AB	sensible coherent argument e.g. that swan will not be as far downstream ✓✓ Possible sketch or description of path✓	3	
				10	
			Section B total	**40**	

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 satisfactory, but contains errors
3 will indicate the description is essentially correct

12	**(a)**	E	Correct line✓ adding amplitudes or lengths of phasor✓	2	
	(b)(i)	E	Sensible choice✓ linked to clear reason✓	2	
	(ii)	DC	Appropriate illustration✓clear ✓and well labelled ✓	3	1/2/3
	(iii)	DC	Broadly correct bare statement of observation (e.g. there are places where no signal is detected) Fuller and clearer detail (e.g. nodal lines along curved paths) ✓✓✓	3	1/2/3
	(iv)	BA	Explanation mentions waves in or out of phase ✓ Explanation mentions phase difference arising from path difference and wavelength (or time difference and difference in frequency) ✓ A correct equation is provided beyond $v = f\lambda$ ✓	3	
				13	
13	**(a)(i)**	E	Relevant example stated✓ Reason why it is inaccessible✓	2	
	(ii)	E	Relevant reason for choice	1	
	(b)(i)	E C/D	Relevant correct physical principle(s) stated e.g. time of flight of ultrasound pulse with known speed✓ Relevant correct equation e.g $2d = c\ \Delta t$ ✓	2	
	(ii)	2E 3C/D 2 B/A	Mark by presence of the following features, accumulating marks: At least one relevant component mentioned✓ Additional relevant components mentioned ✓ Function (job) of at least one component ✓ Description of how at least some components work together✓✓ Relevant characteristic of at least one component ✓ Instrument is discussed as a system, with functions and characteristics related ✓	7	
	(c)	A/B	Relevant factor stated✓	1	
				13	
			Quality of written communication	**4**	
			Section C total	**30**	

QoWC	Marking quality of written communication The appropriate mark (0-4) should be awarded based on the candidates quality of written communication in Section C of the paper.	**4** max
4	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 candidates meaning uncertain.	

Specification grid for OCR Physics B *Advancing Physics* — Specimen paper

Name of paper Unit 2861 Understanding Processes — Component number: - — Page 1 of 1

Question number	Syllabus reference	Assessment objectives: Knowledge with understanding	Application, synthesis and evaluation	Synthesis	Total mark for paper	Level of demand of question: E	D-C	B-A	QoWC	
		AS (60%) A2/4&5 (50%)	AS (40%) A2/4&5 (50%)	A2/6 (100%)	100%	35-45%	25-35%	25-35%	(4 marks)	
1	5.2.2	3			3	3				
2	5.2.2	2			2	2				
3	5.2.2	2			2		2			
4	5.2.2	2	2		4	2	2			
5	5.2.1	2	2		4	3	1			
6	5.2.2		3		3	3				
7	5..2.1	2			2	2				
8	5.2.2	4	6		10	2	2	6		
9	5.2.2	10			10	5	2	3		
10	5.2.1	4	6		10	1	4	5		
11	5.2.2	5	5		10	2	5	3		
12	5.2.1	7	6		13	4	6	3		
13	5.2.2	7	6		13	6	4	3		
QoWC		4			4				4	
		54	36		90	34	29	23		

Oxford Cambridge and RSA Examinations

Advanced GCE

PHYSICS B (Advancing Physics)

RISE AND FALL OF THE CLOCKWORK UNIVERSE **2863/01**

Specimen Paper

Additional materials:
Advancing Physics Reference Booklet

TIME 1 hour 10 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre number, Candidate number and Centre name in the spaces at the top of this page
- Answer **all** the questions.
- Write your answers, in ink, in the spaces provided on the question paper. Extra paper should not be used.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

The values of standard physical constants are given in the Reference booklet. Any additional data required will be given in the appropriate question.

The approximate number of marks for each part question and the total for each question is given in brackets [ ]

You are reminded of the need for good English and clear presentation of your answers.

There are 4 marks for Quality of Written Communication on this paper

Question number	For examiner's use only
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
WC	
TOTAL	

SECTION A

1 The piston of a car engine is modelled as being a simple harmonic motion described by the equation $x = 0.05 \sin 300t$, where x is in metres and t is in seconds.

(a) Write down the amplitude of the motion

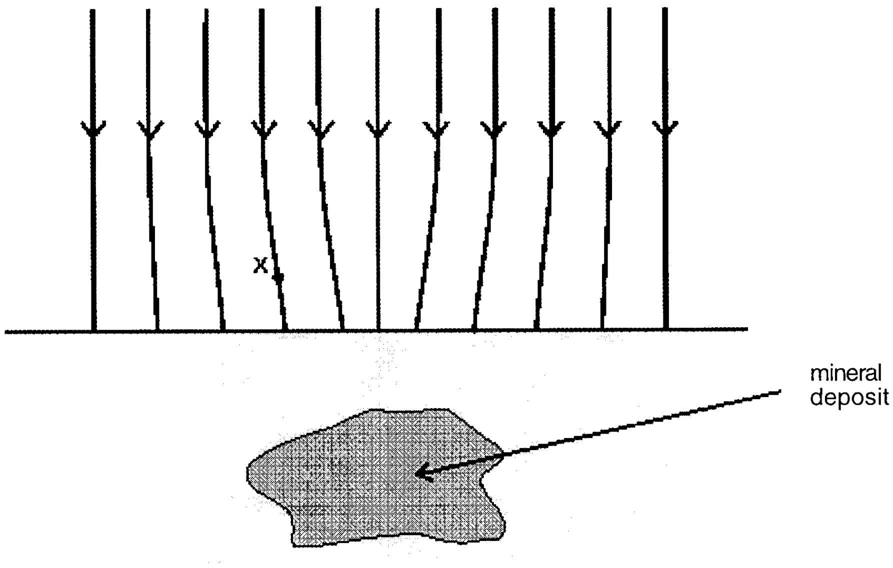
amplitude = ________ m [1]

(b) Calculate the period of the motion.

period = __________ s [2]

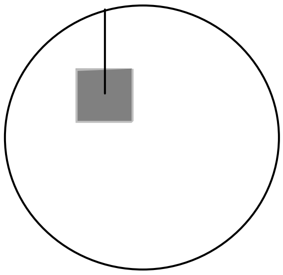
Total: [3]

2 The diagram shows the gravitational field near a dense mineral deposit. Sketch the equipotential surface passing through point **X**.



[2]

3 A very small light metal foil is suspended in a vessel filled with gas at a high temperature.



Use your ideas about molecules to explain why the gas exerts a pressure on both sides of the vane and why these pressures may show slight fluctuations.

[3]

4 A capacitor with a capacitance of 4.7 pF is charged from a battery to a p.d. of 6.0 V. Calculate how many electrons flow through the battery during the charging process.

number of electrons = ___________ [3]

5 An atom has an ionisation energy of about 10 eV, and its nucleus has a binding energy per nucleon of about 4 MeV.

Calculate to an order of magnitude the characteristic temperature at which you would expect

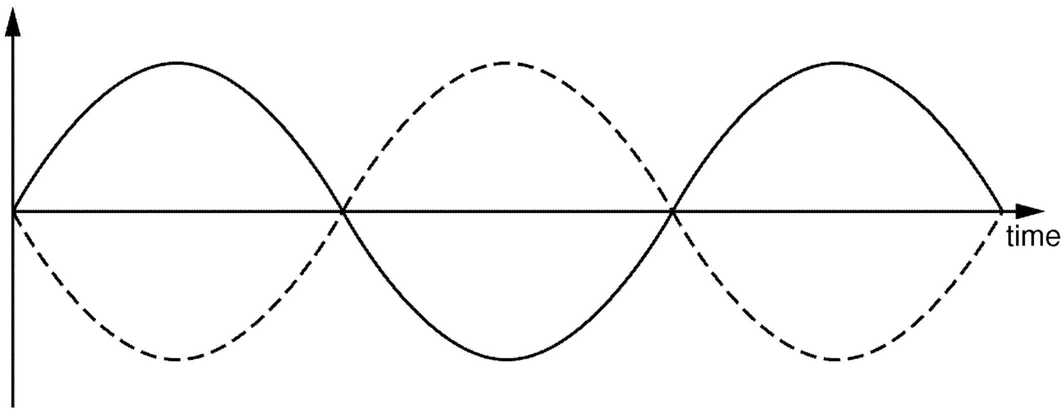
(a) a gas of these atoms to become ionised.

[2]

(b) the nucleus to dissociate into its constituent nucleons

[1]
Total: [3]

6 In the diagram below, the solid line (————) shows the displacement-time graph for an object in simple harmonic motion.



State, with a reason, what function of the motion varies with time as the dotted line (------) on the graph.

[2]

7 A rocket of mass 3×10^{6} kg ejects 15 000 kg of exhaust gases each second. The upward thrust of the rocket is just enough to balance its weight.

(a) Show that the exhaust gases are ejected at about 2000 ms^{-1}.

[3]

(b) Suggest why the acceleration of the rocket increases continuously in the initial stage of the rocket's flight.

[1]

Total: [4]

SECTION B

Four of the marks in this section are awarded for quality of written communication.

8 This question is about testing the performance of a motor car.

The car has a total mass of 1200 kg. In one test the car is accelerated from rest to 12 m s^{-1}. It is found the engine provides a constant driving force of 4.0 kN.

