Lockerbie Academy Physics Department

2021

HIGHER PHYSICS HOMEWORK BOOK1

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RELATIONSHIPS REQUIRED FOR HIGHER PHYSICS

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u + v)t$

$W = mg$

$F = ma$

$E_w = Fd$

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$P = \frac{E}{t}$

$p = mv$

$Ft = mv - mu$

$F = G\frac{m_1 m_2}{r^2}$

$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$

$l' = l\sqrt{1 - \left(\frac{v}{c}\right)^2}$

$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$

$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$

$W = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

$T = \frac{1}{f}$

$v = f\lambda$

$n = \frac{\sin\theta_1}{\sin\theta_2}$

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$

$\sin\theta_c = \frac{1}{n}$

$I = \frac{k}{d^2}$

$I = \frac{P}{A}$

$v = H_0 d$

$z = \frac{v}{c}$

$d\sin\theta = m\lambda$

Path difference= $m\lambda$ or $(m + ½)\lambda$ where m = 0,1,2 .....

$\text{random uncertainty} = \frac{\text{max. value - min. value}}{\text{number of values}}$

$V_{peak} = \sqrt{2}V_{RMS}$

$I_{peak} = \sqrt{2}I_{RMS}$

$Q = It$

$V = IR$

$P = IV = I^2R = \frac{V^2}{R}$

$R_T = R_1 + R_2 + ...$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ...$

$E = V + Ir$

$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)V_S$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$C = \frac{Q}{V}$

$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	Wavelength/nm	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength/nm	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength/nm	Colour
Carbon dioxide	9550 } 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density/kg m^{-3}	Melting Point/K	Boiling Point/K
Aluminium	$2{\cdot}70 \times 10^3$	933	2623
Copper	$8{\cdot}96 \times 10^3$	1357	2853
Ice	$9{\cdot}20 \times 10^2$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^3$	264	377
Water	$1{\cdot}00 \times 10^3$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^5$ Pa.

Electron Arrangements of Elements

Key

Atomic number Symbol Electron arrangement Name

Transition Elements (groups 3–12)

Group 1 (1)	Group 2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 H 1 Hydrogen																	2 He 2 Helium
3 Li 2,1 Lithium	4 Be 2,2 Beryllium											5 B 2,3 Boron	6 C 2,4 Carbon	7 N 2,5 Nitrogen	8 O 2,6 Oxygen	9 F 2,7 Fluorine	10 Ne 2,8 Neon
11 Na 2,8,1 Sodium	12 Mg 2,8,2 Magnesium											13 Al 2,8,3 Aluminium	14 Si 2,8,4 Silicon	15 P 2,8,5 Phosphorus	16 S 2,8,6 Sulfur	17 Cl 2,8,7 Chlorine	18 Ar 2,8,8 Argon
19 K 2,8,8,1 Potassium	20 Ca 2,8,8,2 Calcium	21 Sc 2,8,9,2 Scandium	22 Ti 2,8,10,2 Titanium	23 V 2,8,11,2 Vanadium	24 Cr 2,8,13,1 Chromium	25 Mn 2,8,13,2 Manganese	26 Fe 2,8,14,2 Iron	27 Co 2,8,15,2 Cobalt	28 Ni 2,8,16,2 Nickel	29 Cu 2,8,18,1 Copper	30 Zn 2,8,18,2 Zinc	31 Ga 2,8,18,3 Gallium	32 Ge 2,8,18,4 Germanium	33 As 2,8,18,5 Arsenic	34 Se 2,8,18,6 Selenium	35 Br 2,8,18,7 Bromine	36 Kr 2,8,18,8 Krypton
37 Rb 2,8,18,8,1 Rubidium	38 Sr 2,8,18,8,2 Strontium	39 Y 2,8,18,9,2 Yttrium	40 Zr 2,8,18, 10,2 Zirconium	41 Nb 2,8,18, 12,1 Niobium	42 Mo 2,8,18,13, 1 Molybdenum	43 Tc 2,8,18,13, 2 Technetium	44 Ru 2,8,18,15, 1 Ruthenium	45 Rh 2,8,18,16, 1 Rhodium	46 Pd 2,8,18, 18,0 Palladium	47 Ag 2,8,18, 18,1 Silver	48 Cd 2,8,18, 18,2 Cadmium	49 In 2,8,18, 18,3 Indium	50 Sn 2,8,18, 18,4 Tin	51 Sb 2,8,18, 18,5 Antimony	52 Te 2,8,18, 18,6 Tellurium	53 I 2,8,18, 18,7 Iodine	54 Xe 2,8,18, 18,8 Xenon
55 Cs 2,8,18,18, 8,1 Caesium	56 Ba 2,8,18,18, 8,2 Barium	57 La 2,8,18,18, 9,2 Lanthanum	72 Hf 2,8,18,32, 10,2 Hafnium	73 Ta 2,8,18, 32,11,2 Tantalum	74 W 2,8,18,32, 12,2 Tungsten	75 Re 2,8,18,32, 13,2 Rhenium	76 Os 2,8,18,32, 14,2 Osmium	77 Ir 2,8,18,32, 15,2 Iridium	78 Pt 2,8,18,32, 17,1 Platinum	79 Au 2,8,18, 32,18,1 Gold	80 Hg 2,8,18, 32,18,2 Mercury	81 Tl 2,8,18, 32,18,3 Thallium	82 Pb 2,8,18, 32,18,4 Lead	83 Bi 2,8,18, 32,18,5 Bismuth	84 Po 2,8,18, 32,18,6 Polonium	85 At 2,8,18, 32,18,7 Astatine	86 Rn 2,8,18, 32,18,8 Radon
87 Fr 2,8,18,32, 18,8,1 Francium	88 Ra 2,8,18,32, 18,8,2 Radium	89 Ac 2,8,18,32, 18,9,2 Actinium	104 Rf 2,8,18,32, 32,10,2 Rutherfordium	105 Db 2,8,18,32, 32,11,2 Dubnium	106 Sg 2,8,18,32, 32,12,2 Seaborgium	107 Bh 2,8,18,32, 32,13,2 Bohrium	108 Hs 2,8,18,32, 32,14,2 Hassium	109 Mt 2,8,18,32, 32,15,2 Meitnerium	110 Ds 2,8,18,32, 32,17,1 Darmstadtium	111 Rg 2,8,18,32, 32,18,1 Roentgenium	112 Cn 2,8,18,32, 32,18,2 Copernicium						

Lanthanides	57 La 2,8,18, 18,9,2 Lanthanum	58 Ce 2,8,18, 20,8,2 Cerium	59 Pr 2,8,18,21, 8,2 Praseodymium	60 Nd 2,8,18,22, 8,2 Neodymium	61 Pm 2,8,18,23, 8,2 Promethium	62 Sm 2,8,18,24, 8,2 Samarium	63 Eu 2,8,18,25, 8,2 Europium	64 Gd 2,8,18,25, 9,2 Gadolinium	65 Tb 2,8,18,27, 8,2 Terbium	66 Dy 2,8,18,28, 8,2 Dysprosium	67 Ho 2,8,18,29, 8,2 Holmium	68 Er 2,8,18,30, 8,2 Erbium	69 Tm 2,8,18,31, 8,2 Thulium	70 Yb 2,8,18,32, 8,2 Ytterbium	71 Lu 2,8,18,32, 9,2 Lutetium
Actinides	89 Ac 2,8,18,32, 18,9,2 Actinium	90 Th 2,8,18,32, 18,10,2 Thorium	91 Pa 2,8,18,32, 20,9,2 Protactinium	92 U 2,8,18,32, 21,9,2 Uranium	93 Np 2,8,18,32, 22,9,2 Neptunium	94 Pu 2,8,18,32, 24,8,2 Plutonium	95 Am 2,8,18,32, 25,8,2 Americium	96 Cm 2,8,18,32, 25,9,2 Curium	97 Bk 2,8,18,32, 27,8,2 Berkelium	98 Cf 2,8,18,32, 28,8,2 Californium	99 Es 2,8,18,32, 29,8,2 Einsteinium	100 Fm 2,8,18,32, 30,8,2 Fermium	101 Md 2,8,18,32, 31,8,2 Mendelevium	102 No 2,8,18,32, 32,8,2 Nobelium	103 Lr 2,8,18,32, 32,9,2 Lawrencium

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CHAPTER 1 REVISION

Units, Prefixes & Scientific Notation -Tutorial 1

PREFIXES

1) Use scientific notation to write the measurements in the units shown.

a.	12 gigahertz	=	12 GHz	=	Hz
b.	4.7 megohms	=	4.7 MΩ	=	Ω
c.	46 kilometres	=	46 km	=	M
d.	3.6 millivolts	=	3.6 mV	=	V
e.	0.55 milliamps	=	0.55 mA	=	A
f.	25 microamps	=	25 µA	=	A
g.	630 nanometres	=	630 nm	=	M
h.	2200 picofarads	=	2200 pF	=	F

2) Rewrite the following quantities in the units shown. –

a.	14×10^{3} m	=	km		
b.	2.3×10^{7} Ω	=	MΩ		
c.	5.6×10^{8} Hz	=	GHz	=	MHz
d.	4.6×10^{-3} V	=	mV	=	µV
e.	2.5×10^{-5} A	=	µA	=	mA
f.	4.50×10^{-7} m	=	nm		

3) Express the following quantities in terms of the five base units (Hint think of equations linking the quantities)

a) acceleration, b) force and c) work .

4) Express the unit of charge in terms of the base units.

5) Put the following values into mA or µA

a) O.005A b) 0.080A c) 0.0000078A
d) 0.45A e) 0.670A f) 0.047A
g) 0.00003A h) 1A

6) Put the following into kΩ MΩ, GΩ or TΩ as required:

a) 5000 Ω b) 10000 Ω c) 3000000 Ω d) 600000 Ω e) 340 Ω
f) 3 x 10^{5} Ω g) 4 x l0^{4} Ω h) 9 x 10^{13} Ω i) 8.4 x 1O^{7} Ω j) 3.56 x 1O^{8} Ω
k) 98 x 1O^{5} Ω l) 740 x l0^{11} Ω

7) Change the following distances into the prefix shown in brackets.

a) 500 mm (to m) b) 50 cm (to mm) c)5000000 mm (to km) d) 68000 cm (to km)
e) 0.09 km (to cm) f) 0.28 cm (to mm) g) 9560 m (to cm) h) 9220 m (to cm)
i) 0.78 Mm (to cm)

8) Quote the following values to the number of significant figures shown in the brackets.
   a) 242 cm (to 2 sig fig) b) 273°C (to 2 sig. fig.) c) 31.20 mm (to 3 sig. fig.)
   d) 1786 (to 2 sig fig) e) 74500 (to 3 sig. fig.) f) 15600 (to 2 sig. fig.)

9) A pupil measures the current through a resistor as 0.25A and the voltage across it is 2.0V. What is the resistance of the resistor?

10) How much energy is released when 0.500kg of water (c=4180 $Jkg^{-1}\,^{\circ}C^{-1}$) lowers its temperature by 5°C?

11) What is the power of a heater that uses 1200J of energy in 212.5 seconds?

12) What is the acceleration of a car that changes its speed by 34.5ms^{-1} in a time of 5s?

13) What is the volume of a cuboid with sides length 10cm, 5.5cm and 2.55cm respectively?

Units, Prefixes & Scientific Notation –

1) What current flows through a loudspeaker of power 8W if a voltage of 12.0V is across it?
2) Copy and complete the following table:

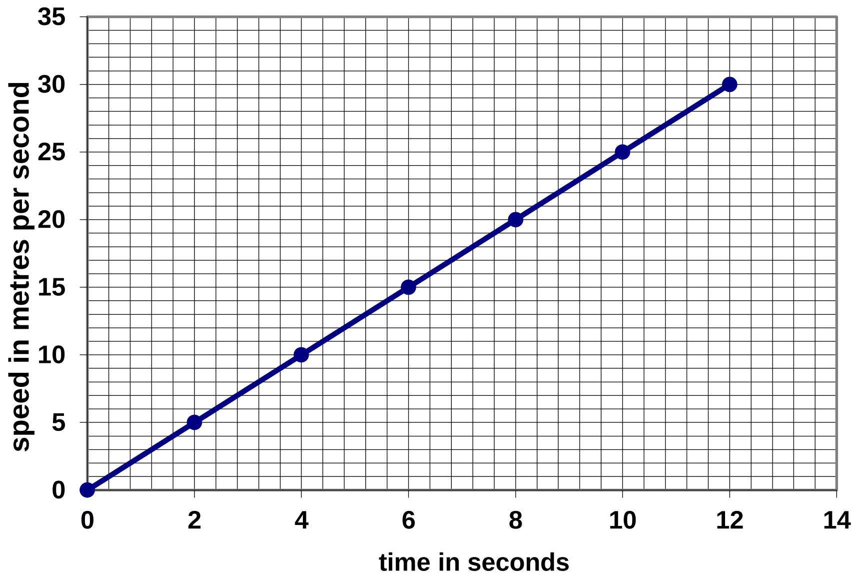
	mass (kg)	gravitational field strength (N/kg)	height, (m)	potential energy, (J)	no. of *sig.* fig.
a)	2	10	3		
b)	2.35	10.00	3.05		
c)		2	4.5	1200	
d)	40.0	1.6		100.00	
e)	60		5	1000	
f)	2	8.8		300	
g)		10	9	9999	

3) What value for the speed of sound would you get if the results were:
   Explain the difference in your values.

Distance (m)	Time(s)	Speed (ms^{-1})
1000	3	
1000.00	3	
1000.00	3.00	
1000	3.0	

4) A circle has a radius of 2.5cm, what is its area?

5) A sphere has a radius of 2.500cm, what is its volume?
6) From the graph below, what distance is travelled by the object in l0s?



7) 68122500J of energy are used by a heater in 136245s. What is the power output of the heater?

CHAPTER 2 Open-Ended Questions

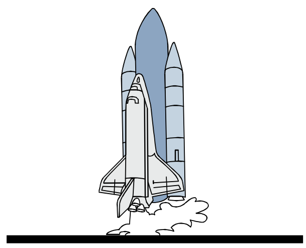
OPEN ENDED QUESTIONS

Question 1

A student is watching the launch of a rocket.

The student states that the rocket takes off because the gas from the rocket engine pushes on the ground.

Using physics principles show that the student's statement is untrue.



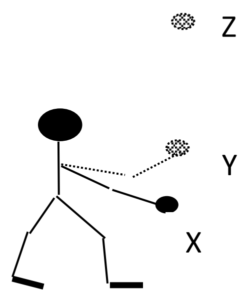
Question 2

A ball is thrown vertically into the air.

The ball starts from rest at point X.

It leaves the thrower's hand at point Y and travels vertically upwards to point Z. A student states "the magnitude of the acceleration of the ball is **always** greater when **being** thrown (from X to Y) from rest than when in the air from Y to Z."

Use your knowledge of physics to comment on this statement.



Question 3

When you jump from a height of 5 m into water it usually does not cause any damage.

Jumping from the same height onto a concrete surface usually causes injury.

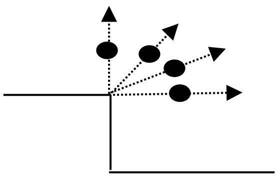
Use physics principles to comment on this statement.

Question 4

A student states "*When a **single** force acts on an object the object can never remain stationary or move with constant speed*"

Using physics principles comment this statement.

Question 5



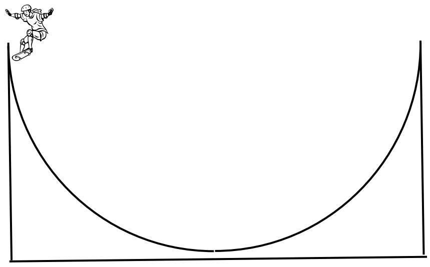
A ball can be thrown into the air at all angles to the horizontal, including 0^o and 90^o.

A student states "*the acceleration of the ball can never be parallel to the velocity of the ball".*

Use your knowledge of physics to comment on the truth or otherwise of this statement.

Question 6

A commentator at a skateboarding competition describes the movement of a competitor on a ramp as shown in the diagram.



"The skateboarder has gained enough force on the down-slope to let her reach the very top of the up- slope".
Using physics principles, comment on the way the commentator has described the movement of this competitor.

Question 7

In a book in which he describes his childhood experiences, an author describes how he used to drop peanuts down the stairwell of a department store. This would annoy the shop owner,"*who would come flying up the stairs at about the speed that the peanut had gone down, giving you less than five seconds to scramble away to freedom*". **© The Life and Times of the Thunderbolt Kid: A Memoir by Bill Bryson, Random House, 2006**

Using physics principles, comment on the way the author has compared the speed of the peanut and the shop owner.

ESTIMATE

These questions are about your thinking and working not the final answer.

1. Estimate the number of atoms in a 1p coin.
2. Estimate the maximum power output of a reasonably fit human being. For example, imagine running up stairs or lifting a heavy weight as quickly as you can.
3. Estimate the mass of food given to a tiger in a zoo each day.
4. Estimate the number of piano tuners in London.
5. Estimate the number of air molecules in the entire atmosphere. (The radius of the Earth is about 6000km, atmospheric pressure at the Earth's surface is about 10^5Pa, the density of air at STP is about $1kgm^{-3}$).
6. Estimate the thickness of the layer of rubber left by a car during normal driving.

Chapter 3 Uncertainties

UNCERTAINTIES

Now try the following six questions. They should be used to make you think of the consequences of uncertainties in experiments

1) In an experiment to measure the speed of a trolley as it runs down a ramp, the timing gate at the top of the ramp takes 0.05s to switch the clock on. The gate at the bottom takes 0.08s to switch the clock off. Explain whether the calculated value of the speed is too low or too high.