(a) **(i)** Calculate the acceleration of the car.

acceleration = ______________m s^{-2}

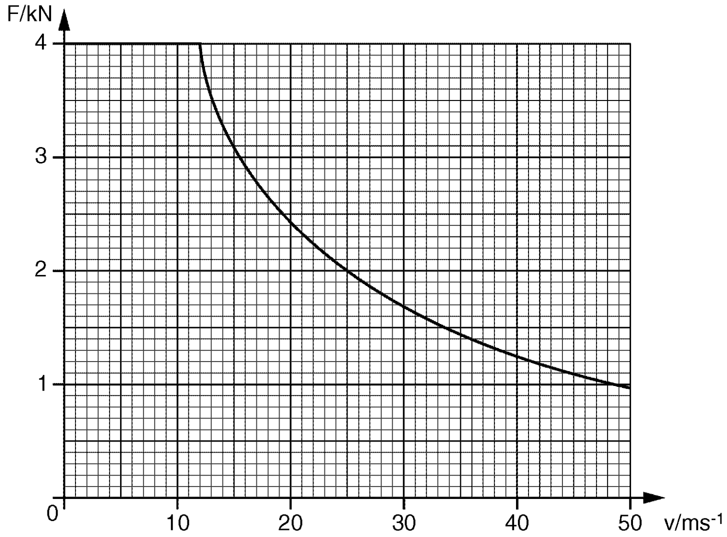
(ii) Sketch a speed-time graph for the car.

[4]

(b) Discuss the suggestion that 86 kJ is dissipated by the braking system if the car then comes quickly back to rest.

[3]

(c) In further tests this graph of the driving force against speed is obtained.



Show that the graph is consistent with a constant engine power of 48 kW above a speed of 12 m s^{-1}.

[3]
Total: [10]

9 This question is about energy transfers in an electric kettle with a power rating of 2.5 kW.

(a) The metal wall of the kettle and the water remain close to thermal equilibrium with each other as the temperature rises. Explain this statement.

[2]

(b) The kettle requires 300 J to raise its own temperature by 1.0 K. It contains 0.75 kg of water of specific heat capacity 4200 J kg^{-1} K^{-1}.

(i) The kettle and its contents are heated from 20°C to 100 °C. Show that the energy transferred during this process is about 280 kJ.

(ii) Calculate the rate of rise of temperature when the kettle is switched on.

rate of temperature rise = _______ K s^{-1} [4]

(c) At 100 °C the kettle and contents are allowed to cool in surroundings of temperature 20°C. They lose energy to the surroundings at a rate of

$$4.0(q - 20) \text{ watt}$$

where q is the temperature of the kettle and its contents.

(i) Calculate the initial rate of fall of temperature of the kettle and its contents.

rate of temperature fall = ____________ K s^{-1}

(ii) Calculate an approximate value of the time taken for the kettle to cool from 100 °C to 60 °C. Justify your answer.

time = ____________ s [5]

Total: [11]

10 This question is about a binary star system, a large star close to a much smaller neutron star.

(a) The neutron star is a star of about one solar mass (2×10^{30} kg) which has collapsed until its density is comparable to that of a nucleus.

(i) A nucleus has a density of about 2 x 1017 kg m-3. Show that the radius of the neutron star is approximately 13 km.

(ii) Calculate the gravitational potential at the surface of the neutron star.

Gravitational potential = _______ J kg^{-1} [4]

(b) Matter is drawn from the larger star towards the neutron star.

(i) Calculate the gravitational potential at the surface of the large star, which has a mass of 5 solar masses and a radius of 10^9m

Gravitational potential = ____________ J kg^{-1}

(ii) Calculate a maximum value for the energy gained by a particle of mass 1.7×10^{-27} kg as the matter moves from the larger star to the neutron star.

energy = ________________ J

(iii) As it falls, and gains this energy, the temperature of the matter increases. The matter becomes very hot, emitting radiation.
If the typical energy of photons emitted is of the order of magnitude of the mean energy per atom of the hot matter, estimate the wavelength of the radiation emitted.

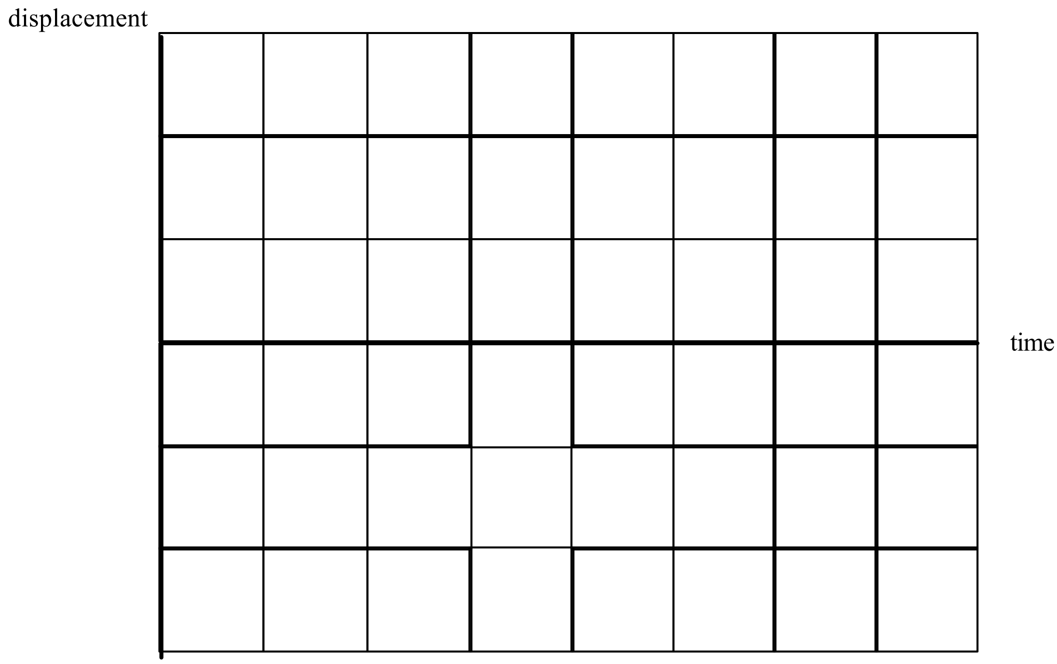
wavelength = ____________ m

(iv) In what region of the electromagnetic spectrum does this fall?

[6]

11 This question is about damping

(a) **(i)** Sketch a graph for a damped oscillation.



(ii) How does the graph show any changes in velocity?

[4]

(b) Suggest a situation in which some damping would be desirable. Explain the origins of the damping and the benefits of the damping of an oscillating system in the case you choose to discuss.

[3]

Total: [7]

12 This question is about a puddle evaporating on a sunny summer day.

The energy needed to break a hydrogen bond between two water molecules is 3.4×10^{-20} J. To evaporate from the surface of water a molecule must break two such bonds.

(a) **(i)** Calculate the difference in internal energy between a water molecule at the same temperature in the liquid and vapour state.

(ii) Calculate the fraction of water molecules with sufficient energy to evaporate when the temperature is 300K.

[4]

(b) **(i)** Suggest why the temperature of a puddle may fall during rapid evaporation.

(ii) Discuss one application of cooling by evaporation

[4]

Total: [8]
[Quality of Written Communication: 4]

Oxford Cambridge and RSA Examinations

OCR
RECOGNISING ACHIEVEMENT

Advanced GCE

PHYSICS B (Advancing Physics)
RISE AND FALL OF THE CLOCKWORK UNIVERSE **2863/01**

Mark Scheme

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owtte	– or words to that effect
( )	– material in brackets not needed for mark
vv	– vice versa

SECTION A

Qn		level	Expected answers	Marks	Additional guidance
1	**(a)**	E	0.05 m ✓	1	
	(b)	E	0.02 s ✓✓	2	frequency =48 Hz✓
				3	
2		D/C	peak in centre above deposit✓		
		B/A	dropping down to parallel to Earth surface at sides ✓	2	
				2	
3		E	pressure is due to collision with surface✓		
		D/C	many such collisions give steady average force✓		
		B/A	random collisions so over a small area fluctuations ✓	**3**	
4		E	$Q = CV$ ✓		
			$Q = 4.7 \times 10^{-12} \times 6.0$ ✓ $= 2.82 \times 10^{-11}$		
			electrons $= 2.82 \times 10^{-11} / 1.6 \times 10^{-19}$	3	
			$= 1.76 \times 10^{8}$ ✓		
				3	
5	**(a)**	E	E=kT so T= 10^5K✓✓	2	m✓ e✓
	(b)	E	E=kT so T=10^{10}K✓	1	
				3	
6		E	acceleration ✓		
			$\propto -x$ or equivalent argument ✓	2	
				2	
7	**(a)**	E	$F = m g = 3 \times 10^{6} \times 9.8 = 2.9 \times 10^{6}$ N ✓		
		BA	$Dp = F\,Dt = 2.9 \times 10^{6}$ N$\times$1 s $= 2.9 \times 10^{6}$ N s		
			$v = Dp/Dm$ ✓ $= 2.9 \times 10^{6}$ N s / 15000 kg		
			$= 1.96 \times 10^{3}$ m s^{-1} ≈ 2000 m s^{-1} ✓	3	
	(b)	DC	mass decreases as fuel ejected so constant force produces increased acceleration ✓	1	
				4	
			Section A total	**20**	

SECTION B

8	**(a)(i)**	E	$a = F / m = 4000 / 1200$ ✓ $= 3.3$ ✓ $m\ s^{-2}$	2	
	(ii)	DC	straight line through origin ✓ and through $12\ m\ s^{-1}$, 3.6 s ✓	2	
	(b)	EDC	$0.5\ m\ v^2 = 86.4$ kJ ✓✓ + KE transfer heat in brakes (owtte)✓	3	✓ m✓ e
	(c)	DC BA	test rule $P = F\ v = 48$ kW ✓ reading pairs of points off graph and testing rule ✓ testing at least twice ✓	3	
				10	
9	**(a)**	E	energy flows from hotter to colder to maintain equal temperatures✓, both transport energy quickly for a small temperature difference✓	2	
	(b)(i)	E DC	energy = $(0.75 \times 4200 + 300) \times 80$ ✓ = 276 kJ ✓		
	(ii)	BA	$2500\ \Delta t = (0.75 \times 4200 + 300) \times \Delta\theta$ ✓ $\Delta\theta / \Delta t = 2500 / 3450 = 0.72$ ✓ ($K\ s^{-1}$)	4	
	(c) (i)	BA	$\Delta E/\Delta t = 4(100\text{-}20) = 320$ W $320 = (0.75 \times 4200 + 300)\ \Delta\theta$ ✓ $\Delta\theta = 320 / 3450 = 0.93$ ✓		
	(ii)	D/C BA	mean temperature = 80°C✓ so average power is $4 \times (80\text{-}20) = 240$ W ✓ cooling time $= (0.75 \times 4200 + 300) \times (100 - 60) / 240$ = 575 ✓ (s)	5	
				11	
10	**(a)(i)**	E	$\rho = m/V = m/4\pi r^3/3$ r= 13,365 m	2	m✓ e✓
	(ii)	DC	$V = -GM/r = -9.98\text{x}10^{15}\ J\ kg^{-1}$	2	m✓ e✓ must have - for both marks
	(b)(i)	DC	$V = -GM/r = -6.67\text{x}10^{11}\ J\ kg^{-1}$	1	repeat calculation
	(ii)	DC	energy gained=$\Delta V\text{x}m = 1.7\text{x}10^{-11}$ J	2	m✓ e✓
	(iii)	AB	$E = hc/\lambda$ so $\lambda = 1.2\text{x}10^{-14}$ m	2	m✓ e✓
	(iv)	E	Hard x ray, gamma✓	1	
				10	
11	**(a)(i)**	DC	amplitude decay✓, same period✓	2	(or changing period clear heavy damping)
	(ii)	AB	the changing gradient shows velocity changing sign and size within a period✓ between periods max gradient and so velocity decreases ✓	2	
	(b)	EDC	suggestion✓, origin ✓, benefits✓	3	
				7	
12	**(a)(i)**	E	energy $= 2 \text{ x } 3.4 \text{ x } 10^{-20}$ ✓ $= 6.8\text{x}10^{-20}$ ✓ J	2	
	(ii)	AB	fraction $= e^{-(E/kT)}$ ✓$= 7.4\text{x}10^{-8}$✓	2	
	(b)(i)	CD	it will decrease ✓as most energetic molecules are those leaving ✓(implying temp related to energy)	2	
	(ii)	CD	e.g. sweating; named✓ + some detail✓	2	
				8	
			Quality of written communication (see over for criteria)	**4**	
			Section B total	**50**	

QoWC	Marking quality of written communication The appropriate mark (0-4) should be awarded based on the candidates quality of written communication in Section B of the paper.	**4** max
4	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 candidates meaning uncertain.	

Specification grid for OCR Physics B *Advancing Physics* — Specimen paper

Name of paper Unit 2863 Rise and fall of the Clockwork Universe | Component number: 01 | Page 1 of 1

Question number	Syllabus reference	Assessment objectives: Knowledge with understanding	Application, synthesis and evaluation	Synthesis	Total mark for paper	Level of demand of question: E	D-C	B-A	QoWC	
		AS (60%) A2/4&5 (50%)	AS (40%) A2/4&5 (50%)	– A2/6 (100%)	100%	35-45%	25-35%	25-35%	(4 marks)	
1	5.4.1	3			3	3				
2	5.4.2		2		2		1	1		
3	5.4.4	3			3	1	1	1		
4	5.4.1	3			3	3				
5	5.4.5	3			3	3				
6	5.4.1	1	1		2	2				
7	5.4.2	2	2		4	1	1	2		
8	5.4.2	2	8		10	4	4	2		
9	5.4.4	3	8		11	3	2	6		
10	5.4.3	3	7		10	3	5	2		
11	5.4.1	5	2		7	3	2	2		
12	5.4.5	4	4		8	2	4	2		
QoWC		4			4				4	
		36	34		70	28	20	18	4	

Oxford Cambridge and RSA Examinations

RECOGNISING ACHIEVEMENT

Advanced GCE

PHYSICS B (Advancing Physics)

FIELD AND PARTICLE PICTURES **2864/01**

Specimen Paper

Additional materials:
Advancing Physics Reference Booklet

TIME 1 hour 10 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre number, Candidate number and Centre name in the spaces at the top of this page.
- Answer **all** the questions.
- Write your answers, in ink, in the spaces provided on the question paper. Extra paper should not be used.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

The values of standard physical constants are given in the Reference booklet. Any additional data required will be given in the appropriate question.

The approximate number of marks for each part question and the total for each question is given in brackets [ ].

You are reminded of the need for good English and clear presentation of your answers.

There are 4 marks for Quality of Written Communication on this paper.

Question number	For examiner's use only
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
WC	
TOTAL	

SECTION A

1 Which of the values in the list below is the best estimate of

(a) the radius of an nucleus?________ [1]

(b) the wavelength of visible light?_________ [1]

(c) the wavelength of a 1.5 MeV electron? _________ [1]

10^{-4} m 10^{-7} m 10^{-10} m 10^{-12} m 10^{-15} m

Total: [3]

2 $^{4}_{2}He$ represents a helium nucleus, $^{6}_{3}Li$ a lithium nucleus, and $^{12}_{6}C$ a carbon nucleus

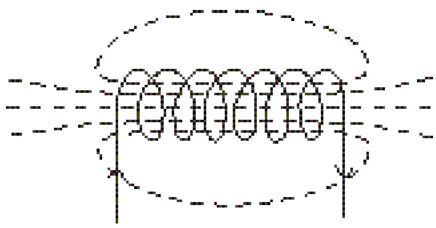
(a) Which one has exactly 6 nucleons? [1]

(b) Which one has exactly 6 neutrons? [1]

(c) Which one is identical with an alpha particle? [1]

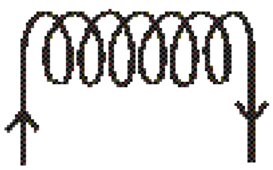
Total: [3]

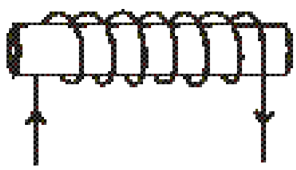
3 The diagram shows the magnetic field around a solenoid.



On the two diagrams below sketch field lines to show how the field is modified:

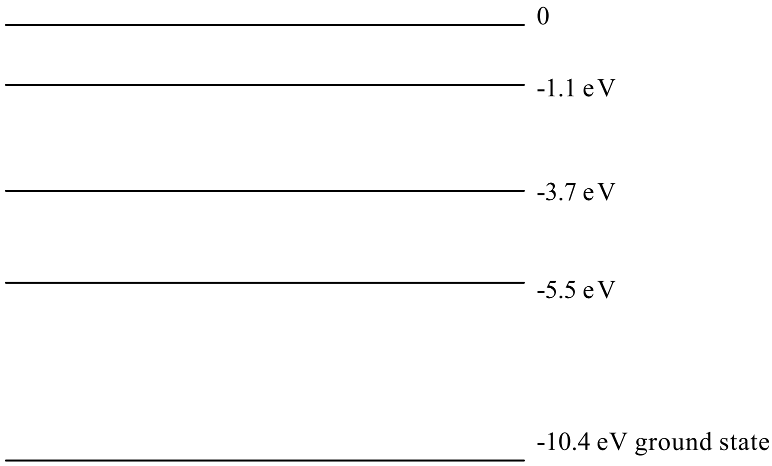
(a) if the current is smaller   **(b)** if an iron core is added [1+1]





Total: [2]

4 The diagram shows five energy levels in a mercury atom: the ground state and four excited states. Calculate the longest wavelength photon that could be emitted when this atom is excited by collision with a 8 eV electron.



[3]

5 A 1000 turn flat coil with a cross-sectional area of $2.4 \times 10^{-3}\ m^2$ is positioned with its axis parallel to a uniform B-field of flux density 0.75 mT.

(a) Calculate the flux linked with the coil.

[2]

(b) Calculate the emf induced in the coil when the flux falls uniformly to zero in 10 ms.

[2]

Total: [4]

6 The maximum demand for electricity by a small village of 200 houses is 2.5 MW. This is delivered by an 11 kV power line. The voltage is transformed from 11 kV to 230 kV where the supply reaches the village.

Which of the values in the list below is the best **estimate** of

(a) the current, in ampères in the power lines at peak demand times? ______ [1]

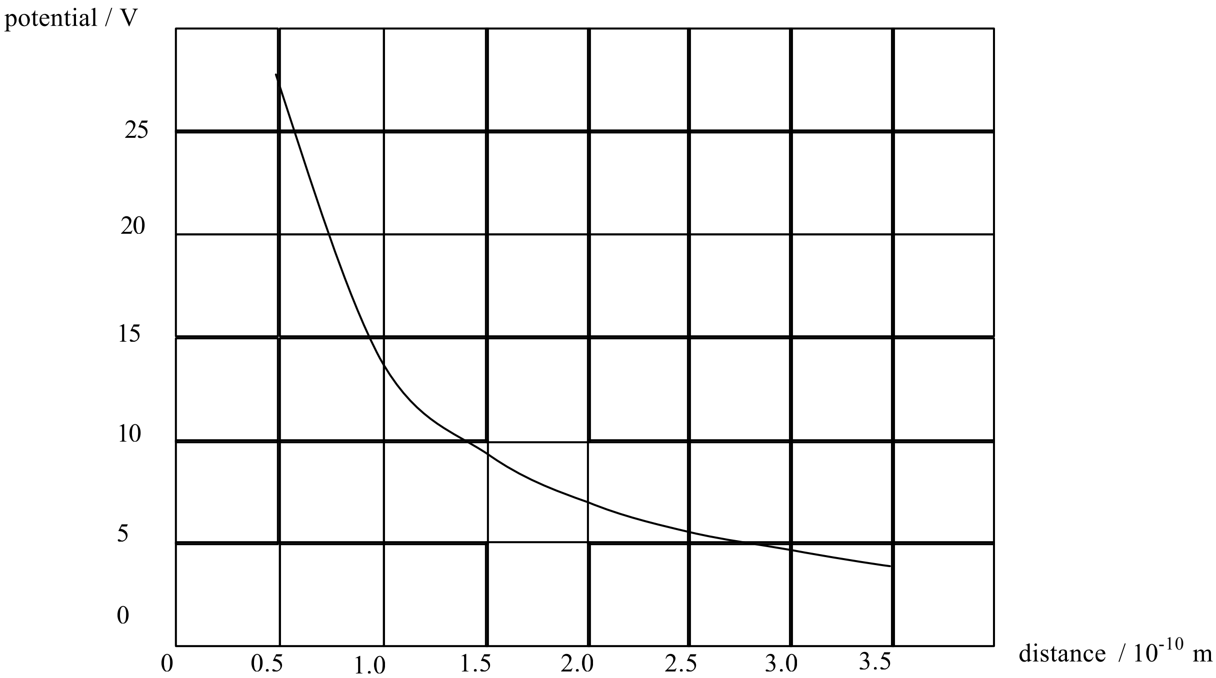
(b) the current, , in ampères, supplied to each house at peak demand times? ______ [1]

(c) the ratio of the primary to secondary turns of he transformer? ______ [1]

4500 2250 9 4.5 0

Total: [3]

7 The graph of electric potential against distance for a nucleus, modelled as a small point charge, is as shown.



Use the graph to calculate the electric field strength due to this charge at a point 1.5 x 10^{-10} m from it.