2) A pupil boils some water for a time and calculates the amount of heat delivered in the process. He then measures the amount of water turned into steam and calculates the specific latent heat of vaporisation of the water, l, using the relationship $E_h = m\,l$, where m is the mass in kilogrammes.

Results:
power of the heater = 500.00 W
boiling time = 5 min 16.4 s
Find E_h =
initial mass of water = 800.0 g
final mass of water = 720.0 g
Find mass of water evaporated =

(a) What does the pupil calculate as the value of *l*?
(b) Suggest a reason why his answer is lower than the accepted value of 2.26×10^{6} Jkg^{-1}.

3). Three groups in a class are trying to measure the velocity of water waves by noting down the frequency on the generator and measuring the wavelength in the tank.

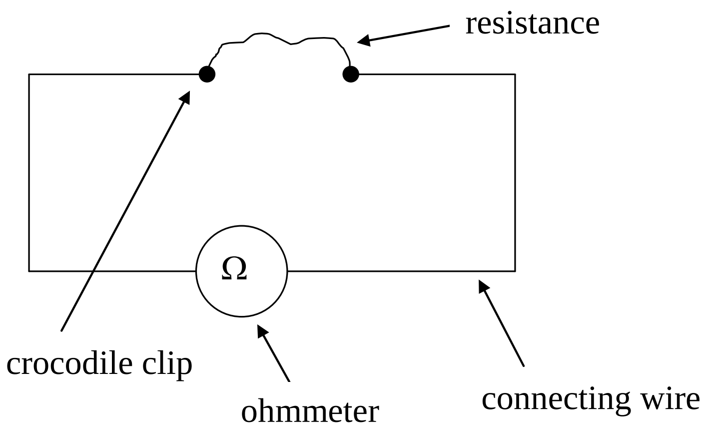
Results:

Group	Number of Waves	Length (cm)
1	4	21.2
	6	31.8
	3	15.9
	5	26.5
2	12	63.6
	13	68.6
	17	90.1
	15	79.5
3	9	48.6
	11	59.4
	7	37.8
	8	43.2

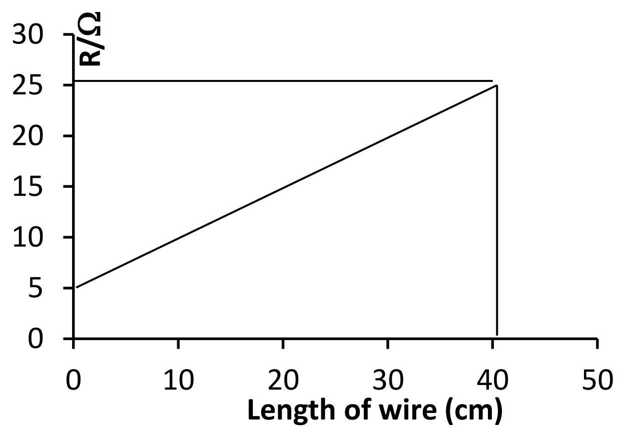
(a) Which group has the short metre stick?

(b) If they use the formula $v = f \times \lambda$ to calculate the velocity, does this make their calculated result slower or faster than the other two groups?

5). A National 5 pupil is investigating the relationship between the length of a wire and its resistance using the following arrangement:



The graph of her results shows the expected straight line but it does not pass through the origin:

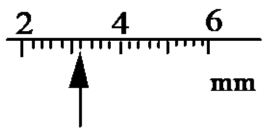


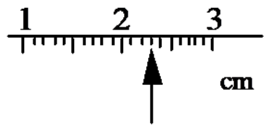
a) What is the resistance of zero centimetres of any wire?
b) Why do you think the graph does not pass through the origin?
c) What do these results give as the resistance of one metre of wire

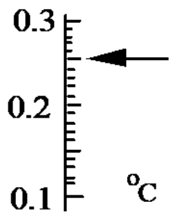
<u>The following problems are from the HSDU Notes</u>

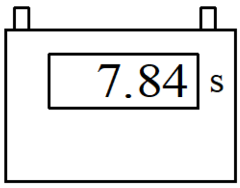
1. Calculate the percentage uncertainties for the following absolute readings:
   a) (4.65 ± 0.05) V b) (892 ± 5) cm c) (1.8 ± 0.4) A
   d) (2.87 ± 0.02) s e) (13.8 ± 0.5) Hz f) (5.2 ± 0.1) m.
2. State the three types of uncertainty, explaining the difference between them.
3. Manufacturers of resistors state the uncertainty in their products by using colour codes.
   Gold - 5 % accuracy. Silver - 10 % accuracy.
   Calculate the possible ranges for the following resistors for each colour.
   a) 1 k Ω b) 10 k Ω c) 22 Ω

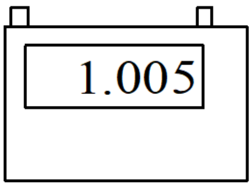
4. For each of the following scales, write down the reading and estimate the uncertainty.

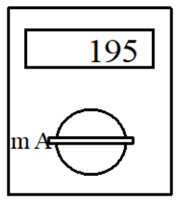
a)


b)


c)


d)


e)


f)


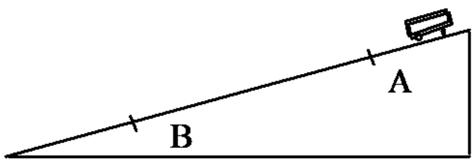
5. Calculate the mean time and random uncertainty for the following readings:
   0.8 s, 0.6 s, 0.5 s, 0.6 s and 0.4 s.

6. A student uses light gates and suitably interfaced computer to measure the acceleration of a trolley as it moves down a slope. The following results were obtained.

a / m s^2	5.16	5.24	5.21	5.19	5.12	5.20	5.17	5.19

Calculate the mean acceleration and the corresponding random uncertainty.

7. AB is measured using a metre stick.A trolley is timed between AB.
The following results were obtained.



AB = (60.0 + 0.1) cm

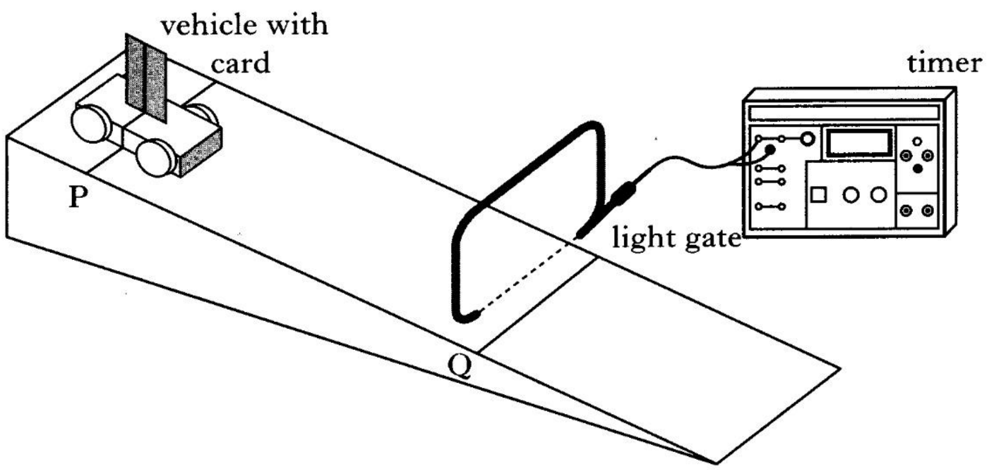
t/s	1.21	1.21	1.26	1.27	1.24	1.28

Express the average speed in the form (value ± absolute uncertainty)

Chapter 4 Our Dynamic Universe

UNCERTAINTIES IN MECHANICS

1. A student uses the apparatus shown to measure the average acceleration of a trolley travelling down a track.



The line on the trolley is aligned with line P on the track.

The trolley is released from rest and allowed to run down the track.

The timer measures the time for the card to pass through the light gate.

The procedure is repeated a number of times and the results shown below.

0·015 s 0·013 s 0·014 s 0·019 s 0·017 s 0·018 s

(a) Calculate:

(i) the mean time for the card to pass through the light gate; 1

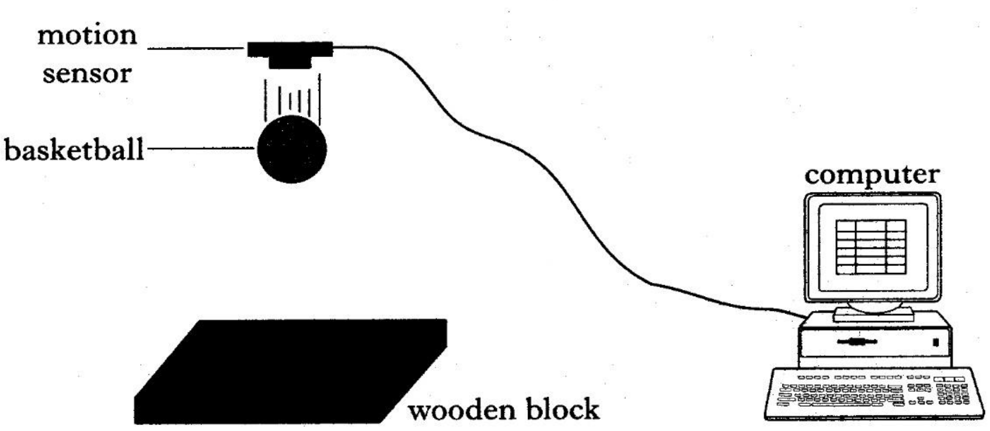
(ii) the approximate absolute random uncertainty in this value. 1

(b) The length of the card is 0·020 m and the distance PQ is 0·60 m.

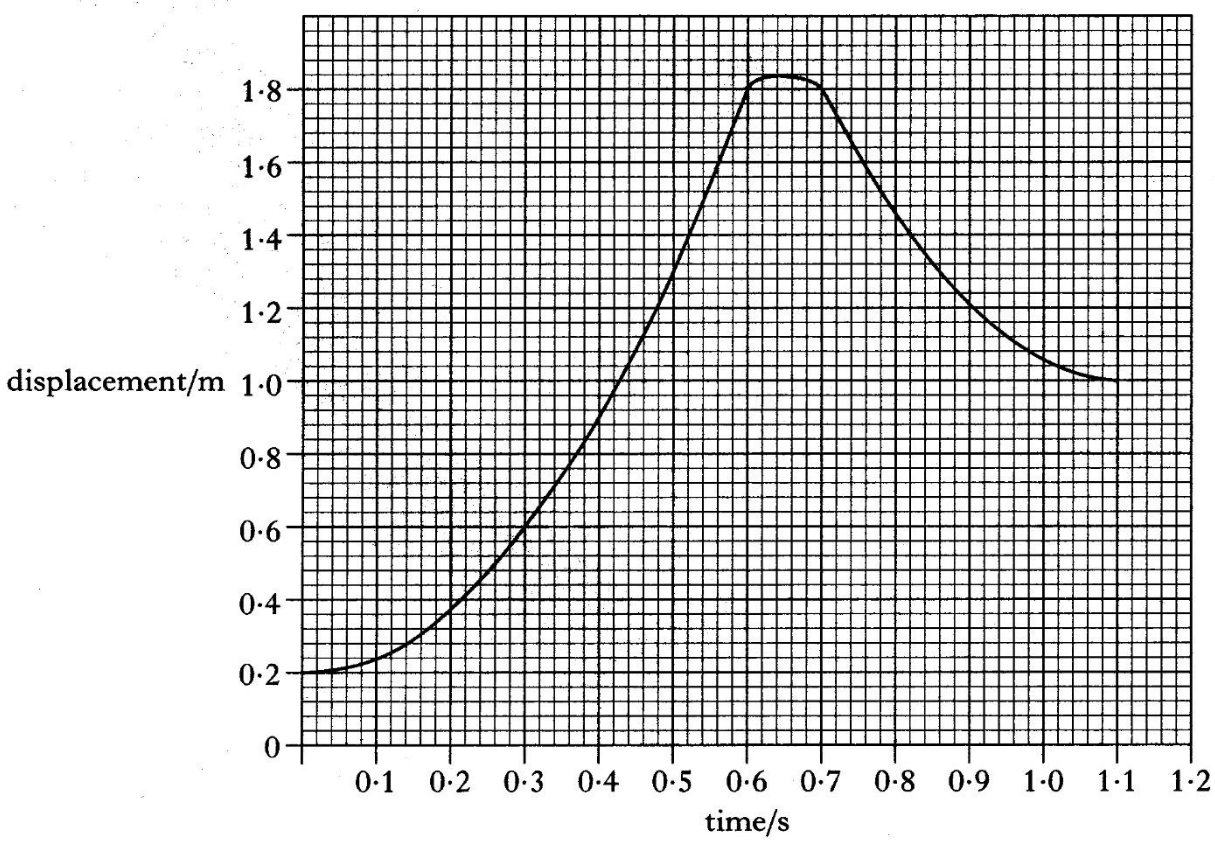
Calculate the acceleration of the trolley (an uncertainty in this value is not required). 3

(5)

2. A basketball is held below a motion sensor. The basketball is released from rest and falls onto a wooden block. The motion sensor is connected to a computer so that graphs of the motion of the basketball can be displayed.



A displacement-time graph for the motion of the basketball from the instant of its release is shown.



(a) (i) What is the distance between the motion sensor and the top of the basketball when it is released? 1

(ii) How far does the basketball fall before it hits the wooden block? 1

(iii) Show, by calculation, that the acceleration of the basketball as it falls is 8·9 m s^{-2}. 1

(b) The basketball is now dropped several times from the same height. The following values are obtained for the acceleration of the basketball.

8·9 m s^{-2} 9·1 m s^{-2} 8·4 m s^{-2} 8·5 m s^{-2} 9·0 m s^{-2}

Calculate:

(i) the mean of these values; 1

(ii) the approximate random uncertainty in the mean. 1

(c) The wooden block is replaced by a block of sponge of the same dimensions. The experiment is repeated and a new graph obtained.

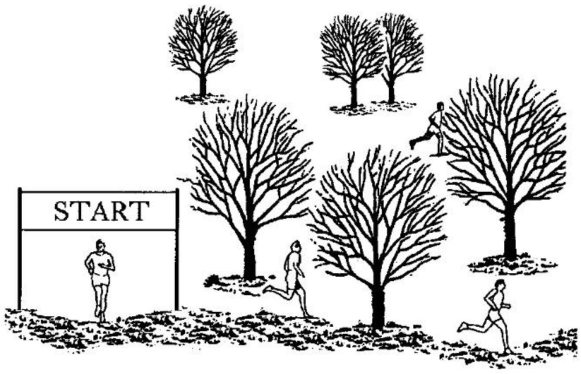
Describe and explain any **two** differences between this graph and the original graph. 2

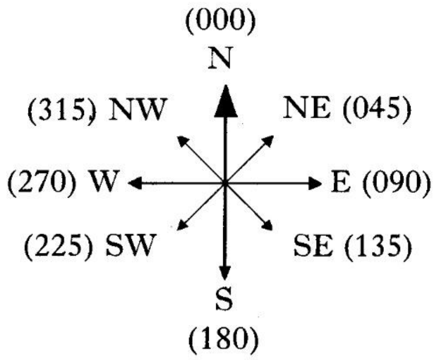
(7)

VECTORS

1. (a) State the difference between vector and scalar quantities. 1

(b) In an orienteering event, competitors navigate from the start to control points around a set course.
Two orienteers, Andy and Paul, take part in a race in a flat area. Andy can run faster than Paul, but Paul is a better navigator.





From the start, Andy runs 700 m north (000) then 700 m south-east (135) to arrive at the first control point. He has an average running speed of 3·0 m s^{-1}.

(i)By scale drawing or otherwise, find the displacement of Andy, from the starting point, when he reaches the first control point. 3

(ii)Calculate the average velocity of Andy between the start and the first control point. 2

(iii)Paul runs directly from the start to the first control point with an average running speed of 2·5 m s^{-1}.

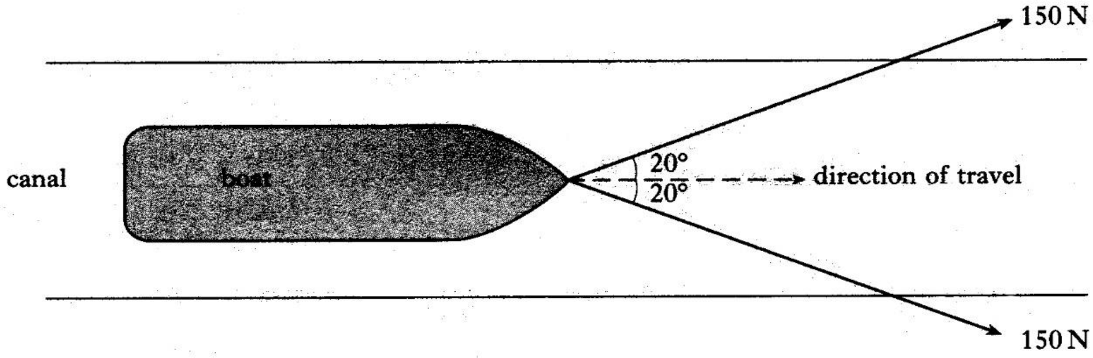
Determine the average velocity of Paul. 1

(iv)Paul leaves the starting point 5 minutes after Andy.

Show by calculation who is first to arrive at the first control point. 3

(10)

2. Two ropes are used to pull a boat at constant speed along a canal.



Each rope exerts a force of 150 N at 20° to the direction of travel of the boat as shown.