[2]

SECTION B

Four marks in this section are awarded for quality of written communication.

8 This question is about the motion of charged particles in magnetic fields.

(a) Explain why a charged particle, moving with a constant speed v perpendicular to a uniform magnetic field of strength B, will follow a circular path.

[1]

(b) Show that for a particle of mass m and charge q the radius of the circular path is given by the expression:

$$r = \frac{mv}{Bq}$$

[2]

(c) When a charged particle moves in a circular path it emits radiation at a frequency determined by the number of times it completes a circle in a second. Show that this frequency, known as the cyclotron frequency, is:

$$f = \frac{qB}{2pm}$$

[2]

(d) (i) Some astrophysicists believe that the radio signals of 10^9 Hz reaching us from Jupiter are emitted by electrons orbiting in Jupiter's magnetic field. Assuming the frequency of the radio emission is identical to the cyclotron frequency, calculate the strength of the magnetic field around Jupiter.

strength of magnetic field = ________________ T

(ii) The electrons lose energy as they emit radiation. Discuss what effect, if any, this will have on the frequency of the radio signals detected.

[5]

Total: [10]

9 This question is about the contribution to background radiation due to the potassium content of a human body.

(a) Potassium-40 is a radioactive isotope of potassium. The main decay mode is for ${}^{40}_{19}\text{K}$ to decay by the emission of a β^- to produce the stable product ${}^{40}_{20}\text{Ca}$.
Write an equation for this decay.

[1]

(b) The mass of ${}^{40}_{19}\text{K}$ is 39.963999u. The energy emitted per decay is$1.3\text{x}10^{-13}$ J.
0.3% of the human body mass is potassium. Only 0.0117% of potassium consists of the isotope ${}^{40}_{19}\text{K}$.
Show that there are approximately 5.5×10^{18} atoms of the isotope ${}^{40}_{19}\text{K}$ per kilogram of the human body.

[2]

(c) **(i)** The half life of ${}^{40}_{19}\text{K}$ is $1.28\text{x}10^{9}$ years. Calculate the decay constant.

=______ per year

(ii) Calculate the decay rate of ${}^{40}_{19}K$ per kilogram in the human body.

[4]

(d) **(i)** One third of the energy of each decay is deposited in the body.
Calculate the dose received each year, assuming the β^- radiation has a biological dose equivalent of 1.

= ________ Sv

(ii) Discuss whether it is dangerous to be exposed to this level of radiation.

[4]

Total: [11]

10 This question is about monitoring radiation levels.

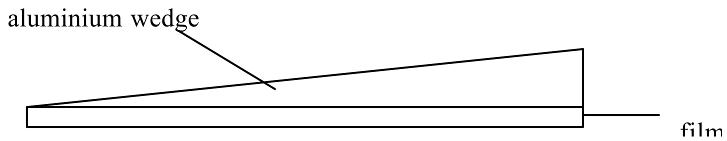
(a) A source of gamma radiation in a hospital is surrounded by a protective shell.

(i) Explain the link between ionising power and penetrating power.

(ii) Suggest a suitable material for constructing the protective shell and discuss its properties.

[4]

(b) Monitoring badges worn by hospital staff are used to measure their exposure to radiation. A student suggests using a photographic film covered by a wedge of aluminium foil as shown in the diagram to help distinguish different types of radiation.



(i) What would you expect to observe if the radiation was

gamma only?

beta only?

[2]

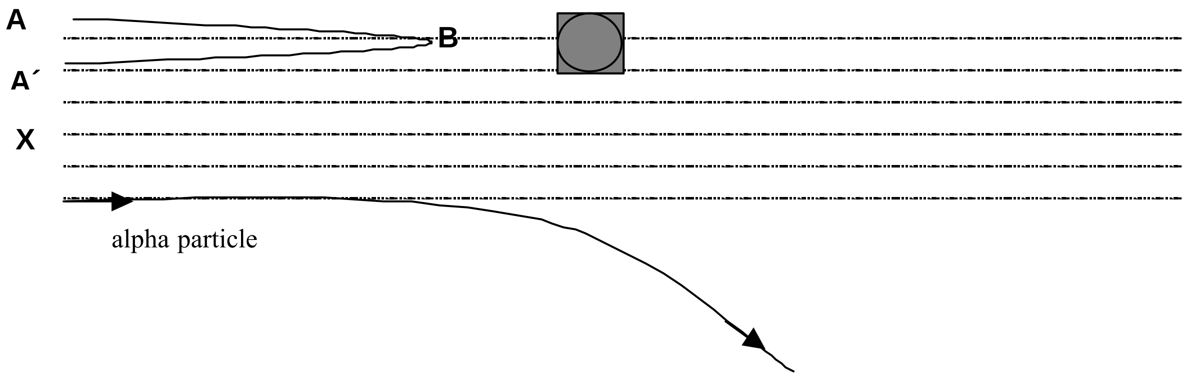
(ii) Discuss whether this design might be able to detect the presence of two different types of radiation at once.

[3]

Total: [9]

11 This question is about the use of scattering to determine structure.

(a) The lower track on the diagram shows an 8MeV alpha particle being scattered by a gold nucleus (^{197}Au).



(i) Draw and label on the diagram the path of another 8MeV alpha particle starting at point **X.**

(ii) Draw and label on the diagram the path of an electron starting at point **X.**

[4]

(b) An 8MeV alpha particle can also follow the path **ABA¢.**

(i) Write down a numerical value for the potential energy of the particle at **B**.

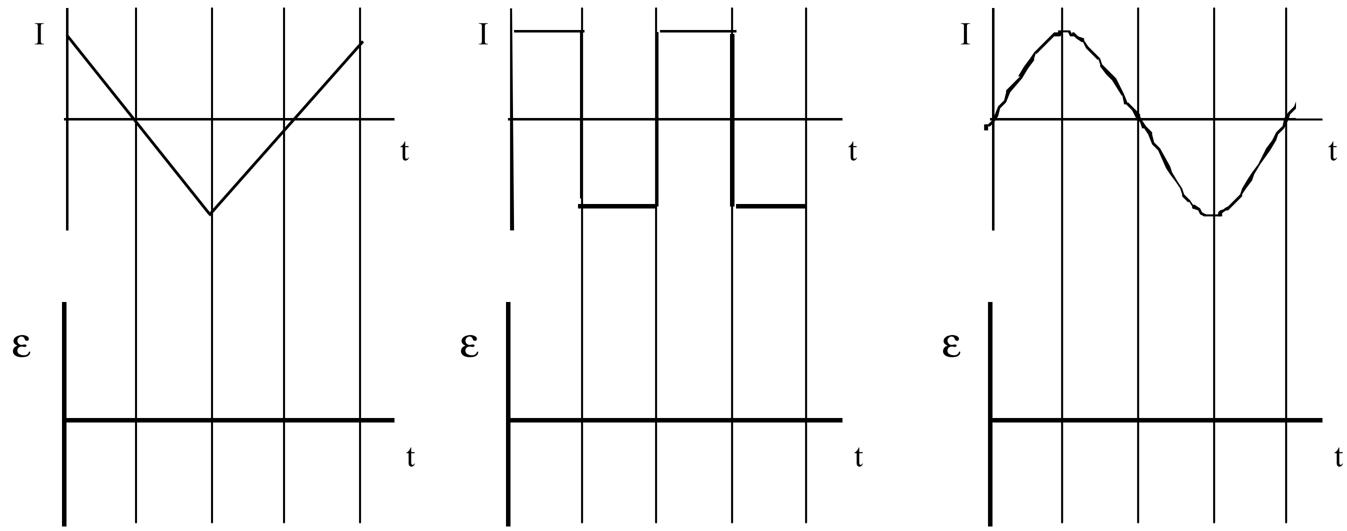
(ii) Calculate a value for an upper limit on the size of the gold nucleus.

[4]

Total: [8]

12 This question is about a transformer

(a) The three graphs show the current at the primary of a transformer. On the blank axis below each one sketch the emf induced in the secondary coil.



[3]

(b) Explain the action of a step down transformer

[4]

(c) Suggest a reason for using a transformer with the same number of turns on the secondary as the primary.

[1]

Total: [8]
[Quality of Written Communication: 4]

Oxford Cambridge and RSA Examinations

Advanced GCE

PHYSICS B (Advancing Physics)
FIELD AND PARTICLE PICTURES **2864/01**

Mark Scheme

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 B permit of 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 the method, 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 numbers of significant figures in a final answer are penalised by the loss of a mark, generally once 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. Missing or incorrect units in a final answer are penalised by the loss of a mark, generally once per examination paper.
- Quality of written communication will be assessed in Section B where there are more opportunities to write extended prose.

Within the marks scheme the following notation is adopted

m	– method mark
s	– substitution mark
e	– evaluation mark
;	– separates individual marking points
/	– separates alternative answers
= 0	– common answers which should not be given credit
ecf	– error carried forward
owtte	– or words to that effect
( )	– material in brackets not needed for mark
vv	– vice versa

Qn		level	Expected answers	Marks	Additional guidance
SECTION A					
1	**(a)**	E	10^{-15} m ✓	1	
	(b)		10^{-7} m✓	1	
	(c)		10^{-12} m✓	1	
				3	
2	**(a)**	E	Lithium ✓	1	
	(b)	E	Carbon ✓	1	
	(c)	E	Helium ✓	1	
				3	
3	**(a)**	E	similar pattern, less field lines in coil	1	
	(b)	E	similar pattern, more field lines in core	1	
				2	
4		A/B	5.5-3.7= 1.8 eV✓		
			$E=hc/\lambda$		✓m✓e
			λ= 690nm✓✓	**3**	
5	**(a)**	E	$\Phi = NAB$✓= $1.8\text{x}10^{-3}$ Wb turns✓	2	
	(b)	D/C	ε = -d(BAN)/dt ✓= 0.18 V✓	2	
				4	
6	**(a)**	E	225	1	
	(b)	E	50	1	
	(c)	E	50	1	
				3	
7		BA	use of graph (to infer charge or take slope)✓	1	
			evaluation = 6.4×10^{10}NC^{-1}✓	1	
				2	
			Total Section A	**20**	

SECTION B

8	**(a)**	E	force at right angles to speed provides centripetal force (owtte) ✓	1	
	(b)	E	$Bqv=mv^2/r$ ✓ then rearrange ✓	2	
	(c)	D/C	$v=df=f2\pi r$ ✓and sub v from above✓ (or equivalent)	2	
	(d)(i)	D/C	=0.036T rearrange✓sub✓e✓	3	
	(ii)	B/A	none ✓, v and so energy not in f expression✓	2	
				10	
9	**(a)**	E	$^{40}K \rightarrow ^{40}Ca+\beta^-+\nu$	1	
	(b)	D/C	=0.03x0.000117/39.963999xu = $5.3x10^{18}$	2	✓m✓e
	(c)(i)	D/C	$\ln 2/t$ = $5.4x10^{-10}$ per year	2	✓m✓e
	(ii)	B/A	$5.4 \times 10^{-10} \times 5.3 \times 10^{18} = 2.8 \times 10^9$	2	
	(d)(i)	B/A	$1/3 \times 1.3 \times 10^{-13} \times 3 \times 10^9 = 0.13 \times 10^{-3}$Sv	2	✓m✓e
	(ii)	B/A	relative risk discussion ✓ detail eg natural background 1mSv per year ✓	2	
				11	
10	**(a)(i)**	DC BA	large ionising /low penetrating ✓ mechanism of energy loss ✓	2	
	(ii)	E DC	eg lead, concrete ✓ some relevant property ✓	2	
	(b)(i)	E	Gamma - essentially uniform exposure ✓ Beta - exposure decreasing as thickness increases ✓	1 1	
	(ii)	BA	sensible comments about gamma plus beta looking like increased beta only as gamma simply adds constant or comment on how to separate data.	3	Use 1/2/3 scheme
				9	
11	**(a)(i)**	E	larger deflection, closer to nucleus, (symmetry)	2	
	(ii)	D/C	other way, more	2	
	(b)(i)	D/C	8 MeV	1	
	(ii)	B/A	$KE = Qq/4\pi\varepsilon_0 r$ $r = 2.8x10^{-14}$m	3	m ✓sub✓ e✓
				8	
12	**(a)**	DC	e.g. constant negative then constant positive✓;	1	not interested in sign or size
		BA	spikes at changes one each way✓;	1	
		BA	- cos shape✓.	1	
	(b)	E D/C	changing current changing field✓ role of core✓ changing flux changing emf✓ then relate to number of turns etc✓	4	
	(c)	DC	eg electrical isolation ✓	1	
				8	
			QoWC in Section B	**4**	
			Section B total	**50**	

QoWC	Marking quality of written communication The appropriate mark (0-4) should be awarded based on the candidates quality of written communication in Section B of the paper.	**4** max
4	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.	
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Specification grid for OCR Physics B *Advancing Physics* — Specimen paper

Name of paper Unit 2864 Field and Particle Pictures — Component number: 01 — Page of

Question number	Syllabus reference	Assessment objectives: Knowledge with understanding	Application, synthesis and evaluation	Synthesis	Total mark for paper	Level of demand of question: E	D-C	B-A	QoWC	
		AS (60%) A2 (40%)	AS (40%) A2 (40%)	– A2 (20%)	100%	35-45%	25-35%	25-35%	(4 marks)	
1	5.5.3	3			3	3				
2	5.5.3	3			3	3				
3	5.5.1	2			2	2				
4	5.5.3		3		3			3		
5	5.5.1	2	2		4	2	2			
6	5.5.1	3			3	3				
7	5.5.2		2		2			2		
8	5.5.2	4	6		10	3	5	2		
9	5.5.4	5	6		11	1	4	6		
10	5.5.4	4	5		9	3	2	4		
11	5.5.3	4	4		8	2	3	3		
12	5.5.1	4	4		8	2	4	2		
QoWC		4			4				4	
		38	32		70	24	20	22	4	

Oxford Cambridge and RSA Examinations

Advanced GCE

PHYSICS B (Advancing Physics)
ADVANCES IN PHYSICS **2865**

Specimen Paper

Additional materials:
Text passage for this question paper
Advancing Physics Reference Booklet

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre number, Candidate number and Centre name in the spaces at the top of this page.
- Answer **all** the questions.
- Write your answers, in ink, in the spaces provided on the question paper. Extra paper should not be used.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

The values of standard physical constants are given in the Reference booklet. Any additional data required will be given in the appropriate question.
The approximate number of marks for each part question and the total for each question is given in brackets [ ]
You are reminded of the need for good English and clear presentation of your answers.
There are four marks for Quality of Written Communication on this paper.
This paper requires you to show that you can make connections between different areas of physics and draw ideas together.
In this paper you have the opportunity to draw together ideas in physics in contexts which are new to you.
Use diagrams to help your explanations and take particular care with your written English.

Question number	For examiner's use only
1	
2	
3	
4	
5	
6	
7	
8	
WC	
TOTAL	

SECTION A

You are advised to spend 45 minutes on this section. Up to four marks will be awarded in this section for the quality of written communication.

These questions are about the passage *Gravity Waves*.

1 Lines 11-15 refer to three characteristics of waves.
Both ultrasound and x-rays are used in medicine.

(a) For each of these waves state one medical situation where the waves are used, describing why those waves are chosen for that purpose.

ultrasound

x-ray

[4]

(b) Write down **two** differences between ultrasound waves and x-ray waves.

1

2

[2]

(c) The three characteristics listed on lines 11-15 concentrate mainly on the energy transferred by the wave.
Write down **one** other property that is characteristic of all waves.

[1]

Total: [7]

2 Lines 28-43 refer to gravitational waves giving new possibilities for astronomical observations. When gamma-ray wavelength observations were first made from high-flying balloons and from satellites similar new possibilities for observations were created

(a) Explain why astronomical gamma-ray observations were not possible from observatories at the Earth's surface.

[1]

(b) Typical gamma-ray photons have an energy of around 120 MeV.

(i) Show that this energy of a gamma-ray photon is about 2×10^{-11} J.

(ii) Hence calculate the frequency of the gamma radiation.

(iii) Calculate the wavelength of the gamma radiation.

[5]

(c) Intense, short-lived bursts of gamma-rays are sometimes detected from distant points in the galaxy. Suggest why it is thought that these are associated with cataclysmic events, such as black holes colliding.

[2]

Total: [8]

3 In lines 56-60 the ratio between the electromagnetic force and the gravitational force between a proton and an electron is stated to be about 10^{40}.

(a) Use data from the Reference booklet to show that this is true if the distance between proton and electron is 5.3×10^{-11} m.

[5]

(b) What would the ratio of the forces be for the two protons in an alpha particle, separated by about 10^{-14} m?

[3]

(c) Explain why these ratios do not in fact depend on the separation of the two charged particles.

[1]

Total: [9]

4 In lines 152-169 the gravitational wave detector called a Weber bar is described. It is made from aluminium, of density 2700 kg m $^{-3}$.

(a) Calculate the mass of the Weber bar from the dimensions given in the article.

mass = _________ kg [2]

(b) If the change in shape of the mass is just one part in 10^{22}, estimate the amplitude of oscillations detected by the piezoelectric sensors at the centre of the rod.

amplitude = _________ m [2]

(c) Given that the diameter of an aluminium atom is about 3×10^{-10} m, comment on the practical problems of making such a measurement.

[1]

(d) Explain Weber's reasons for expecting that much larger oscillations could be detected.

[2]

(e) Lines 195-197 state that modern work using a Weber bar is taking place in the US, Switzerland and Italy. This reflects the increasingly international nature of scientific research. By giving another example, discuss two possible reasons for this trend.

[5]

Total: [12]

5 **(a)** Lines 235-239 state that interferometers have very much wider bandwidths than Weber bars. On the axes below, sketch and label the frequency spectra of a Weber bar and of an interferometer. Indicate any significant values on the axes.

[3]

(b) The LIGO interferometer has its mirrors 4000 m from the beam splitter [lines 245-260]. If a gravitational wave 'stretches' the horizontal distance by one part in 10^{20}, and 'shrinks' the vertical distance by the same amount, calculate the path difference travelled by the light, in wavelengths, where the wavelength $\lambda = 600$ nm.

path difference = _______wavelengths [4]

(c) It is proposed to build an even larger interferometer by placing three orbiting satellites at the corners of an equilateral triangle with sides 5 million kilometres long.
Calculate the path difference, in wavelengths, that would be detected by this interferometer.
Comment on your answer.

[3]

Total: [10]

[Quality of Written Communication: 4]

SECTION B

You are advised to spend 45 minutes on this section.