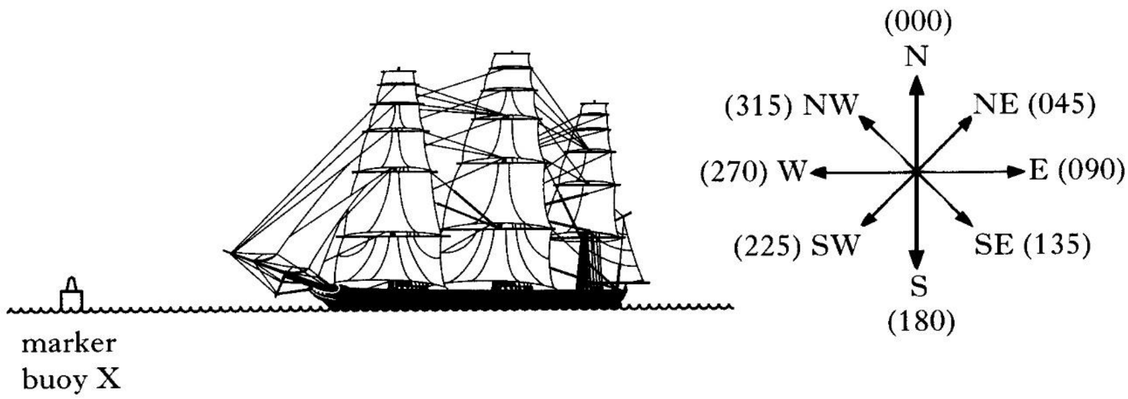
(a) Calculate the magnitude of the resultant force exerted by the ropes. 2

(b) What is the magnitude of the frictional force acting on the boat? 1

(3)

4. (a) State the difference between speed and velocity. 1

(b) During a tall ships race, a ship called the Mir passes a marker buoy X and sails due West (270). It sails on this course for 30 minutes at a speed of 10·0 km h^{-1}, then changes course to 20° West of North (340). The Mir continues on this new course for 1·5 hours at a speed of 8·0 km h^{-1} until it passes marker buoy Y.



(i) Show that the Mir travels a total distance of 17 km between marker buoys X and Y. 2

(ii) By scale drawing or otherwise, find the displacement from marker buoy X to marker buoy Y. 2

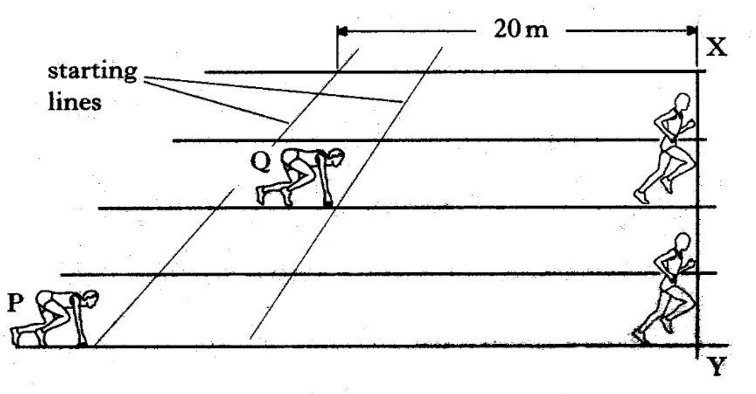
(iii) Calculate the average velocity, in km h^{-1}, of the Mir between marker buoy X and Y. 2

(c) A second ship, the Leeuvin, passes marker buoy X fifteen minutes after the Mir and sails directly for marker buoy Y at a speed of 7·5 km h^{-1}. Show by calculation which ship first passes marker buoy Y. 2

(9)

EQUATIONS OF MOTION

1. In a "handicap" sprint race, sprinters P and Q both start at the same time but from different starting lines on the track.
The handicapping is such that both sprinters reach line XY, as shown below, at the same.



Sprinter P has a constant acceleration of 1·6 m s^{-2} from the start line to the line XY. Sprinter Q has a constant acceleration of 1·2 m s^{-2} from the start line to line XY.

(a) Calculate the time taken by the sprinters to reach line XY. 2

(b) Find the speed of **each** sprinter at this line. 3

(c) What is the distance, in metres, between the starting lines for sprinters P and Q? 2

(7)

2. (a) An object starts from rest and moves with constant acceleration a. After a time t, the velocity v and displacement s are given by

$$v = at \text{ and } s = \tfrac{1}{2}at^2 \text{ respectively.}$$

Use these relationships, to show that

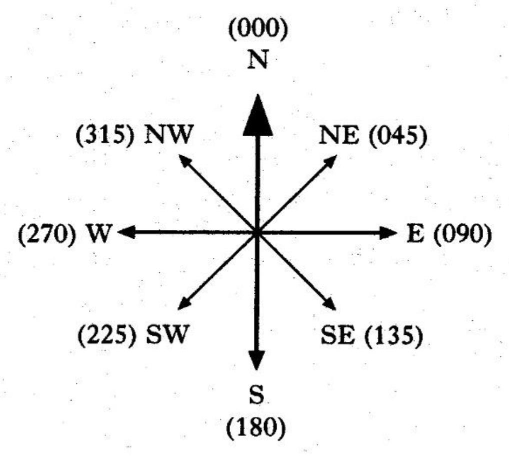
$$v^2 = 2as.$$ 2

(b) An aircraft of mass 1000 kg has a speed of 33 m s^{-1} before it takes off from a runway. The engine of the aircraft provides a constant thrust of 3150 N. A constant frictional force of 450 N acts on the aircraft as it moves along the runway.

(i) Calculate the acceleration of the aircraft along the runway. 2

(ii) The aircraft starts from rest. Calculate the minimum length of runway required for a take-off. 2

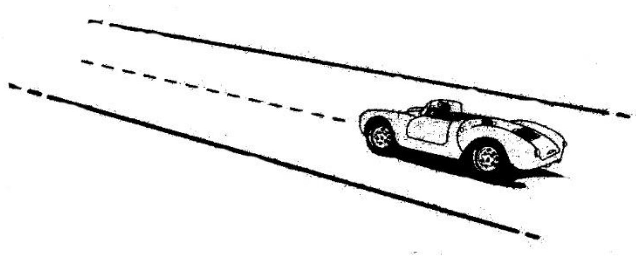
(c) During a flight the aircraft is travelling with a velocity of 36 m s^{-1} due north (000).
A wind with a speed of 12 m s^{-1} starts to blow **towards** the direction of 40° west of north (320).



Find the magnitude and direction of the resultant velocity of the aircraft. 3

(9)

3. (a) A sports car is being tested along a straight track.

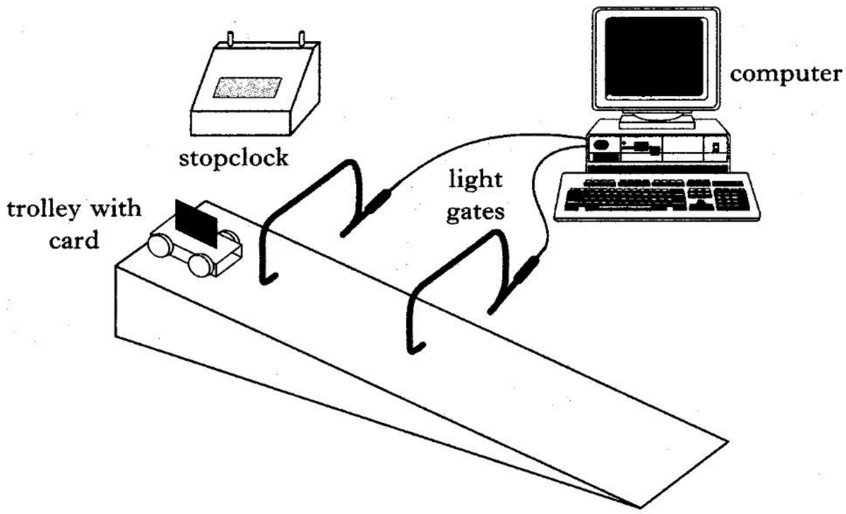


(i) In the first test, the car starts from rest and has a constant acceleration of $4{\cdot}0 \text{ m s}^{-2}$ in a straight line for $7{\cdot}0$ s.
Calculate the distance the car travels in the $7{\cdot}0$ s. 2

(ii) In a second test, the car again starts from rest and accelerates at $4{\cdot}0 \text{ m s}^{-2}$ over twice the distance covered in the first test.
What is the **increase** in the final speed of the car at the end of the second test compared with the final speed at the end of the first test? 2

(iii) In a third test, the car reaches a speed of 40 m s^{-1}. It then decelerates at $2{\cdot}5 \text{ m s}^{-2}$ until it comes to rest.
Calculate the distance travelled by the car while it decelerates to rest. 2

(b) A student measures the acceleration of a trolley as it moves freely down a sloping track.



The trolley has a card mounted on it. As it moves down the track the card cuts off the light at each of the light gates in turn. Both the light gates are connected to a computer which is used for timing.

The student uses a stopclock to measure the time it takes the trolley to move from the first light gate to the second light gate.

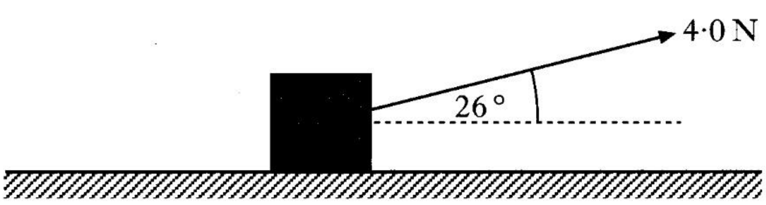
(i) List all the measurements that have to be made by the student and the computer to allow the acceleration of the trolley to be calculated. 2

(ii) Explain fully how each of these measurements is used in calculating the acceleration of the trolley as it moves down the slope. 2

(10)

FORCE, ENERGY AND POWER

1. (a) A box of mass 18 kg is at rest on a horizontal frictionless surface. A force of 4·0 N is applied to the box at an angle of 26° to the horizontal.

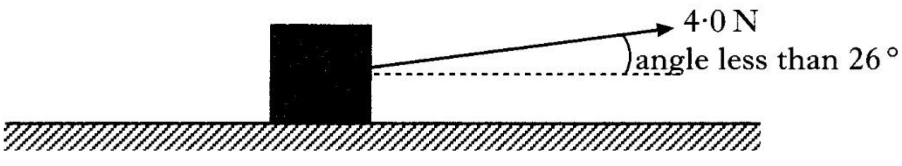


(i) Show that the horizontal component of the force is 3·6 N. 1

(ii) Calculate the acceleration of the box along the horizontal surface. 2

(iii) Calculate the horizontal distance travelled by the box in a time of 7·0 s. 2

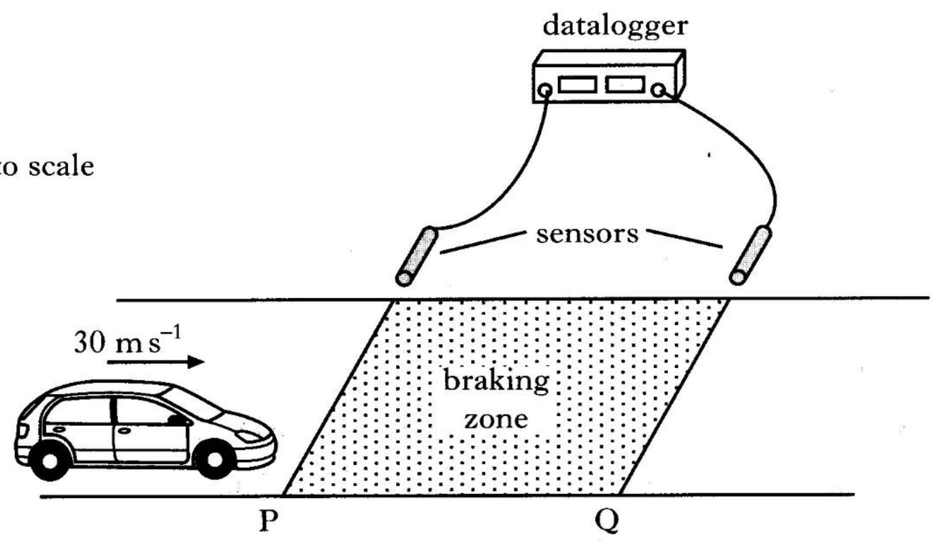
(b) The box is replaced at rest at its starting position. The force of 4·0 N is now applied to the box at an angle of less than 26° to the horizontal.



The force is applied for a time of 7·0 s as before. How does the distance travelled by the box compare with your answer to part (a)(iii)? You must justify your answer. 2

(7)

2. To test the braking system of cars, a test track is set up as shown.



The sensors are connected to a datalogger which records the speed of the car at both P and Q.

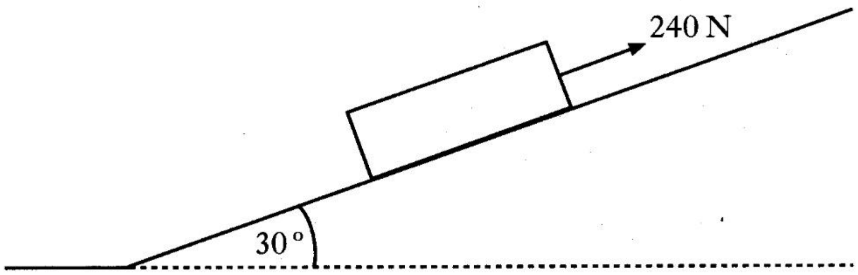
A car is driven at a constant speed of 30 m s^{-1} until it reaches the start of the braking zone at P. The brakes are then applied.

(a) In one test, the datalogger records the speed at P at 30 m s^{-1} and the speed at Q as 12 m s^{-1}. The car slows down at a constant rate of 9·0 m s^{-2} between P and Q.
Calculate the length of the braking zone. 2

(b) The test is repeated. The same car is used but now with passengers in the car. The speed at P is again recorded as 30 m s^{-1}.
The same braking force is applied to the car as in part (a).
How does the speed of the car at Q compare with its speed at Q in part (a)? Justify your answer. 2

(4)

3 A crate of mass 40·0 kg is pulled up a slope using a rope.
The slope is at an angle of 30° to the horizontal.

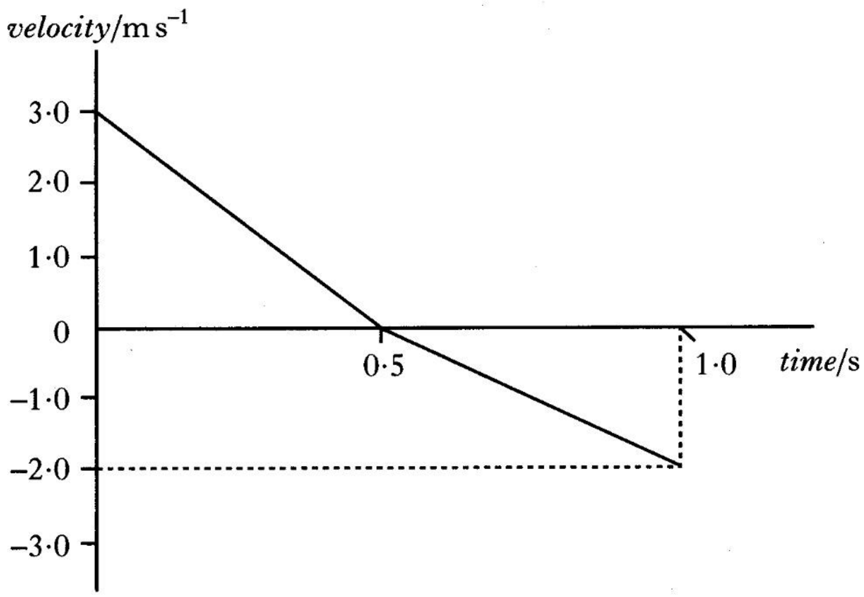


A force of 240 N is applied to the crate parallel to the slope.
The crate moves at a constant speed of 3·0 m s^{-1}.

(a) (i) Calculate the component of the weight acting parallel to the slope, 2

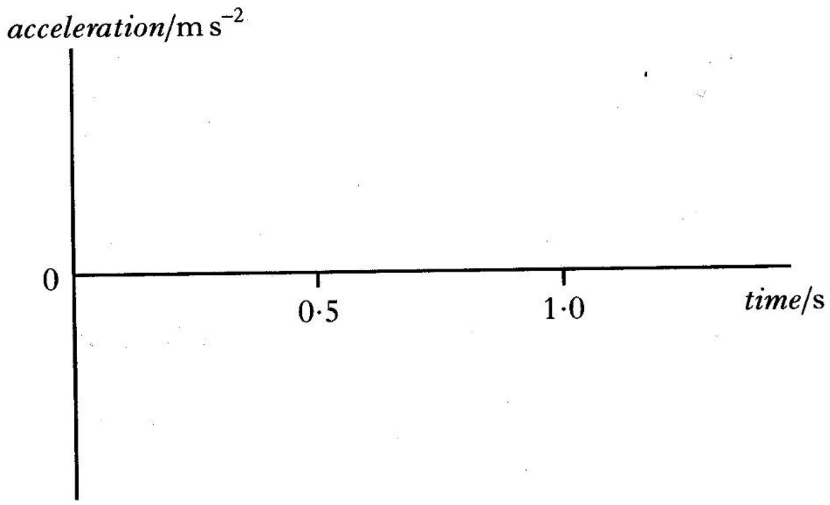
(ii) Calculate the frictional force acting on the crate. 2

(b) As the crate is moving up the slope, the rope snaps.
The graph shows how the velocity of the crate changes from the moment the rope snaps.