6 This question is about the use of a digital camera.

(a) The camera has a 4.1 V battery which lasts for two hours of continuous use of the camera. The capacity of the battery (total charge available) is 1400 mA hours. It takes 7 hours for a charging unit to re-charge the battery.

(i) Express the capacity of the battery in coulombs.

capacity = ______________ C

(ii) Show that the average current in the camera during continuous use is 0.7 A.

(iii) Calculate the power consumption of the camera in continuous use.

power = _________ W [6]

(b) The square light sensitive surface in the camera is 20 mm x 20 mm, and is divided into 1024 x 1024 pixels. Each pixel consists of a pair of small square conducting plates, with a 1 μm gap between the plates, which act as a capacitor. Light falls on one plate and gives rise to a charge stored on the pair of plates, the charge is proportional to the light falling on the pixel.

(i) Give a reason why the electric field between the plates will be uniform.

(ii) Calculate the electric field between the plates if the charge stored gives rise to a potential difference of 1 mV between them.

electric field =____________ [3]

(c) The camera has a lens of focal length 10 mm.

(i) The camera forms an image of a 5 m long car which is 25 m from the lens. Show that the length of the image of the car is approximately 2 mm.

(ii) How many pixels does the length of this image cover?

(iii) Comment on the resolution of the image of the car.

(iv) The car is moving across the field of view when photographed. The camera is fixed and the image is blurred because the image of the car moves a distance equal to 1 pixel in the exposure time of 1/500 s.
Calculate the speed of the car at that moment.

[8]

(d) The light sensitive surface detects light down to a wavelength of 600 nm.
If an arriving photon removes an electron from the surface, show that the energy needed to do so cannot exceed about 3×10^{-19} J.

[3]

Total: [20]

7 This question is about a proposal to use solar radiation in space as a source of power. Electrical energy can be generated from the Sun's radiation by solar cells on a satellite and converted to 10 mm electromagnetic waves for transmission to Earth, and conversion back to electrical energy.

(a) **(i)** The orbit of the satellite needs to be geostationary (have a time period of 1 day and be over the Earth's equator).

Explain why you think this might be necessary.

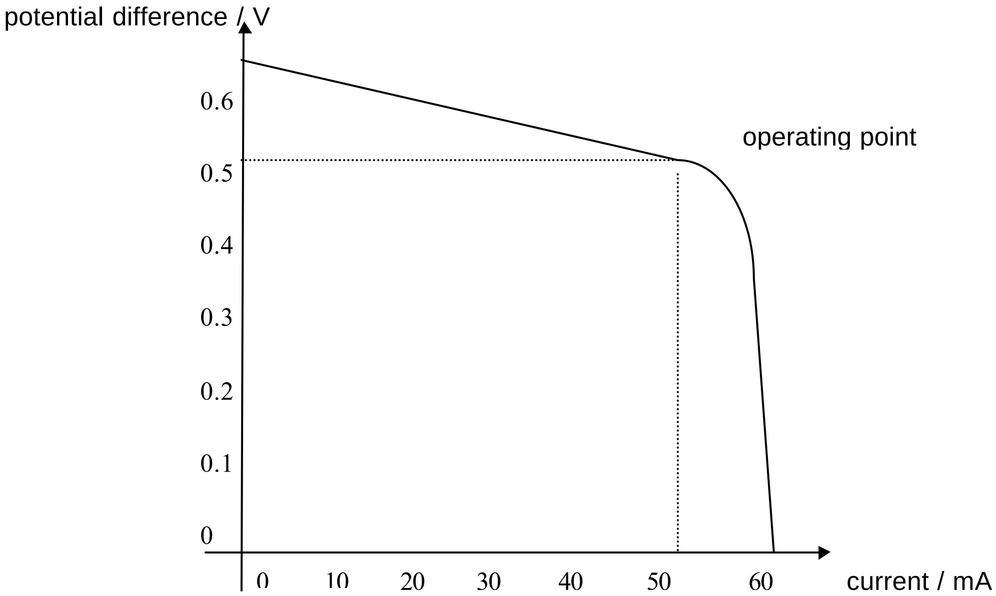
(ii) Write an equation equating the gravitational force acting on the satellite to the centripetal force needed for circular orbit, and hence show that

$$R^3 = \frac{GMT^2}{4p^2}$$

(iii) Show that the radius of the orbit of the satellite is 4.0×10^7 m.

[6]

(b) The graph shows the characteristic of an individual solar cell under a variable resistive load in full sunlight conditions.



(i) Describe how the power output of the cell varies as the current increases.

(ii) Calculate the power output of the solar cell at the operating point.

(iii) Calculate the internal resistance of the solar cell at the operating point.

(iv) An amplifier circuit in the satellite requires a d.c. power supply rated at 15 V and 2 A. What arrangement of cells could achieve this ?

[9]

(c) (i) The satellite transmits electromagnetic waves of wavelength 10 mm.
Calculate the frequency of the waves and state what part of the spectrum they are in.

(ii) The satellite has a 1 km diameter transmitting aerial.
Estimate the angle of diffraction of the focused beam transmitted with this wavelength, and show that the radius of the footprint of the main diffraction beam at the Earth, i.e. the receiver dish radius, is about 350m.

[5]

Total: [20]

Oxford Cambridge and RSA Examinations

RECOGNISING ACHIEVEMENT

Advanced Subsidiary GCE

PHYSICS B (Advancing Physics)

ADVANCES IN PHYSICS **2865**

Specimen Paper (Reading Material)

Additional materials:
Answer paper

Reading Time six weeks

INSTRUCTIONS TO CANDIDATES

You will have received this paper six weeks before the Physics examination.
You should take the paper away and read through the passage. You should spend some time looking up any technical terms or phrases you do not understand. However you are not be required to research further the particular topic described in the passage.
For the examination on <**insert date of examination**> you will be given a fresh copy of this passage, together with a question paper. You will not be able to take this copy into the examination with you.
The values of standard physical constants will be given in the *Advancing Physics* Reference booklet. Any additional data required will be given in the appropriate question.

GRAVITY WAVES

Steve Adams

Colliding black holes and exploding stars should cause ripples in space and time called gravity waves. Gigantic experiments are now being built to detect them, and if they succeed they could start a revolution in astronomy

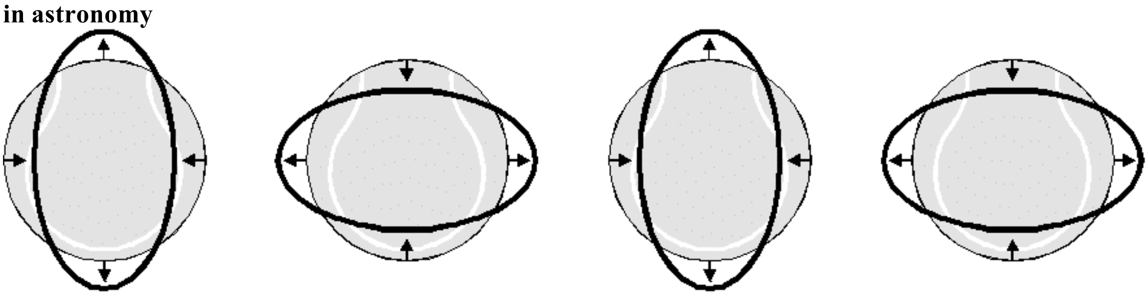


Figure 1: The effect of a gravitational wave on a tennis ball as a gravitational wave hits at right angles to the plane of the page. The effect has been exaggerated 10^{21} times.

CATACLYSMIC events that release large amounts of energy are not only felt at the point where they strike. Here on Earth, for example, an earthquake will send seismic waves echoing around the world. These disturbances of the Earth's crust distort the rocks through which they pass, and can transfer some of the earthquake's energy to the far side of the world. Seismic waves illustrate three characteristics common to all types of wave: they are created by an event that releases energy; the disturbance is passed from one place to another at a finite speed; and they transfer energy from the original disturbance to other bodies.

Physicists believe that gravitational waves should occur as a consequence of events on an even larger scale than this. According to Einstein's general theory of relativity, they are radiated by accelerating masses, such as coalescing black holes or exploding supernovae. They cause periodic variations in the geometry of space-time as they pass. They travel at the speed of light. And they make distant masses vibrate, causing them to absorb some of the energy carried by the waves.

Nobody has yet detected gravitational waves directly, though there is compelling indirect evidence that they do exist. Physicists in several countries are now setting up experiments that aim to observe gravitational waves. If they are successful, these waves might open a new window for astronomical observation, just as the first observations of radio waves and X-rays did in the past. Indeed, the consequences could be even more profound because gravitational waves are a completely different type of wave to light, radio and X-rays. If detected, it would be like hearing the Universe for the first time whereas previously we have only ever seen it.

The principle behind experiments to detect gravitational waves is simple. Any object that has mass will vibrate in response to the waves as they pass, so all that is needed is a test mass, plus a detector to pick up and measure its vibrations.

In practice, however, there are huge problems. The vibrations that gravitational waves produce are expected to be incredibly small. This is because gravity is extremely weak compared to other fundamental forces such as electromagnetism. The gravitational force between a proton and an electron in a hydrogen atom, for example, is 10^{40} times weaker than the electromagnetic force between these particles. To pick up even the strongest gravitational waves generated by the violent motion of massive bodies, a detector needs to be sensitive enough to measure vibrations that change the shape of a test mass by just 1 part in 10^{22}. This is equivalent to measuring a change in height of a human to about a hundred-millionth of the diameter of a single atomic nucleus. Even gravitational waves from violent events in our Galaxy, such as a collapsing star, would cause changes of less than 1 part in 10^{18}, which would alter a human's height by much less than the diameter of an atomic nucleus.

Physicists have to look for vibrations such as these because there is no more direct way to detect a gravitational wave. You can't simply measure the change in the weight of a test mass caused by a passing gravitational wave – essentially, a variation in gravity with time. This is because all masses in a particular gravitational field free-fall at the same rate, so no relative motion occurs. Gravity can only be observed through its tidal effects – that is, through distortions in a body that are caused by differences in gravity at different points across the body.