(i) Describe the motion of the crate during the first 0·5 s after the rope snaps. 1

(ii) Copy the axes shown below and sketch the graph to show the acceleration of the crate between 0 and 1·0 s.
Appropriate numerical values are also required on the acceleration axis. 2

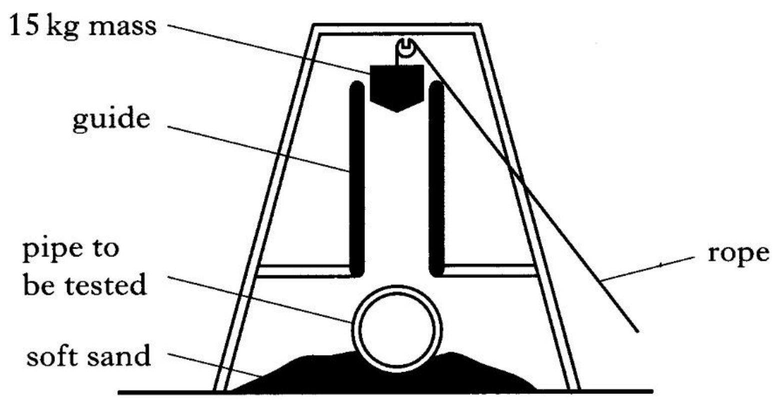


(iii) Explain, in terms of the forces acting on the crate, why the magnitude of the acceleration changes at 0·5 s. 2

(9)

COLLISIONS AND EXPLOSIONS

1. The apparatus shown below is used to test concrete pipes.



When the rope is released, the 15 kg mass is dropped and falls freely through a distance of 2·0 m on to the pipe.

(a) In one test, the mass is dropped on to an uncovered pipe.

(i) Calculate the speed of the mass just before it hits the pipe. 3

(ii) When the 15 kg mass hits the pipe the mass is brought to rest in a time of 0·020 s. Calculate the size and direction of the average unbalanced force on the **pipe**. 2

(b) The same 15 kg mass is now dropped through the same distance on to an identical pipe which is covered with a thick layer of soft material. Describe and explain the effect this layer has on the size of the average unbalanced force on the pipe.

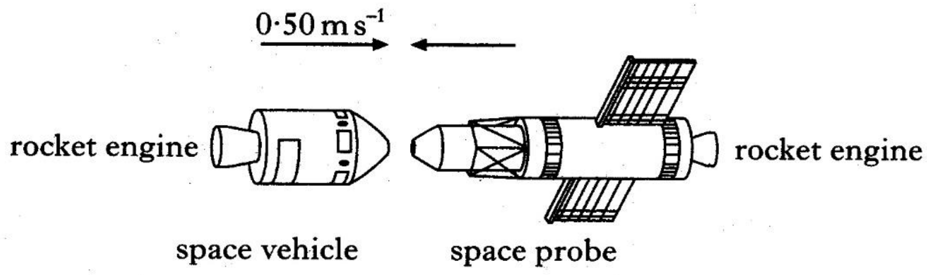
(c) Two 15 kg, X and Y, shaped as shown, are dropped through the same distance on to identical uncovered concrete pipes.

When the masses hit the pipes, the masses are brought to rest in the same time.

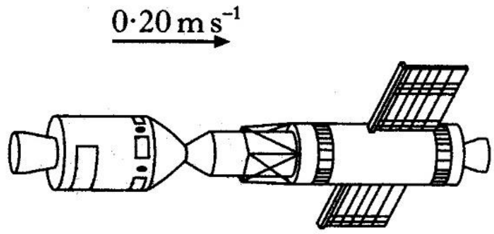
Using your knowledge of physics, explain which mass causes more damage to a pipe. 2

(9)

2. (a) A space vehicle of mass 2500 kg is moving with a constant speed of 0·50 m s^{-1} in the direction shown. It is about to dock with a space probe of mass 1500 kg which is moving with a constant speed in the opposite direction.



After docking, the space vehicle and the space probe move off together at 0·20 m s^{-1} in the original direction in which the space vehicle was moving.



Calculate the speed of the space probe before it docked with the space vehicle. 2

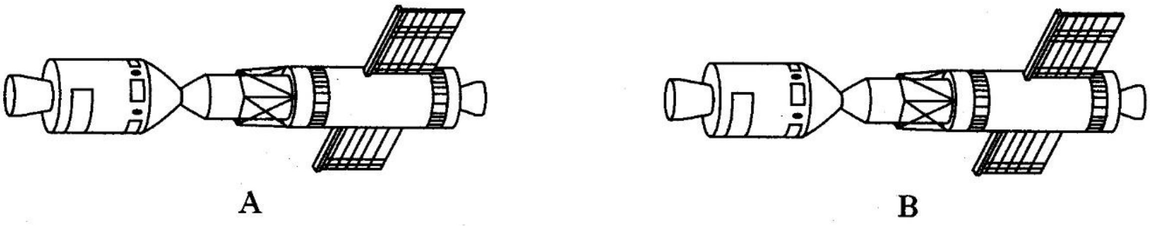
(b) The space vehicle has a rocket engine which produces a constant thrust of 1000 N. The space probe has a rocket engine which produces a constant thrust of 500 N.

The space vehicle and space probe are now brought to dest from their combined speed of 0·20 m s^{-1}.

(i) Which rocket engine was switched on to bring the vehicle and probe to rest? 1

(ii) Calculate the time for which this rocket engine was switched on. You may assume that a negligible mass of fuel was used during this time. 2

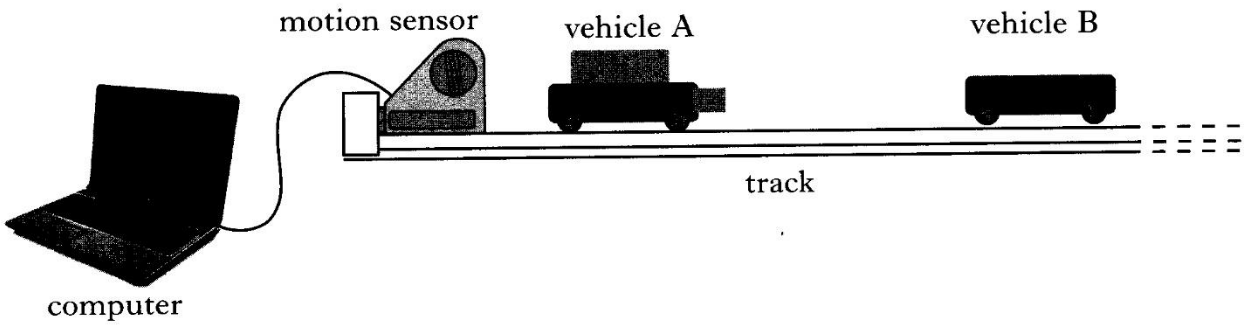
(c) The space vehicle and space probe are to be moved from their stationary position at A and brought to rest at position B, as shown.



Explain clearly how the rocket engines of the space vehicle and the space probe are used to complete this manoeuvre.
Your explanation must include an indication of the relative time for which each rocket engine must be fired.
You may assume that a negligible mass of fuel is used during this manoeuvre. 2

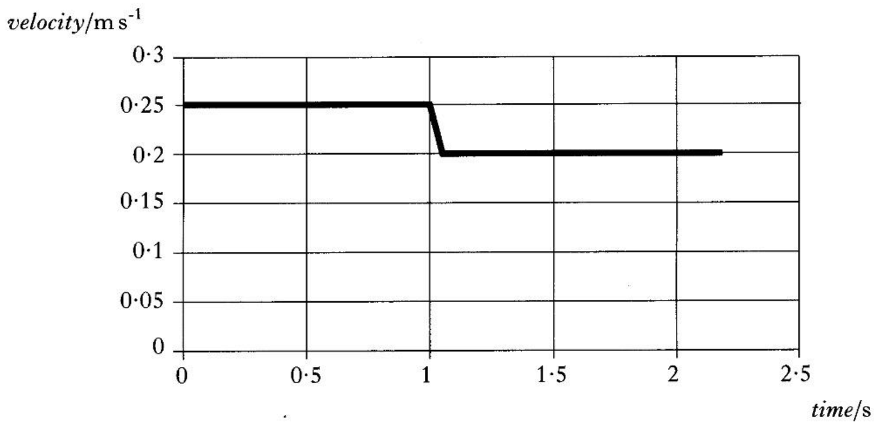
(7)

3. The apparatus shown is set up to investigate collisions between two vehicles on a track.



The mass of vehicle A is 0·22 kg and the mass of vehicle B is 0·16 kg. The effects of friction are negligible.

(a) During one experiment the vehicles collide and stick together. The computer connected to the motion sensor displays the velocity-time graph for vehicle A.



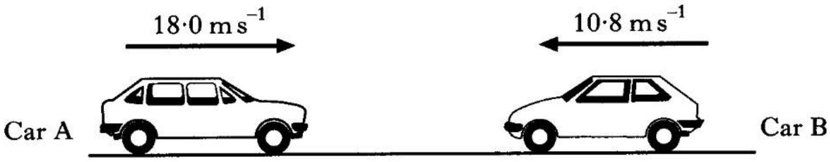
(i) State the law of conservation of momentum.

(ii) Calculate the velocity of vehicle B before the collision.

(b) The same apparatus is used to carry out a second experiment. In this experiment, vehicle B is stationary before the collision. Vehicle A has the same velocity before the collision as in the first experiment. After the collision, the two vehicles stick together. Is their combined velocity less than, equal to, or greater than that in the first collision? Justify your answer.

(7)

4. During a test on car safety, two cars are crashed together on a test track as shown below.



(a) Car A, which has a mass of 1200 kg and is moving at 18·0 m s^{-1}, approaches car B, which has a mass of 1000 kg and is moving at 10·8 m s^{-1}, in the opposite direction.

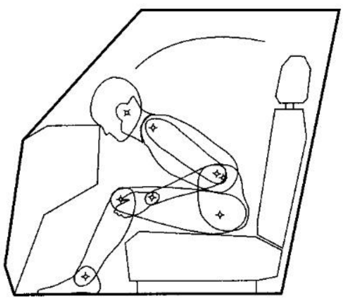
The cars collide head on, lock together and move off in the direction of car A.

(i) Calculate the speed of the cars immediately after the collision. 2

(ii) Show by calculation that the collision is inelastic. 2

(b) During a second safety test, a dummy in a car is used to demonstrate the effects of a collision.

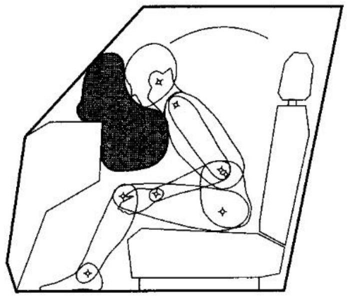
During the collision, the head of the dummy strikes the dashboard at 20 m s^{-1} as shown and comes to rest in 0·020 s.



The mass of the head is 5·0 kg.

(i) Calculate the average force exerted by the dashboard on the head of the dummy during the collision. 2

(ii) The test on the dummy is repeated with an airbag which inflates during the collision. During the collision, the head of the dummy again travels forward at 20 m s^{-1} and is brought to rest by the airbag.

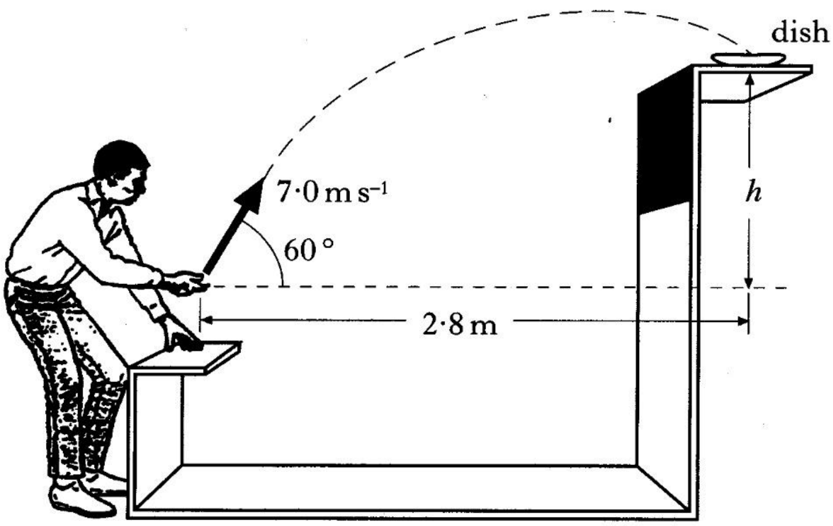


Explain why there is less risk of damage to the head of the dummy when the airbag is used. 2

(8)

GRAVITATION

1. At a funfair, a prize is awarded if a coin is tossed into a small dish. The dish is mounted on a shelf above the ground as shown.



A contestant projects the coin with a speed of 7·0 m s^{-1} at an angle of 60° to the horizontal. When the coin leaves his hand, the **horizontal distance** between the coin and the dish is 2·8 m. The coin lands in the dish.

The effect of air resistance on the coin may be neglected.

(a) Calculate:

(i) the horizontal component of the initial velocity of the coin; 1

(ii) the vertical component of the initial velocity of the coin. 1

(b) Show that the time taken for the coin to reach the dish is 0·8 s. 1

(c) What is the height, h, of the shelf above the point where the coin leaves the contestant's hand? 2

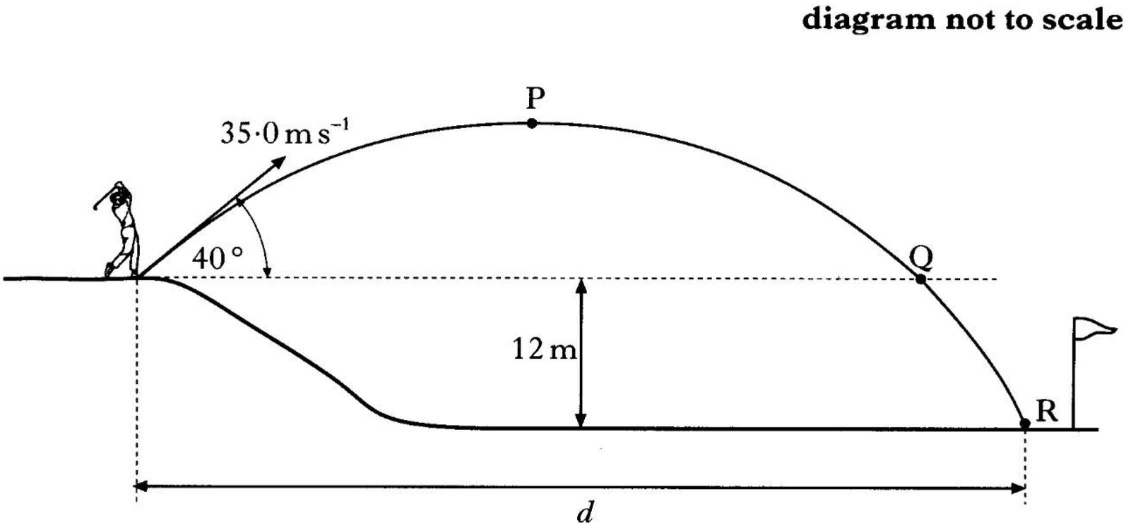
(d) How does the value of the kinetic energy of the coin when it enters the dish compare with the kinetic energy of the coin just as it leaves the contestant's hand? Justify your answer. 2

(7)

2. A golfer on an elevated tee hits a golf ball with an initial velocity of $35{\cdot}0 \text{ m s}^{-1}$ at an angle of 40° to the horizontal.

The ball travels through the air and hits the ground at point R.

Point R is 12 m below the height of the tee, as shown.



The effects of air resistance can be ignored.

(a) Calculate:

(i) the horizontal component of the initial velocity of the ball; 1

(ii) the vertical component of the initial velocity of the ball; 1

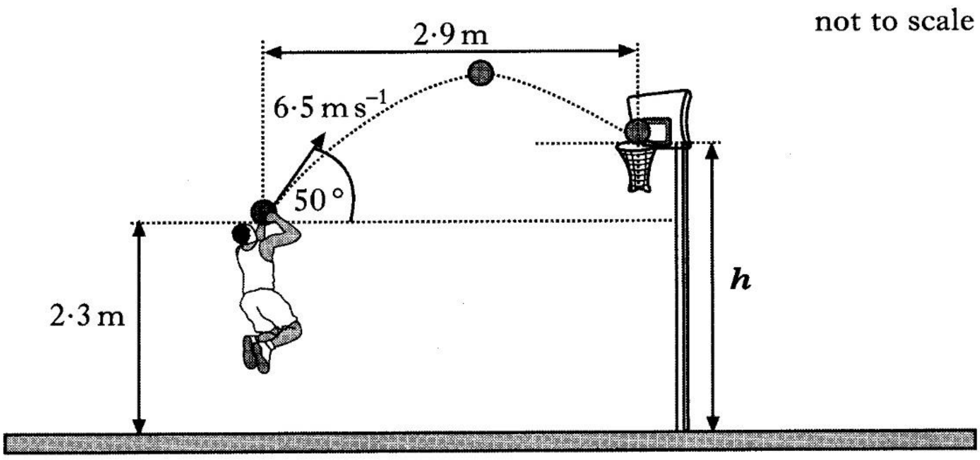
(iii) the time taken for the ball to reach its maximum height at point P. 2

(b) From its maximum height at point P, the ball falls to point Q, which is at the same height as the tee.

It then takes a further 0·48 s to travel from Q unit it hits the ground at R.

Calculate the total horizontal distance d travelled by the ball 3

3. A basketball player throws a ball with an initial velocity of 6·5 m s^{-1} at an angle of 50° to the horizontal. The ball is 2·3 m above the ground when released



The ball travels a horizontal distance of 2·9 m to reach the top of the basket.

The effects of air resistance can be ignored.

(a) Calculate:

(i) the horizontal component of the initial velocity of the ball; 1

(ii) the vertical component of the initial velocity of the ball. 1

(b) Show that the time taken for the ball to reach the basket is 0·69 s. 1

(c) Calculate the height h of the top of the basket. 2

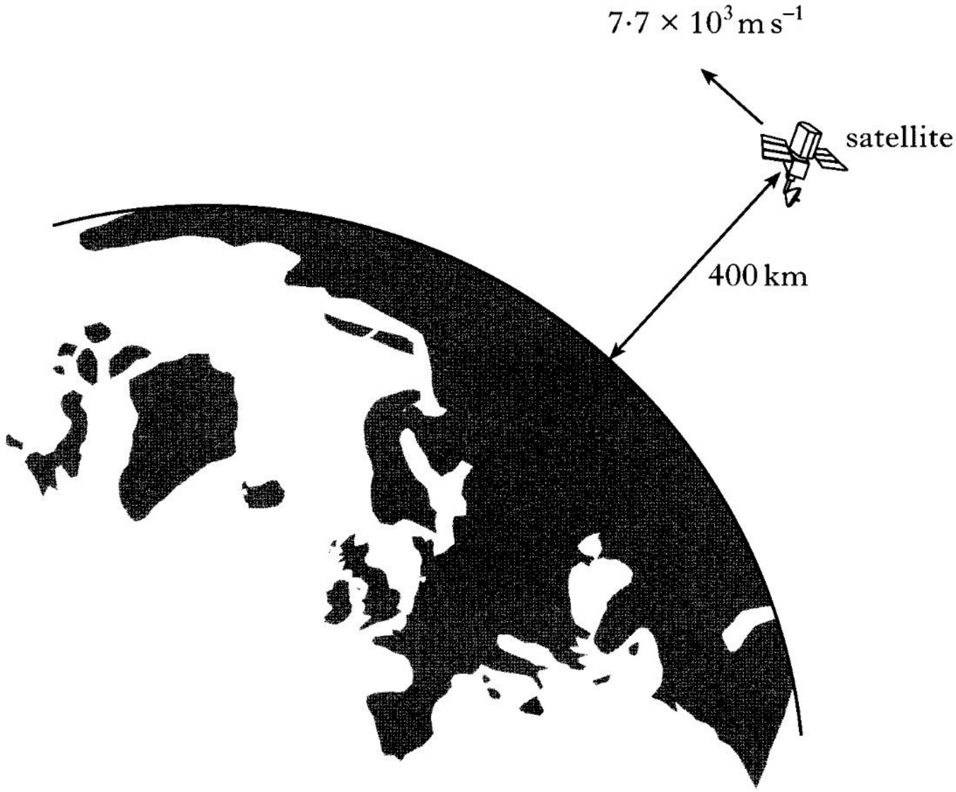
(d) A student observing the player makes the following statement.

"The player should throw the ball with a higher speed at the same angle. The ball would then land in the basket as before but it would take a shorter time to travel the 2·9 m."

Explain why the student's statement is incorrect. 2

(7)

4. A satellite orbits 400 km above the surface of the Earth as shown.



The Earth has a mass of $6{\cdot}0 \times 10^{24}$ kg and a radius of $6{\cdot}4 \times 10^6$ m.

The satellite has a mass of 900 kg and a speed of $7{\cdot}7 \times 10^3$ m s^{-1}.

(a) Explain why the satellite remains in orbit around the Earth. 2

(b) Calculate the gravitational force acting on the satellite. 2

(4)

5. (a) (i) State what is meant by the term *gravitational field strength*. 1

(ii) The gravitational field strength g at the surface of Mars is $3{\cdot}7\ \text{N kg}^{-1}$.

The radius r of Mars is $3{\cdot}4 \times 10^3$ km.

(A) Use Newton's universal law of gravitation to show that the mass of Mars is given by the equation

$$M = \frac{gr^2}{G}$$

where $G = 6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$. 2

(B) Calculate the mass of Mars. 1

(b) A spacecraft of mass 100 kg is in a circular orbit 300 km above the surface of Mars.

Calculate the force exerted by Mars on the satellite. 2

(6)

SPECIAL RELATIVITY

1. A beam of charged particles is accelerated in particle accelerators to a speed of $2{\cdot}0 \times 10^8\ \text{m s}^{-1}$.

(a) The particles are unstable and decay with a half-life of $8{\cdot}2 \times 10^{-7}$ s when at rest.

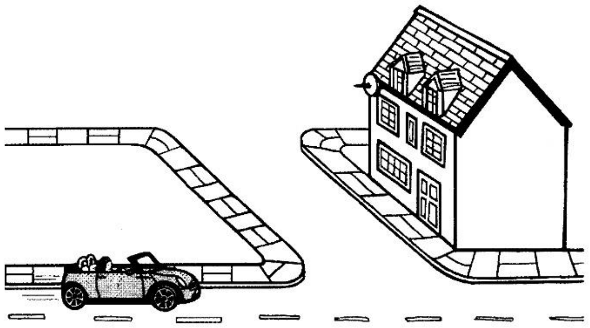
Calculate the half-life of the particles in the beam as observed by a stationary observer. 2

(b) Calculate the mean distance travelled by a particle in the beam before it decays as observed by a stationary observer. 2

(4)

THE EXPANDING UNIVERSE

1. (a) A car approaches a building where there is a stationary observer. The car sounds its horn



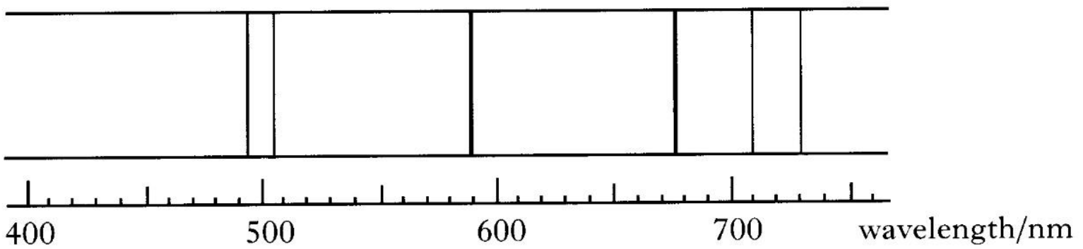
The speed of the car is 25·0 m s^{-1} and the frequency of the sound emitted by the horn is 1250 Hz.

(i) Explain in terms of wavefronts why the sound heard by the observer does not have a frequency of 1250 Hz. You may wish to include a diagram to support your answer. 2

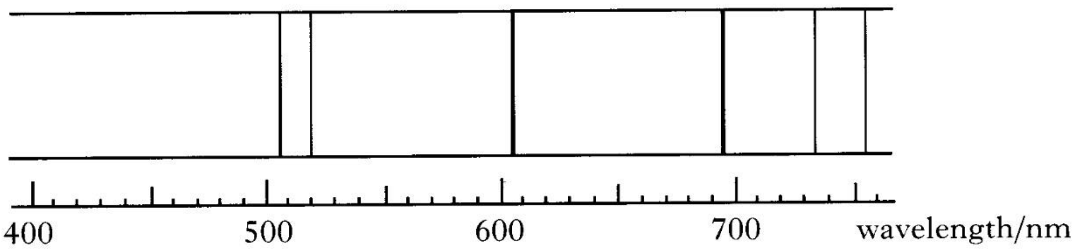
(ii) Calculate the frequency of the sound from the horn heard by the observer. 2

(b) The spectrum of light from most stars contains lines corresponding to helium gas.

The diagram below shows the helium spectrum from the Sun.



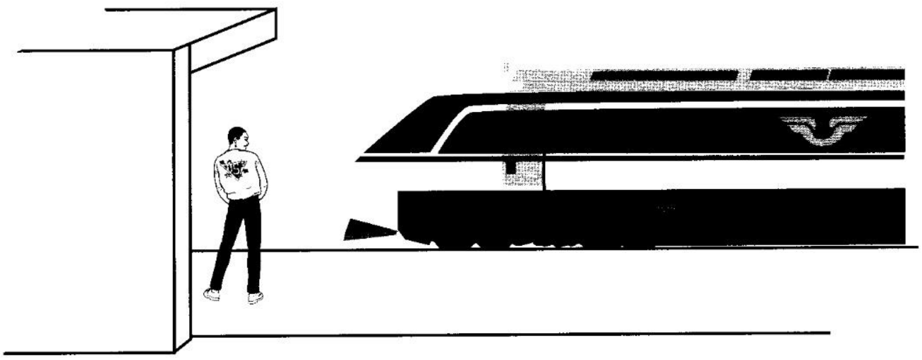
The diagram below shows the helium spectrum from a distant star.



By comparing these spectra, what conclusion can be made about the distant star? Justify your answer. 2

(6)

2. A train emits a sound of frequency 800 Hz as it passes through a station. The sound is heard by a person on the station platform as shown.



(a) Describe how the frequency of the sound, heard by the person, changes as the train passes through the station. 1

(b) Explain, in terms of wavefronts, why this frequency change occurs. You may wish to include a diagram as part of your answer. 2

(c) At one instant the person hears a sound of frequency 760 Hz.

Calculate the speed of the train relative to the person on the platform at this time. 2

(5)

3. By observing the spectrum of light received from galaxy M101, astronomers have determined that the galaxy is moving away from us with a velocity of $5{\cdot}5 \times 10^5$ m s^{-1}.

(a) Calculate the distance of the galaxy from us. 3

(b) The observation that galaxies are moving away from us is evidence for the expanding universe. As the universe expands it cools down.

What property of the Cosmic Microwave Background has been measured by astronomers to determine the present temperature of the universe? 1

4 (a) In 1929 Edwin Hubble suggested that distant galaxies are moving away (receding) from our own galaxy with velocities that are directly proportional to the distance to the galaxy. This is known as Hubble's Law.

Some data collected by Hubble are given in the table below.

galaxy	distance to galaxy /light years	recessional velocity /m s^{-1}
NGC 221	$9·0 \times 10^5$	$2·0 \times 10^5$
NGC 379	$2·3 \times 10^7$	$2·2 \times 10^6$
Gemini cluster	$1·4 \times 10^8$	$2·3 \times 10^7$

(i) Using **all** of the data, determine whether or not this data supports Hubble's Law. 3

(ii) Use the data on the Gemini cluster given in the table to calculate a value for the Hubble constant, H_0. 3

(iii) Comment on how this early value for the Hubble constant compares to the accepted value today. 1

(b) The speed of recession of the galaxies is found from observations of redshift.

(i) State what is meant by the term *redshift*. 1

(ii) Explain why the expansion of space will cause light from more distant galaxies to show a greater redshift. 2

(10)

BIG BANG THEORY

1. Mu Cephei is possibly the largest star yet discovered. Its radius is $1{\cdot}2 \times 10^{12}$ m and its surface temperature is 3500 K.

   (a) Calculate the wavelength of the peak in the black body radiation curve for Mu Cephei. 2

   (b) Copy the graph axes below and sketch the black body radiation curve for Mu Cephei.

2

2. All stars emit radiation with a range of wavelengths. The peak wavelength of radiation, λ_{peak}, emitted from a star is related to the surface temperature, T, of the star.

   The table gives the surface temperatures, in kelvin, of four different stars and the peak wavelength radiated from each star.

Surface temperature of star T/K	Peak wavelength radiated λ_{peak} /m
4200	$6{\cdot}90 \times 10^{-7}$
5800	$5{\cdot}00 \times 10^{-7}$
7900	$3{\cdot}65 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

   (a) Use **all** the data in the table to show that the relationship between the surface temperature, T, of a star and the peak wavelength radiated, λ_{peak}, from the star is

$$T = \frac{2{\cdot}9 \times 10^{-3}}{\lambda_{peak}}$$

2

(b) The blue supergiant star Eta Carinae is one of the largest and most luminous stars in our galaxy. It emits radiation with a peak wavelength of 76 nm.

Calculate the surface temperature, in kelvin, of this star. 2

(c) Radiation of peak wavelength 1·06 mm can be detected on Earth coming from all directions in space.

(i) What name is given to this radiation? 1

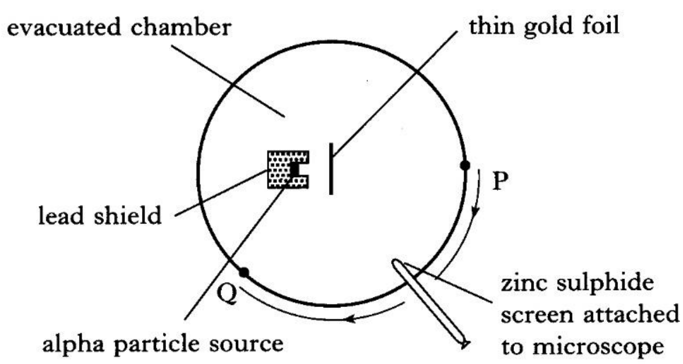
(ii) Give a reason why the existence of this radiation supports the Big Bang Theory. 1

(6)

Chapter 5 Particles and Waves

THE STANDARD MODEL

1. The diagram shows the apparatus used by Rutherford to investigate the scattering of alpha particles by a gold foil.



From the observations made as the microscope and screen were moved from P to Q, Rutherford deduced that an atom has a nucleus which is:

(a) positively charged;
(b) massive;
(c) much smaller than the volume of the atom.

Explain how the observations from the scattering experiment led to these three deductions. 3

(3)

2. Information on the properties of three elementary particles together with two types of quarks and their corresponding antiquarks is shown in the tables below.

Properties of elementary particles			
Particle	Number of quarks	Charge	Baryon number
Proton	3	+e	1
Antiproton	3	−e	−1
Pi-meson	2	−e	0

Properties of quarks and antiquarks		
Particle	Charge	Baryon number
Up quark	$+\frac{2}{3}e$	$+\frac{1}{3}$
Down quark	$-\frac{1}{3}e$	$+\frac{1}{3}$
Anti-up quark	$-\frac{2}{3}e$	$-\frac{1}{3}$
Anti-down quark	$+\frac{1}{3}e$	$-\frac{1}{3}$

(a) Using information from the tables above, show that a proton consists of two up quarks and one down quark. 1

(b) State the combination of quarks that forms a pi-meson. 1

(2)

3. (a) The equation for a β^- decay can be written as:

$$n \rightarrow p + \beta^- + \bar{\nu}$$

(i) For each of these four particles, state its name, and where appropriate, its quark composition. 3

(ii) Write a similar equation for a β^+ decay. 1

(iii) State the interaction associated with β decay. 1

(iv) State exchange particle for each of these decays:
(A) β^-;
(B) β^+. 1

(b) In 1995 scientists at CERN created atoms of antihydrogen.

(i) Name the particles that make up an atom of antihydrogen. 1

(ii) State the charge of an atom of antihydrogen. 1

(iii) Explain why it is not possible to store atoms of antihydrogen. 1

4. In February 2000 scientists at CERN announced that they had made some "quark-gluon plasma" (QGP), the extremely dense energetic matter that was present throughout the universe about 1 μs after the Big Bang. This was done by colliding lead ions in a particle accelerator.

(a) (i) A particular isotope of lead has 82 protons and 124 neutrons in its nucleus. Write the symbol for this isotope of lead in the form

$$^{x}_{y}\text{Z}$$

2

(ii) State the other particle present in an atom of this isotope of lead. 1

(b) When QGP existed in the early universe, all the particles in the table below were present.

Quarks			Leptons		
Name	Symbol	Charge	Name	Symbol	Charge
up	u	+2/3	electron	e^-	–1
down	d	–1/3	electron-neutrino	ν_e	0
charm	c	+2/3	muon	μ	–1
strange	s	–1/3	muon-neutrino	ν_μ	0
top	t	+2/3	tau	τ^-	–1
bottom	b	–1/3	tau-neutrino	ν_τ	0

(i) Protons and neutrons are made entirely of up and down quarks. Show how an appropriate number of quarks can combine to give the correct charge for a proton. 1

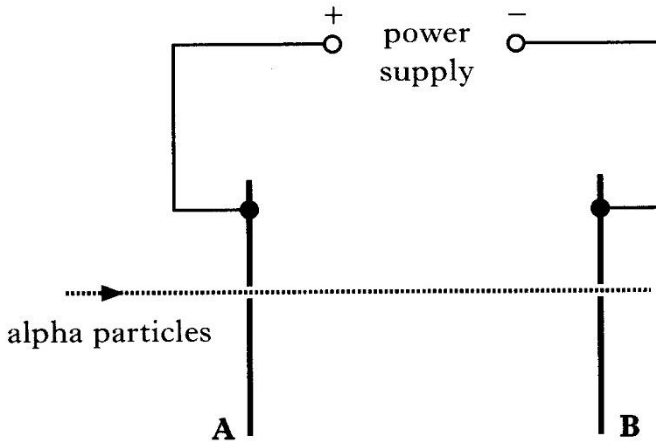
(ii) Describe briefly the circumstances required for the remaining quarks in the table to be created. 1

(iii) The early universe also contains positrons. Describe how the positron compares to the electron. 1

(6)

FORCES ON CHARGED PARTICLES

1. The apparatus shown in the diagram is designed to accelerate alpha particles.



An alpha particle travelling at a speed of $2{\cdot}60 \times 10^{6}$ m s^{-1} passes through a hole in plate A. The mass of an alpha particle is $6{\cdot}64 \times 10^{-27}$ kg and its charge is $3{\cdot}20 \times 10^{-19}$ C.