To see the distinction, imagine a free-falling laboratory, first in a uniform gravitational field and secondly in a non-uniform field. Imagine the laboratory is full of dust which is initially spread evenly throughout the room. In the first case, every dust particle falls with the same acceleration and retains its relative position with respect to all the others. If the strength of the field is uniformly cranked up everywhere, the acceleration of the laboratory and all that it contains increases at the same rate, so the dust is not redistributed and the change is undetectable.

Now think about the non-uniform field, perhaps in a laboratory free-falling towards the Earth. Here, the field is stronger near its base. As the room falls, dust particles near the bottom of the laboratory have a greater than average free-fall acceleration so they collect on the floor. Those near the top collect on the ceiling, as they have a less than average free-fall acceleration. There is also pa horizontal effect, since the direction of gravity converges towards the centre of the Earth. This gives the falling dust particles a horizontal component of acceleration, which makes them concentrate toward the centre of the laboratory.

To an observer inside the laboratory, there is a **tidal force** that separates the dust vertically and compresses it horizontally. This is exactly what happens to the Earth as it free-falls in the gravitational field of the Moon: the oceans are extended along the line joining the centres of the Earth and Moon and are squeezed perpendicular to it, producing two high tides per day as the Earth spins.

In the same way, gravitational waves appear as a periodic tidal force to a stationary observer. This causes massive objects in the path of the wave to be squeezed and stretched in the directions perpendicular to the incoming wave (see Figure 1).

Catch the wave

Detection methods

GRAVITATIONAL **wave detectors** are designed to respond to the tiny displacement of particles caused by these tidal forces. These vibrations are expected to be slighter than the random motion of atoms in the detector that is due to their thermal energy. They are anticipated to be even smaller than the quantum uncertainty in the position of atoms that stems from the inherent fuzziness of nature at very small scales. And yet, physicists have been able to devise two methods that they hope will detect gravitational waves as they pass.

The first of these is called a **Weber bar,** after the American physicist Joseph Weber, who first pursued the idea at the University of Maryland in the early 1960s. He used a cylindrical aluminium bar about 2 metres long and 0.5 metres in diameter. Waves travelling along the bar's long axis cause it to stretch and compress at right angles to this axis (see Figure 2). The key to the bar's sensitivity is that it has a natural frequency at which it prefers to vibrate. If the incoming gravitational waves contain frequencies close to this frequency, the bar will resonate and amplify the vibration. Piezoelectric sensors attached to the middle of the bar convert the tiny displacements to electrical signals that can be recorded and processed.

Weber guessed the likely frequency of incoming gravitational waves by thinking about possible sources. For example, a very tightly bound **binary star system,** in which two stars orbiting their common centre of mass were about to coalesce, would be a strong source of gravitational waves. As the stars got closer together, their orbital frequency would increase to about 1 kilohertz and the system would generate gravitational waves which include this frequency. By coincidence, some of the other sources of gravitational waves – colliding black holes, coalescing neutron stars and exploding supernovae – are also expected to produce gravitational waves which include similar frequencies. Weber's bars had a resonant frequency around 1 kilohertz and a sensitivity of about 1 part in 10^{15}.

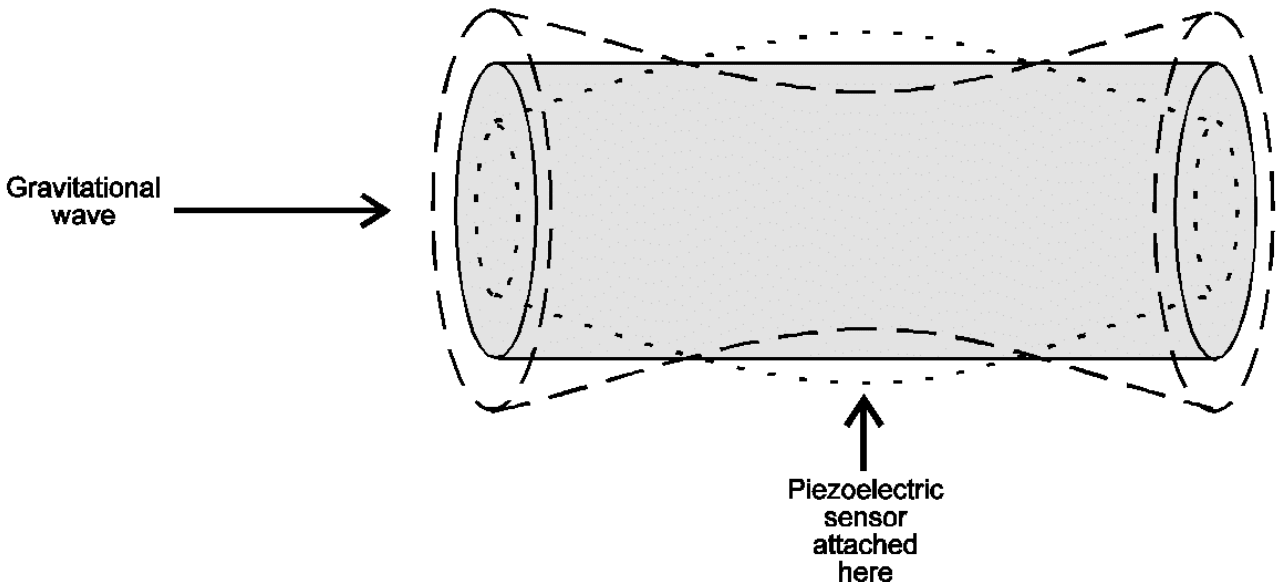


Figure 2: A metal Weber bar vibrates when it is hit by a gravitational wave travelling along its long axis; the piezoelectric sensors convert this movement to electrical signals that are recorded and analysed

Modern versions use bars cooled by super-cold liquids to minimise the thermal motion of the atoms they contain. Reducing this thermal noise gives the bars a sensitivity of about 1 part in 10^{18}. They should be sensitive enough to detect violent events in our own Galaxy. Work on such experiments is under way in the US, Switzerland and Italy. Researchers are also working on similar experiments using spherical detectors which are equally sensitive to gravitational waves from all directions. This work is being carried out in the US, Brazil and the Netherlands.

Another way to detect small changes in position is to use a laser interferometer. In this device light from a laser is split into two beams which travel along paths at right angles to one another (see Figure 3). The beams are reflected back the way they came by mirrors placed at equal distances from the beam splitter. The returning beams are recombined to produce an interference pattern, similar to the bright and dark stripes seen when light passes through two narrow parallel slits. If the length of either arm changes, one beam is delayed with respect to the other and the pattern of bright and dark stripes shifts. The path difference between the two beams – which is twice the difference in the lengths of the two arms – can then be calculated from the changes in the interference pattern.

As a gravitational wave passes perpendicularly to the plane of an interferometer, one arm is stretched while the other shrinks. A little later the first one shrinks and the other stretches. Gravitational waves are likely to contain a broad spectrum of vibration frequencies, and interferometers could be used to detect and analyse this spectrum. As different sources are likely to produce different gravitational wave spectra, this information could be used to identify and measure the source.

Interferometers have two major advantages over Weber bars. First, they respond to almost all frequencies of gravitational waves; in other words, they have a very wide bandwidth. Secondly, by placing the mirrors a long way away from each other, they can be made much more sensitive.

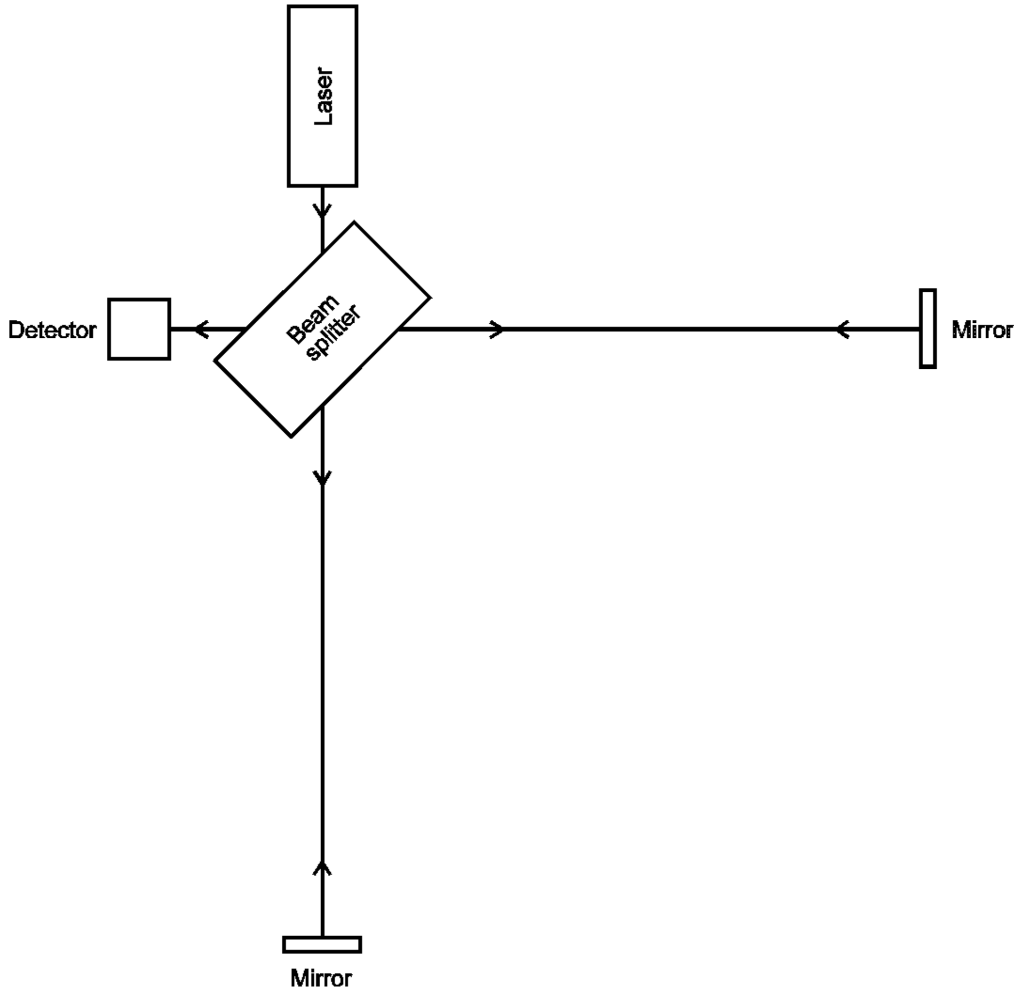


Figure 3: The arms of a laser interferometer change length when a gravitational wave strikes, shifting the pattern of dark and light stripes. By measuring the change in the pattern, this device can detect gravitational waves

Several projects to detect gravitational waves are under way. The biggest of these is in the US. The **LIGO** (laser interferometer gravitational-wave observatory) project, run from Caltech in Pasadena, California, is building a pair of interferometers in opposite corners of the country: one in Washington state and one in Louisiana. Each interferometer consists of two freely suspended test masses hanging at the ends of vacuum tubes 4 kilometres from the beam splitter. Each test mass has a mirror attached, in order to reflect the laser light. The two interferometers are about 3000 kilometres apart, and the idea is to compare any signals they produce so that disturbances due to local effects or seismic movements can be discounted.