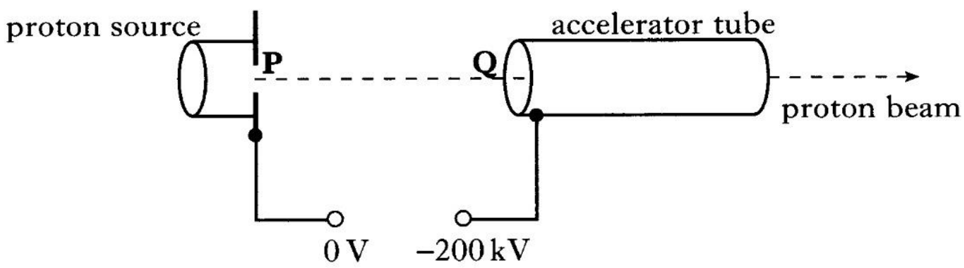
(a) When the alpha particle reaches plate B, its kinetic energy has increased to $3{\cdot}05 \times 10^{-14}$ J.
Show that the work done on the alpha particle as it moves from plate A to plate B is $8{\cdot}1 \times 10^{-15}$ J, 2

(b) Calculate the potential difference between plates A and B. 2

(c) The apparatus is now adapted to accelerate **electrons** from A to B through the same potential difference.
How does the increase in kinetic energy of an electron compare with the increase in kinetic energy of the alpha particle in part (a)? Justify your answer. 2

(6)

2. The diagram below shows the basic features of a proton accelerator. It is enclosed in an evacuated container.



Protons released from the proton source start from rest at **P**.
A potential difference of 200 kV is maintained between **P** and **Q**.

(a) What is meant by the term *potential difference of 200 kV*? 1

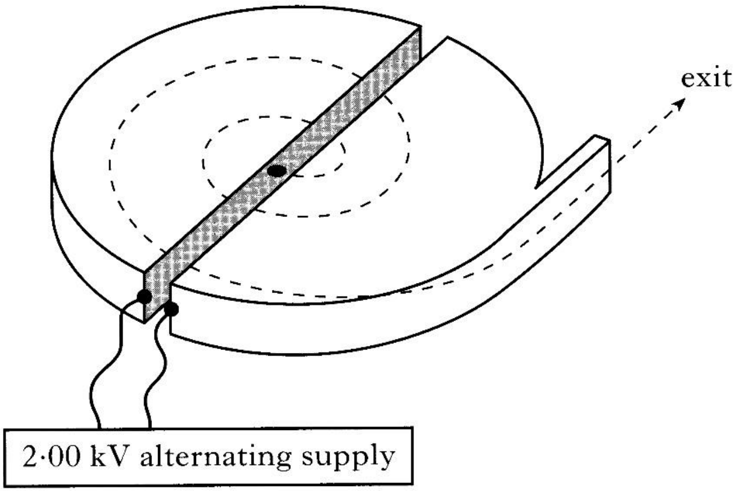
(b) Explain why protons released at **P** are accelerated towards **Q**. 1

(c) Calculate:
  (i) the work done on a proton as it accelerates from **P** and **Q**; 2
  (ii) the speed of a proton as it reaches **Q**. 2

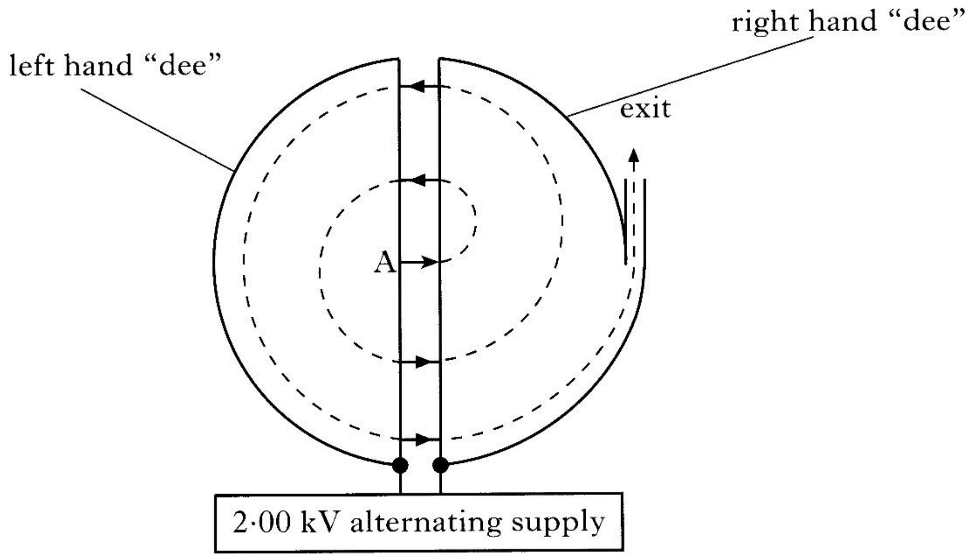
(d) The distance between **P** and **Q** is now halved.
What effect, if any, does this change have on the speed of a proton as it reaches **Q**? Justify your answer. 2

(8)

3. A cyclotron is a particle accelerator which consists of two D-shaped hollow structures, called “dees”, placed in a vacuum.



The diagram below shows the cyclotron viewed from above.



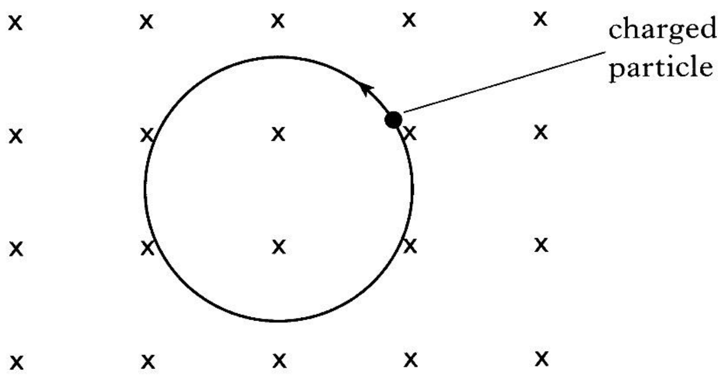
(a) Protons are released from rest at point A and accelerated across the gap between the “dees” by a voltage of 2·00 kV.
Show that the speed of the protons as they **first** reach the right hand “dee” is $6{\cdot}19 \times 10^{5}$ m s^{-1}. 2

(b) Inside the “dees” the electric field strength is zero but there is a uniform magnetic field. This forces the protons to move in semi-circular paths when inside the “dees”.
State the direction of the magnetic field in the “dees”. 1

(c) While the protons are inside the “dee”, the polarity of the applied voltage is reversed so that the protons are again accelerated when they cross to the left hand “dee”.
Calculate the speed of the protons as they **first** enter the left hand “dee”. 2

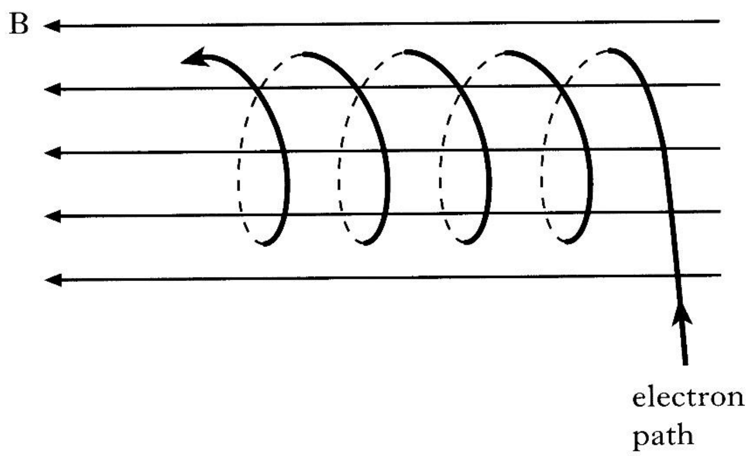
(5)

4. (a) A charged particle moves with a speed of $2{\cdot}0 \times 10^6$ m s^{-1} in a circular orbit in a uniform magnetic field directed into the page as shown below.



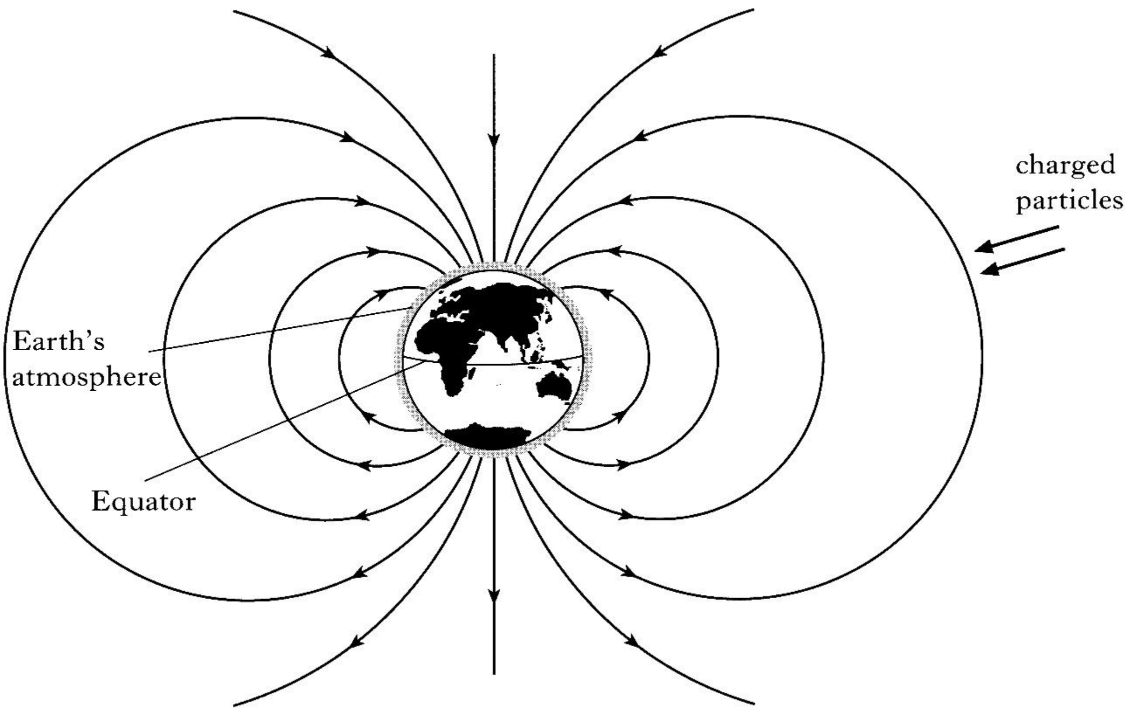
State whether the charge on the particle is positive or negative. 1

(b) An electron enters a uniform magnetic field at an angle to the magnetic field lines as shown below.



Explain the shape of the electron path in the magnetic field. 2

(c) Charged particles which enter the Earth's atmosphere near the North pole collide with air molecules. The light emitted in this process is called the Aurora Borealis.
In the figure below, the Earth's magnetic field is indicated by continuous lines which show the magnetic field direction in the region surrounding the Earth. The extent of the Earth's atmosphere is also shown.



Charged particles approach the Earth in the direction shown in the diagram. Explain why these particles do not cause an aurora above the Equator. 2

(5)

NUCLEAR REACTIONS

1. A smoke alarm contains a very small sample of the radioactive isotope Americium-241, represented by the symbol

$$^{241}_{95}\mathrm{Am}$$

(a) How many neutrons are there in a nucleus of this isotope? 1

(b) This isotope decays by emitting alpha particles as shown in the following statement.

$$^{241}_{95}\mathrm{Am} \longrightarrow {}^{s}_{r}\boldsymbol{T} + \alpha$$

(i) Determine the numbers represented by the letters $\boldsymbol{r}$ and $\boldsymbol{s}$. 1

(ii) Use the data booklet to identify the element $\boldsymbol{T}$. 1

(3)

2. Some power stations use nuclear fission reactions to provide energy for generating electricity. The following statement represents a fission reaction.

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{139}_{57}\text{La} + {}^{\boldsymbol{r}}_{42}\text{Mo} + 2\,{}^{1}_{0}\text{n} + \boldsymbol{s}\,{}^{0}_{-1}\text{e}$$

(a) Determine the numbers represented by the letters ***r*** and ***s*** in the above statement. 1

(b) Explain why a nuclear fission reaction releases energy. 1

(c) The masses of the particles involved in the reaction are shown in the table.

Particle	*Mass*/kg
$^{235}_{92}\text{U}$	$390{\cdot}173 \times 10^{-27}$
$^{139}_{57}\text{La}$	$230{\cdot}584 \times 10^{-27}$
$^{\boldsymbol{r}}_{42}\text{Mo}$	$157{\cdot}544 \times 10^{-27}$
$^{1}_{0}\text{n}$	$1{\cdot}675 \times 10^{-27}$
$^{0}_{-1}\text{e}$	negligible

Calculate the energy released in this reaction. 3

(5)

3. The following statement represents a nuclear reaction which may form the basis of a nuclear power station of the future.

$$^{2}_{1}\text{H} + ^{3}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + ^{1}_{0}\text{n}$$

(a) State the name given to the above type of nuclear reaction. 1

(b) Explain, using $E = mc^2$, how this nuclear reaction results in the production of energy. 2

(c) Using the information given below, and any other data required from the Data Sheet, calculate the energy released in the above nuclear reaction.

$$\text{mass of } ^{3}_{1}\text{H} = 5\cdot00890\times10^{-27}\,\text{kg}$$
$$\text{mass of } ^{2}_{1}\text{H} = 3\cdot34441\times10^{-27}\,\text{kg}$$
$$\text{mass of } ^{4}_{2}\text{He} = 6\cdot64632\times10^{-27}\,\text{kg}$$
$$\text{mass of } ^{1}_{0}\text{n} = 1\cdot67490\times10^{-27}\,\text{kg}$$

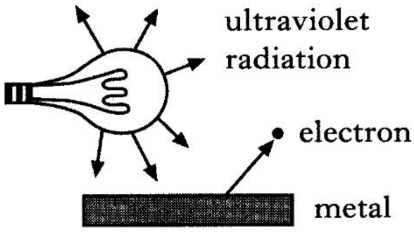
3

(d) Calculate how many of the reactions of the type represented above would occur each second to produce a power of 25 MW. 2

(8)

WAVE-PARTICLE DUALITY

1. Ultraviolet radiation from a lamp is incident on the surface of a metal. This causes the release of electrons from the surface of the metal.



The energy of each photon of ultraviolet radiation is $5{\cdot}23 \times 10^{-19}$ J.

The work function of the metal is $2{\cdot}56 \times 10^{-19}$ J.

(a) Calculate:

(i) the maximum kinetic energy of an electron released from this metal by this radiation; 1

(ii) the maximum speed of an emitted electron. 2

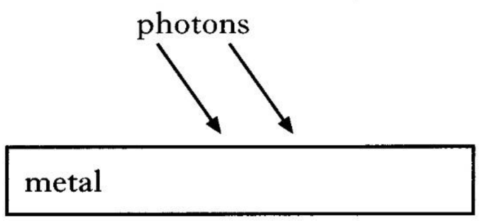
(b) The source of ultraviolet radiation is now moved further away from the surface of the metal.
State the effect, if any, this has on the maximum speed of an emitted electron. Justify your answer. 2

(5)

2. To explain the photoelectric effect, light can be considered as consisting of tiny bundles of energy. These bundles of energy are called photons.

(a) Sketch a graph to show the relationship between photon energy and frequency. 1

(b) Photons of frequency $6{\cdot}1 \times 10^{14}$ Hz are incident on the surface of a metal.



This releases photoelectrons from the surface of the metal.

The maximum kinetic energy of any of these photoelectrons is $6{\cdot}0 \times 10^{-20}$ J.

Calculate the work function of the metal. 3

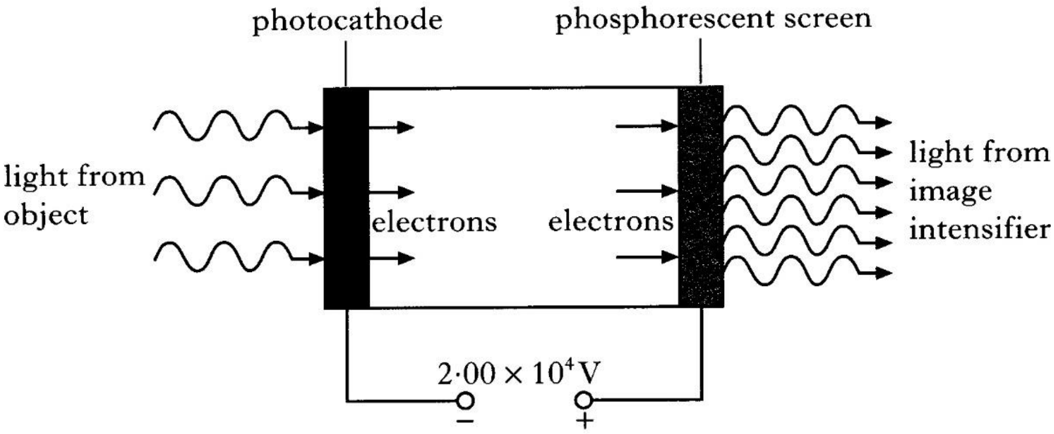
(c) The irradiance due to these photons on the surface of the metal is now reduced.

Explain why the maximum kinetic energy of each photoelectron is unchanged. 1

(5)

3. An image intensifier is used to improve night vision. It does this by amplifying the light from an object.

Light incident on a photocathode causes the emission of photoelectrons. These electrons are accelerated by an electric field and strike a phosphorescent screen causing it to emit light. This emitted light is of a greater intensity than the light that was incident on the photocathode.



The voltage between the photocathode and the phosphorescent screen is $2{\cdot}00 \times 10^4$ V.

The minimum frequency of the incident light that allows photoemission to take place is $3{\cdot}33 \times 10^{14}$ Hz.

(a) What name is given to the minimum frequency of the light required for photoemission to take place? 1

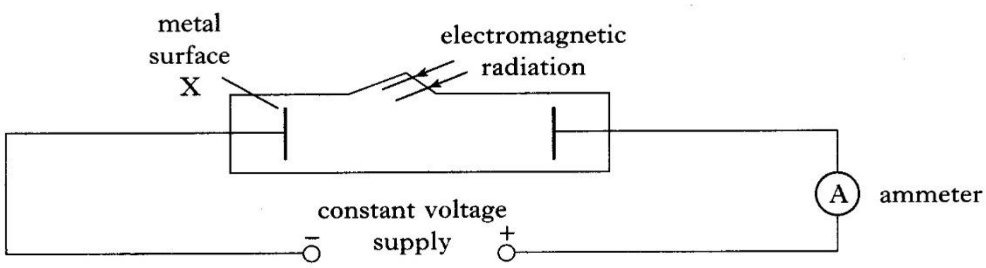
(b) (i) Show that the wok function of the photocathode material is $2{\cdot}21 \times 10^{-19}$ J. 2

(ii) Light of frequency $5{\cdot}66 \times 10^{14}$ Hz is incident on the photocathode. Calculate the maximum kinetic energy of an electron emitted from the photocathode. 2

(iii) Calculate the kinetic energy gained by an electron as it is accelerated from the photocathode to the phosphorescent screen. 2

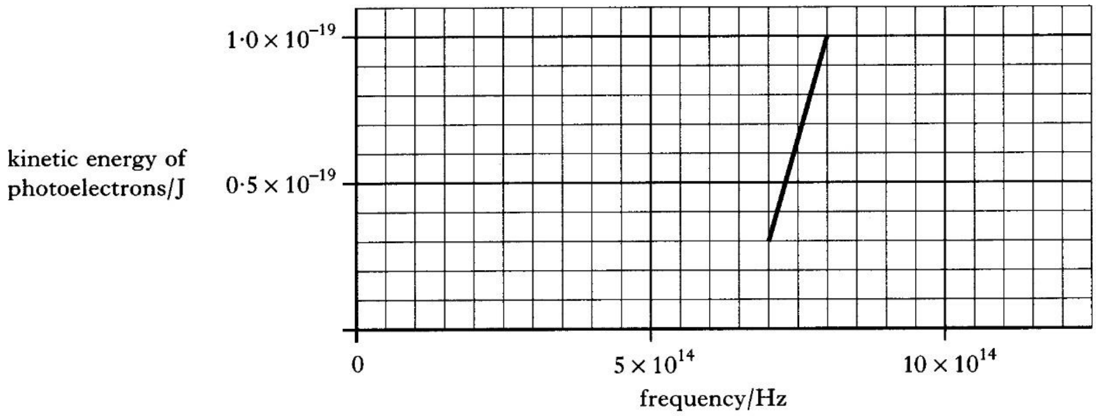
(7)

4 (a) The apparatus shown below is used to investigate photoelectric emission from the metal surface X when the electromagnetic radiation is shone on the surface.
The frequency of the electromagnetic radiation can be varied.



(i)When radiation of a certain frequency is shone on the metal surface X, a reading is obtained on the ammeter.
Sketch a graph to show how the current in the circuit varies with the irradiance of the radiation. 2
(ii)Explain why there is no reading on the ammeter when the frequency of the radiation is decreased below a particular value. 1

(b) The maximum kinetic energy of the photoelectrons emitted from X is measured for a number of different frequencies of the radiation.
The graph shows how this kinetic energy varies with frequency.



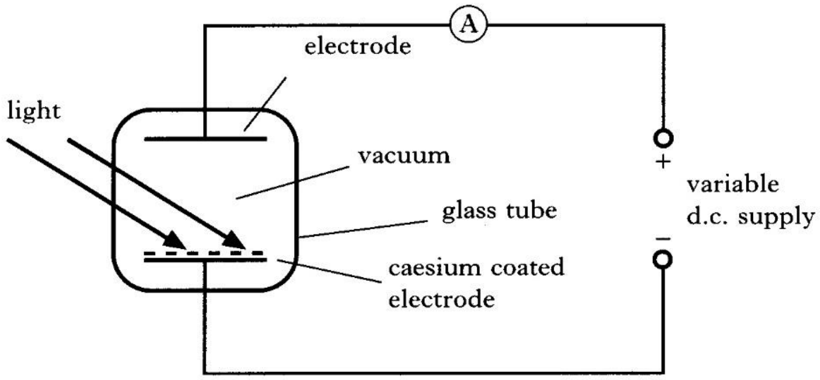
(i)Use the graph to find the threshold frequency for metal X. 1
(ii)The table below gives the work function of different metals.

Metal	*Work function*/J
Potassium	$3{\cdot}2 \times 10^{-19}$
Calcium	$4{\cdot}3 \times 10^{-19}$
Zinc	$6{\cdot}9 \times 10^{-19}$
Gold	$7{\cdot}8 \times 10^{-19}$

Which one of these metals was used in the investigation?
You must justify your answer using the information given in the table. 3

5. (a) It is quoted in a text book that
"the work function of caesium is $3{\cdot}04 \times 10^{-19}$ J".
Explain what is meant by the above statement. 1

(b) In an experiment to investigate the photoelectric effect, a glass vacuum tube is arranged as shown below.



The tube has two electrodes, one of which is coated with caesium.
Light of frequency $6{\cdot}1 \times 10^{14}$ Hz is shone on to the caesium coated electrode.

(i) Calculate the maximum kinetic energy of a photoelectron leaving the caesium coated electrode. 3

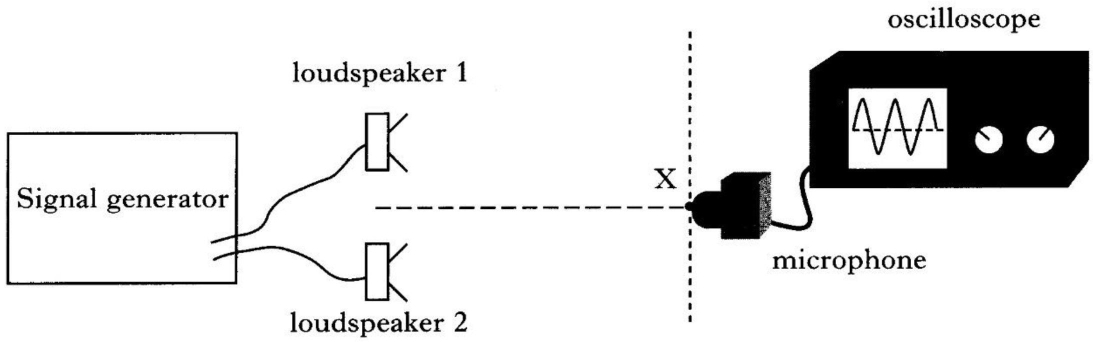
(ii) An electron leaves the caesium coated electrode with this maximum kinetic energy.
Calculate its kinetic energy as it reaches the upper electrode when the p.d. across the electrode is 0·80 V. 3

(c) The polarity of the supply voltage is now reversed.
Calculate the minimum voltage which should be supplied across the electrodes to stop photoelectrons from reaching the upper electrode. 2

(9)

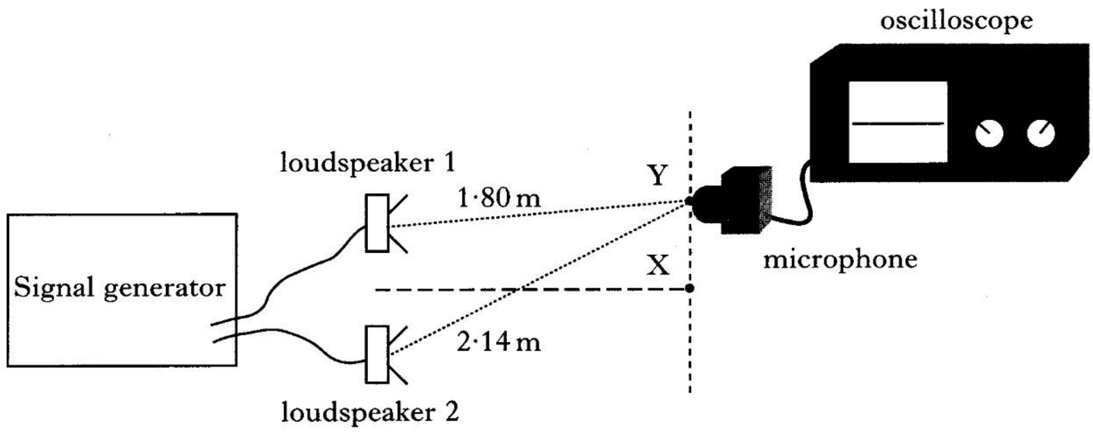
INTERFERENCE AND DIFFRACTION

1. A student is carrying out an experiment to investigate the interference of sound waves. She sets up the following apparatus.



The microphone is initially placed at point X which is the same distance from each loudspeaker. A maximum is detected at X.

(a) The microphone is now moved to the first minimum Y as shown.



Calculate the wavelength of the sound waves. 2

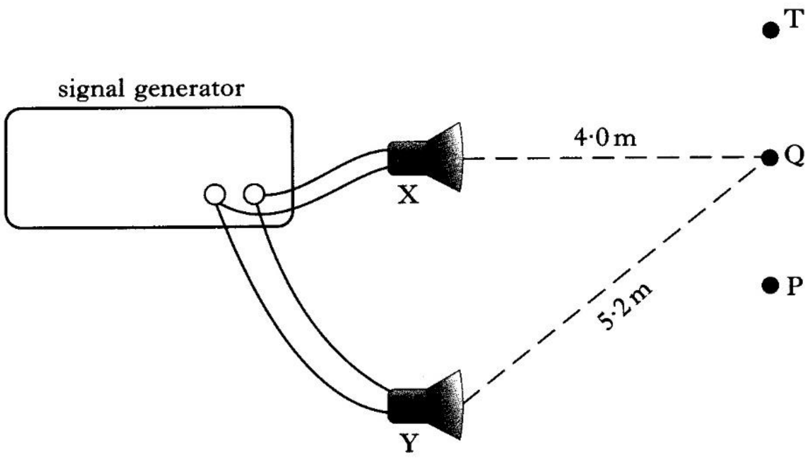
(b) Loudspeaker 1 is now disconnected.

What happens to the amplitude of the sound detected by the microphone at Y?

Explain your answer. 2

(4)

2. Two identical loudspeakers X and Y are set up in a room which has been designed to eliminate the reflection of sound. The loudspeakers are connected to the same signal generator as shown.



(a) (i) When a sound level meter is moved from P to T, maxima and minima of sound intensity are detected.

Explain, in terms of waves, why the maxima and minima are produced. 2

(ii) The sound level meter detects a maximum at P.

As the sound level meter is moved from P, it detects a minimum then a maximum then another minimum when it reaches Q.

Calculate the wavelength of the sound used. 2

(b) The sound level meter is now fixed at Q.

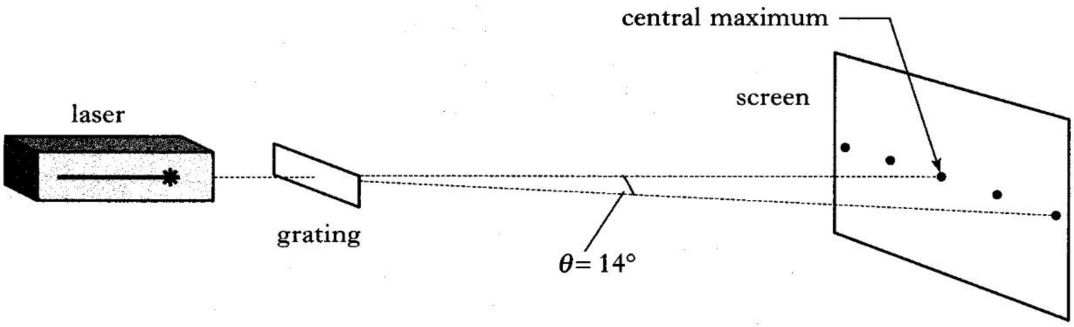
The frequency of the output from the signal generator is increased steadily from 200 Hz to 1000 Hz.

(i) What happens to the wavelength of the sound as the frequency of the output is increased? 1

(ii) Explain why the sound level meter detects a series of maxima and minima as the frequency of the output is increased. 2

(7)

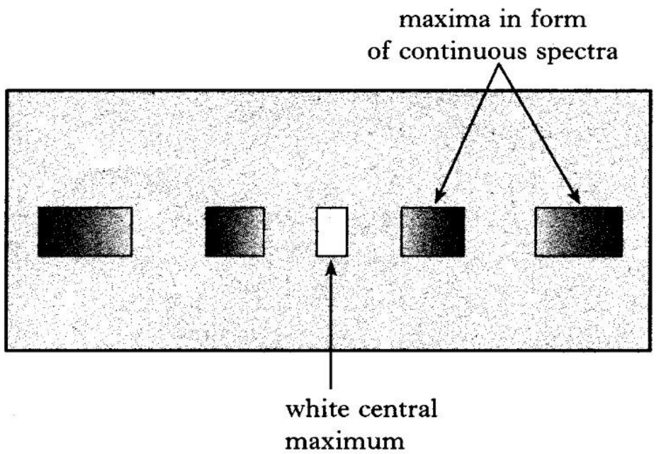
3. Light from a laser is shone onto a grating. The separation of the slits on the grating is $5 \cdot 0 \times 10^{-6}$ m. A pattern is produced on a screen as shown below.



(a) (i) The angle θ between the central maximum and the 2nd order maximum is 14°.
Calculate the wavelength of the light produced by the laser. 2

(ii) A pupil suggests that a more accurate value for the wavelength of the laser light can be found if a grating with a slit separation of $2 \cdot 0 \times 10^{-6}$ m is used.
Explain why this suggestion is correct. 2

(b) The laser is replaced by a source of white light and the pattern on the screen changes to a white central maximum with other maxima in the form of continuous spectra on each side of the central maximum.



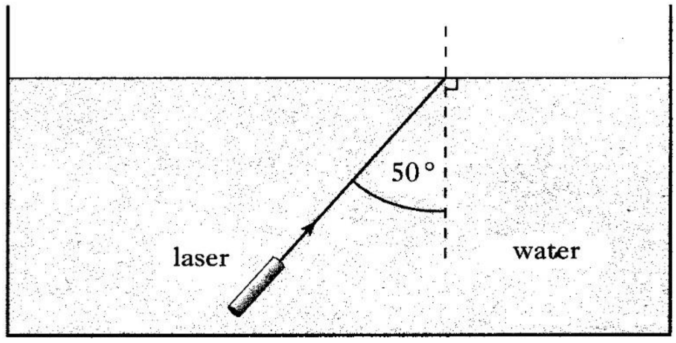
Explain:
(i) why the central maximum is white; 1
(ii) why the other maxima are in the form of continuous spectra. 2

(6)

REFRACTION OF LIGHT

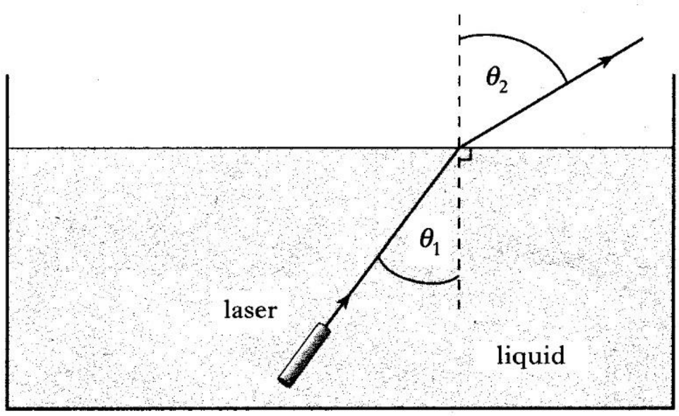
1. A laser beam is used to investigate the refraction of light from water into air.

   A waterproof laser is placed in within a tank of water and the laser beam is directed towards the water surface as shown below.

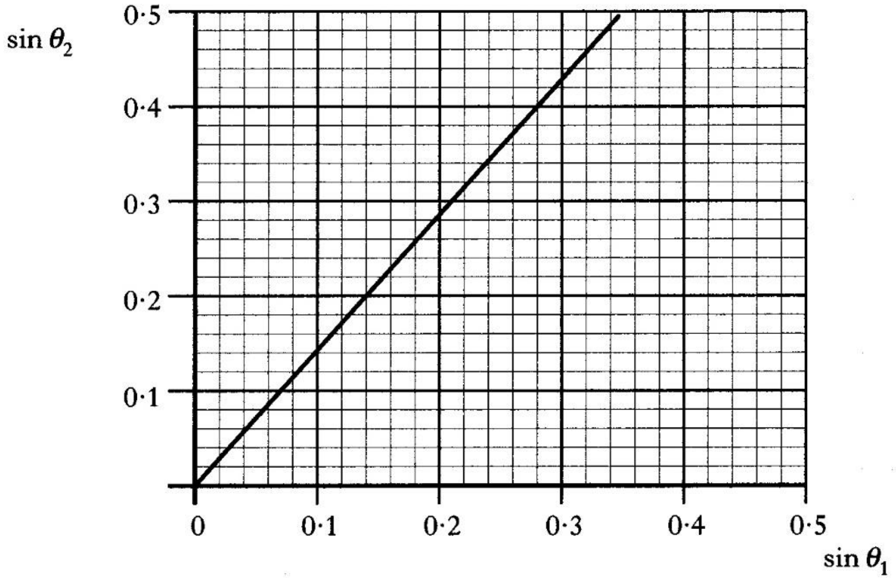


(a) The water in the tank has a refractive index of 1·33. Describe what happens to the light at the water surface. You must justify your answer by calculation. 3

(b) The water in the tank is replaced by another liquid. The position of the laser is altered so that the laser beam follows the path shown in the diagram below. The angle θ_1 and the angle θ_2, as shown in the diagram, are measured.



The measurements are repeated for different values of θ_1 and the corresponding values of θ_2. The values of sin θ_1 and sin θ_2 are used to plot the graph shown below.