Oxford Cambridge and RSA Examinations

Advanced GCE

PHYSICS B (Advancing Physics)
ADVANCES IN PHYSICS **2865**

Mark Scheme

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 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 the method, 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 numbers of significant figures in a final answer are penalised by the loss of a mark, generally once 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. Missing or incorrect units in a final answer are penalised by the loss of a mark, generally once per examination paper.
- Quality of written communication will be assessed in Section A where there are more opportunities to write extended prose.

Within the marks scheme the following notation is adopted

m	– method mark
s	– substitution mark
e	– evaluation mark
;	–separates individual marking points
/	– separates alternative answers
= 0	– common answers which should not be given credit
ecf	– error carried forward
owtte	– or words to that effect
( )	– material in brackets not needed for mark
vv	– vice versa

SECTION A

Qn	level	Expected answers	Marks	Additional guidance
1 (a)	E	Ultrasound use✓ reason✓ x-ray use ✓ reason✓	4	
(b)	E	longitudinal v transverse✓ mechanical versus electromagnetic✓	2	or other valid comparison
(c)	E	superposition✓	1	
			7	
2 (a)	E	Gamma photons are absorbed by the air ✓	1	
(b) (i)	E	E = 120 MeV $\times$ 1.6 $\times$ 10^{-19} C ✓ = 1.92 $\times$ 10^{-11} J	1	
(ii)	E	f = E/h = 2 $\times$ 10^{-11} J / 6.63 $\times$ 10^{-34} ✓ = 3 $\times$ 10^{22} Hz✓	2	m✓ e✓
(iii)	E	λ= c/f = 3 $\times$ 10^8 ms^{-1} / 3 $\times$ 10^{22} Hz✓ = 10^{-14} m ✓	2	m✓ e✓
(c)	B/A	Extremely energetic photons ✓ Created in very short time ✓	2	
			8	
3 (a)	D/C B/A	F = GMm/r^2 = 6.7 $\times$ 10^{-11} $\times$ 1.7$\times$$10^{-27}$ $\times$ 9.1 $\times$ 10^{-31}/(5.3 $\times$ 10^{-11})^2✓ = 3.7 $\times$$10^{-47}$ N ✓ F = ke^2/r^2 = 9.0 $\times$ 10^9 $\times$ (1.6 $\times$ 10^{-19})^2/(5.3 $\times$ 10^{-11})^2 ✓ = 8.2 $\times$ 10^{-8} N ✓ Ratio = 8.2 $\times$ 10^{-8} N /3.7 $\times$ 10^{-47} N = 2.2 $\times$ 10^{39} $\approx$ 10^{40} ✓	5	
(b)	D/C	F = GMm/r^2 = 6.7 $\times$ 10^{-11} $\times$(1.7 $\times$ 10^{-27})^2 /(1 $\times$ 10^{-14})^2 = 2 $\times$ 10^{-36} N ✓ F = ke^2/r^2 = 9.0 $\times$ 10^9 $\times$ (1.6 $\times$ 10^{-19})^2/(1 $\times$ 10^{-14})^2 = 2 N ✓ Ratio = 2 N /2 $\times$ 10^{-36} N = 10^{36}✓	3	
(c)	B/A	r^2 factor occurs in each calculation and ✓therefore cancels out	1	
			9	

4 **(a)**	E	$m = \rho V = 2700 \times 2.0 \times \pi \times (0.25)^2$ ✓ $= 1.1 \times 10^{3}$ kg ✓	2	
(b)	E	Amplitude = $0.5 / 10^{22}$ ✓ $= 5 \times 10^{-23}$ m ✓	2	m✓ e✓
(c)	D/C	This is a very tiny fraction of the size of an atom (or a nucleus) and such displacements would be unmeasurable✓	1	
(d)	B/A	Resonance explained, i.e. bar has a natural frequency of oscillation; ✓ oscillations at that frequency will increase in ampitude;✓	2	
(e)	E D/C	example ✓ possible factor ✓✓ second factor ✓✓ for example: equipment more expensive; equipment large e.g. CERN; increased ease of communication makes it possible; travel easier; location important e.g. Hawaii telescopes	5	statement of factor + some more detail
			12	
5 **(a)**	B/A	Single vertical spike for Weber bar✓ Spike labelled at 1 kHz✓ Horizontal line for interferometer✓	3	
(b)	B/A	Path difference in each limb = $2 \times (4000 \text{ m}/10^{20})$✓ $= 8 \times 10^{-17}$ m✓ $\Delta\lambda$ between both $= 2 \times 8 \times 10^{-17}$ m / 600×10^{-9} m ✓$= 2.7 \times 10^{-10}$ λ✓	4	
(c)	B/A	path difference $= 1/10^{20} \times 5 \times 10^{9}$ ✓ $= 5 \times 10^{-11}$ m ✓ still less than the diameter of an atom; much better than Earth bound ✓	3	
			10	
		QoWC in Section A	**4**	
		Section A total	**50**	

SECTION B

6 (a) (i)	E	charge = 1400 mA × 2 × 24 × 60 × 60 ✓ = 5040 C ✓	2	m✓ e✓
(ii)	E	Current = 5040 C / (2 × 3600 s)✓ = 0.7A	2	Must show working
(iii)	E	power = 4.1 V x 0.7 A ✓= 2.9 W✓	2	m✓ e✓
(b) (i)	D/C	spacing is 20 times less than plate width, so plates are 'close' and field is uniform ?	1	
(ii)	E	10^3 V m^{-1}; method ? ; result + units ?	2	
(c) (i)	D/C	image length in mm/10 mm = 5 m/25 m image length = 2mm method ? ✓	2	m✓ e✓
(ii)	D/C	2 mm / 20 mm × 1024 pixels ✓ = 102 pixels ?	2	m✓ e✓
(iii)	B/A	smallest detail visible about 50 mm?	1	
(iv)	B/A	1 pixel = 50 mm ? speed = 50 mm / .02 s ✓= 2.5 m s^{-1} ? ?	3	
(d)	B/A	use of c = fλ ? ; use of E=hf ? , correct calculations ?	3	
			20	
7 (a) (i)	E	The satellite needs to keep station at a fixed point in the sky over the receiver to avoid having to steer the receiver dish owtte ✓	1	
(ii)	E/D /C	GMm / R^2 = mv^2 / R ✓ sub v = 2πR / T✓ and rearrange ✓	3	
(iii)	D/C	$R^3 = GMT^2/4p^2 = 7.4 \times 10^{22}$ m^3 R = 4.2×10^7	2	sub ✓eval ✓
(b) (i)	D/C	Power increases ✓ (as I increases) reaches a peak when both I and V are relatively large, owtte ✓	2	
(ii)	E	V = 0.5 V, I = 0.05 A ✓ Power = 0.025 W ✓	2	Values from graph✓ evaluation✓
(iii)	D/C	r = (ε - V) / I ✓ = 0.15 / 0.05✓ = 3 Ω ✓	3	
(iv)	B/A	30 cells in series connection give 15V ✓ this repeated 40 times in parallel to deliver 2A Ω ✓	2	
(c) (i)	E	3×10^{10}Hz ✓ in the microwave region of the spectrum ✓	2	
(ii)	B/A	θ = λ / D = 10^{-5} rads ✓ r = Rθ = $3.6\times10^7\times10^{-5}$✓ = 350m✓	3	
			20	
		Section B total	**40**	

QoWC	Marking quality of written communication The appropriate mark (0-4) should be awarded based on the candidates quality of written communication in Section A of this paper.	**4** max
4	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 candidates meaning uncertain.	

Specification grid for OCR Physics B *Advancing Physics* — Specimen paper

Name of paper Unit 2865 Advances in Physics — Component number: - — Page 1 of 1

Question number	Assessment objectives Syllabus reference			Synthesis	Total mark for paper	Level of demand of question			
				A2 100	100%	E 35-45%	D-C 25-35%	B-A 25-35%	QoWC (4 marks)
1	5.1.1			7	7	7			
2	5.5.4	**5.2.1**	**5.4.3**	8	8	6		2	
3	5.4.2	**5.5.2**		9	9		5	4	
4	5.1.3	**5.2.6**	**5.4.1**	12	12	5	5	2	
QoWC				4	4				4
5	5.1.1	**5.2.1**		10	10		3	7	
6	5.1.2, 5.5.2	**5.1.1, 5.2.1**	**5.2.2**	20	20	8	5	7	
7	5.4.3, 5.1.2	**5.2.1**	**5.2.2**	20	20	6	9	5	
					90	32	27	27	4