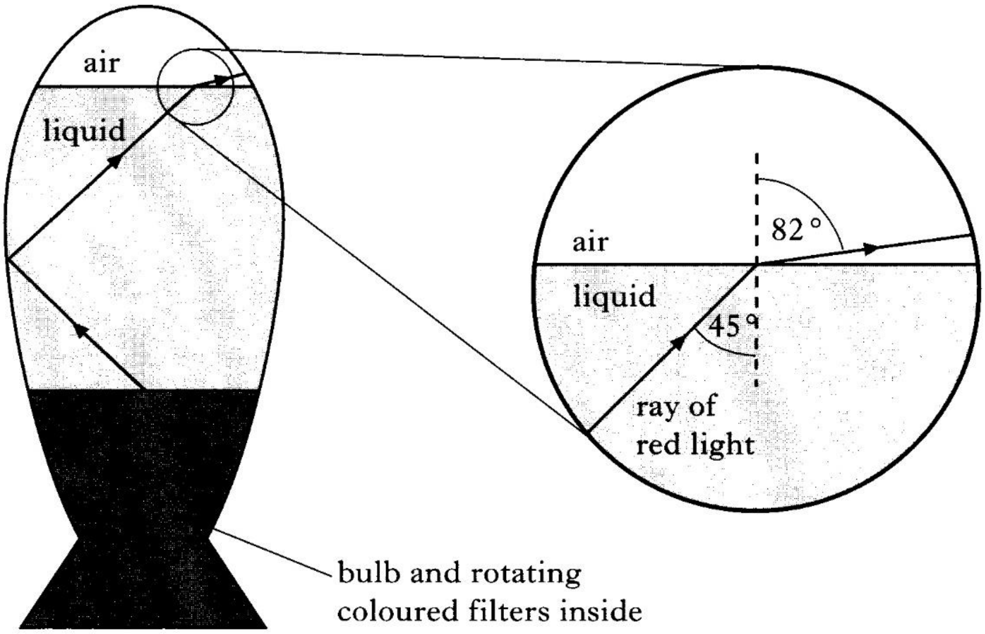
Use information from the graph to calculate the refractive index of the liquid. 2

(c) Light from the laser has a wavelength of 670 × 10^{-9} m. Calculate the wavelength of the laser light when passing through a liquid which has a refractive index of 1·47. 2

(7)

2. A decorative lamp has a transparent liquid in the space above a bulb. Light from the bulb passes through rotating coloured filters giving red or blue light in the liquid.

(a) A ray of red light is incident on the liquid surface as shown.



(i) Calculate the refractive index of the liquid for the red light. 2

(ii) A ray of blue light is incident on the liquid surface at the same angle as the ray of red light.

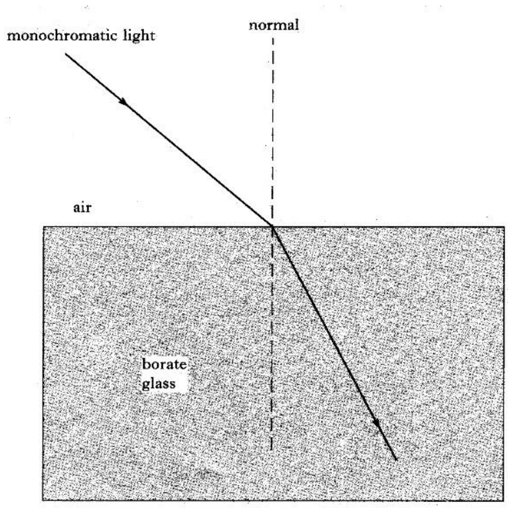
The refractive index of the liquid for blue light is greater than that for red light. Is the angle of refraction greater than, equal to or less than 82° for the blue light? You must justify your answer. 2

(b) A similar lamp contains a liquid which has a refractive index of 1·44 for red light. A ray of red light in the liquid is incident on the surface at an angle of 45° as before.

Sketch a diagram to show the path of this ray after it is incident on the liquid surface.
Mark on your diagram the value of all appropriate angles.
All relevant calculations must be shown. 3

(7)

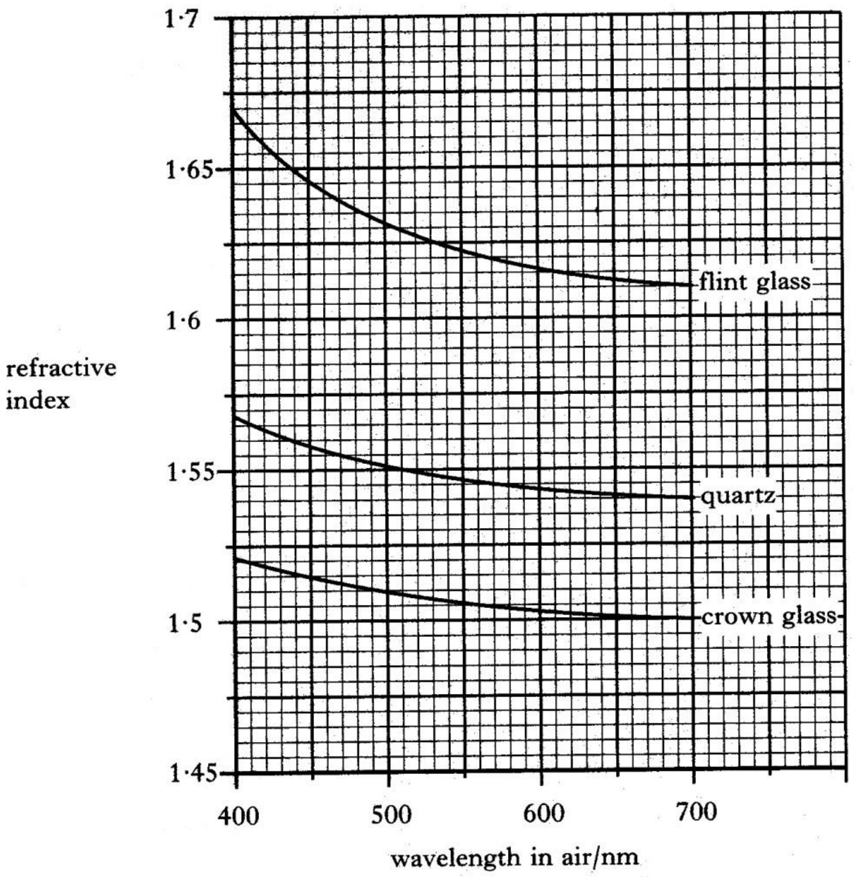
3. (a) The following diagram shows a ray of monochromatic light passing from air into a block of borate glass. The diagram is drawn to scale.



(i) Use measurements taken from the above diagram to calculate the refractive index of borate glass for this light. You will need to use a protractor. 2

(ii) Calculate the value of the critical angle for this light in the borate glass. 2

(b) The following graph shows how refractive index depends on the type of material and the wavelength in air of the light used.

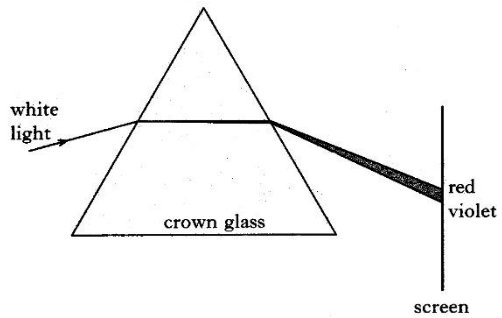


A ray of light of wavelength 510 nm in air passes into a block of quartz.

(i) Calculate the wavelength of this light in the quartz. 2

(ii) Explain what happens to the value of the critical angle in quartz as the wavelength of visible light increases. 2

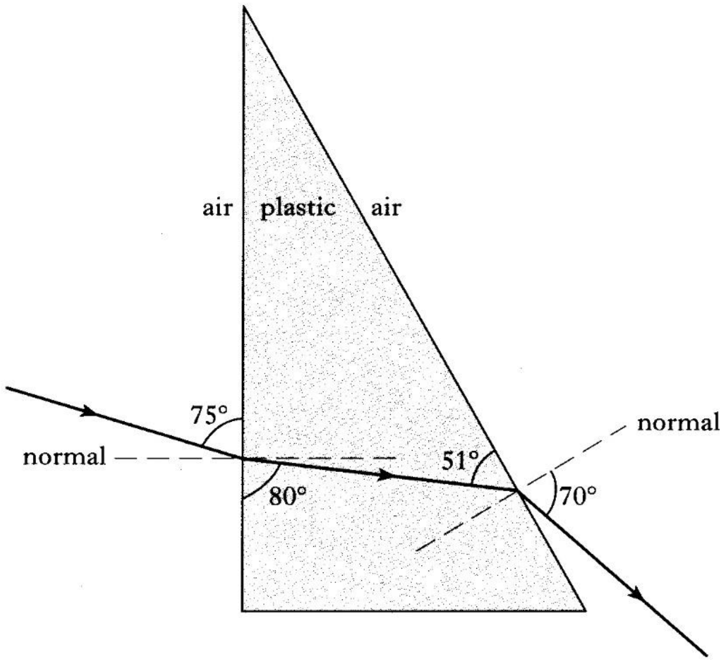
(iii) A ray of white light enters a triangular prism made of crown glass, producing a visible spectrum on a screen, as shown below.



The crown glass prism is now replaced by a similar prism made from flint glass.
Describe how the visible spectrum on the screen is different from before. 1

(9)

4. (a) The diagram below shows the refraction of a ray of red light as it passes through a plastic prism.

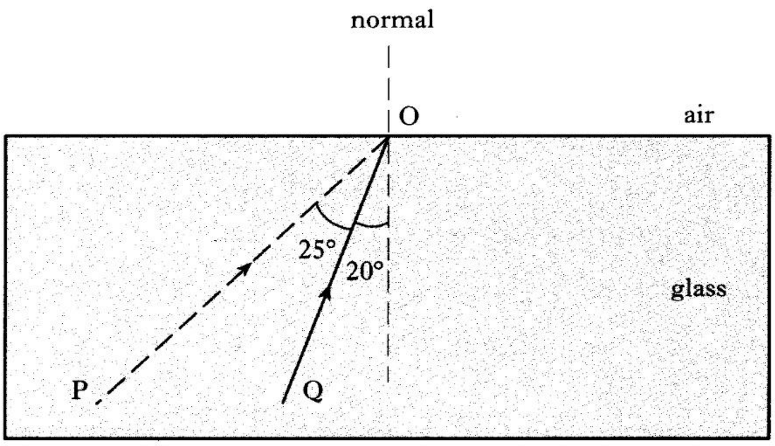


Calculate the refractive index of the plastic for this red light. 2

(b) The refractive index of a glass block is found to be 1·44 when red light is used.

(i) Calculate the value of the critical angle for this red light in the glass. 2

(ii) The diagram shows the paths of two rays of this red light, PO and QO, in the glass block.



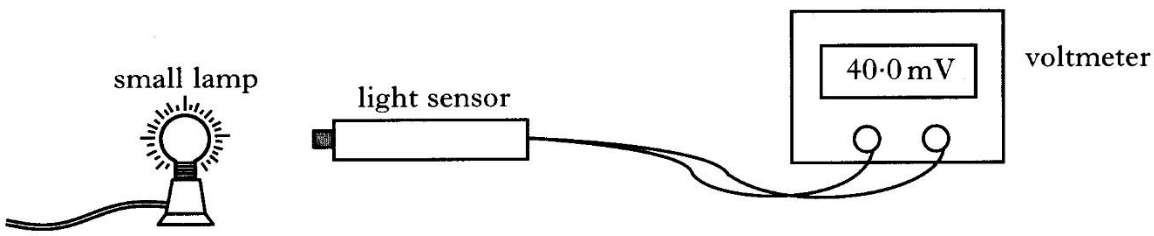
When rays PO and QO strike the glass-air boundary, **three** further rays of light are observed.
Copy and complete the diagram to show **all five** rays.
Clearly indicate which of the three rays came from P and which came from Q. The values of all angles should be shown on the diagram. 4

(8)

SPECTRA

1. The diagram shows a light sensor connected to a voltmeter.

A small lamp is placed in front of the sensor.



The reading on the voltmeter is 20 mV for each 1·0 mW of power incident on the sensor.

(a) The reading on the voltmeter is 40 mV.
The area of the light sensor is $8{\cdot}0 \times 10^{-5}$ m^2.
Calculate the irradiance of light on the sensor. 3

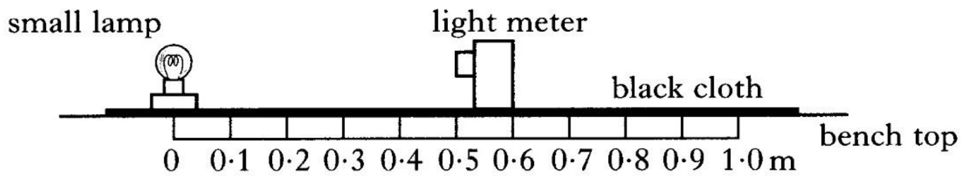
(b) The small lamp is replaced by a different source of light.
Using this new source, a student investigates how irradiance varies with distance.
The results are shown.

Distance/m	0·5	0·7	0·9
Irradiance/W m^{2}	1·1	0·8	0·6

Can this new source be considered to be a point source of light?
Use **all** the data to justify your answer. 2

(5)

2. A student carries out an experiment to investigate how irradiance on a surface varies with distance from a small lamp.
Irradiance is measured with a light meter.
The distance between the small lamp and the light meter is measured with a metre stick.
The apparatus is set up as shown in a darkened laboratory.



The following results are obtained.

Distance from source/m	0·20	0·30	0·40	0·50
Irradiance/units	675	302	170	108

(a) What is meant by the term *irradiance*? 1

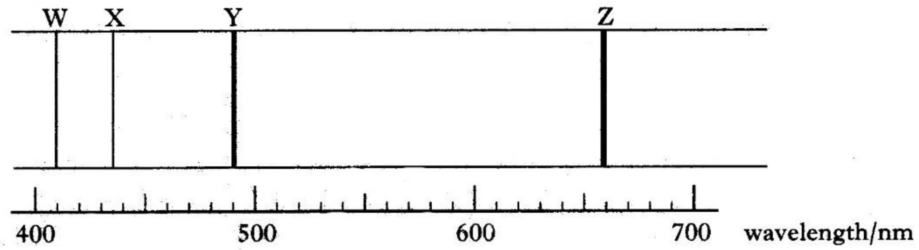
(b) Use **all** the data to find the relationship between irradiance I and the distance d from the source. 2

(c) What is the purpose of the black cloth on top of the bench. 1

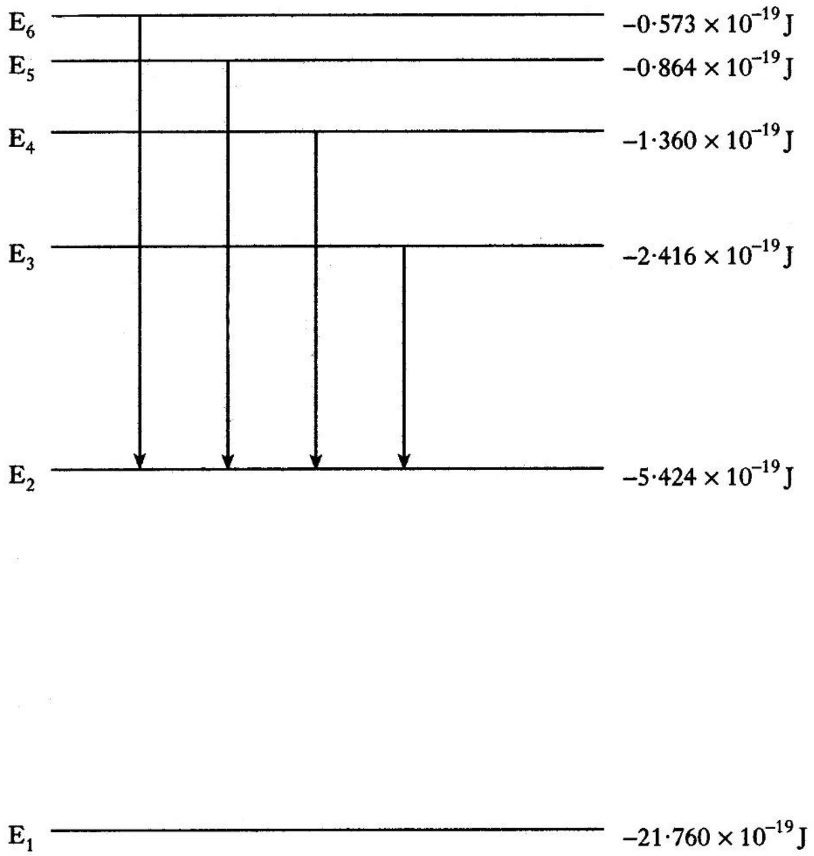
(d) The small lamp is replaced by a laser. Light from the laser is shone on the light meter.
A reading is taken from the light meter when the distance between it and the laser is 0·50 m.
The distance is now increased to 1·00 m.
State how the new reading on the light meter compared with the one taken at 0·50 m. Justify your answer. 2

(6)

3. The line emission spectrum of hydrogen has four lines in the visible spectrum as shown in the following diagram.



These four lines are caused by electron transitions in a hydrogen atom from high energy levels to a low energy level E_2 as shown below.



(a) From the information above, state which spectral line W, X, Y or Z is produced by an electron transition from E_3 to E_2. 1

(b) Explain why lines Y and Z in the line emission spectrum are brighter than the other two lines. 1

(c) Infrared radiation of frequency $7{\cdot}48 \times 10^{13}$ Hz is emitted from a hydrogen atom.

(i) Calculate the energy of one photon of this radiation. 2

(ii) Show by calculation which electron transition produces this radiation. 2

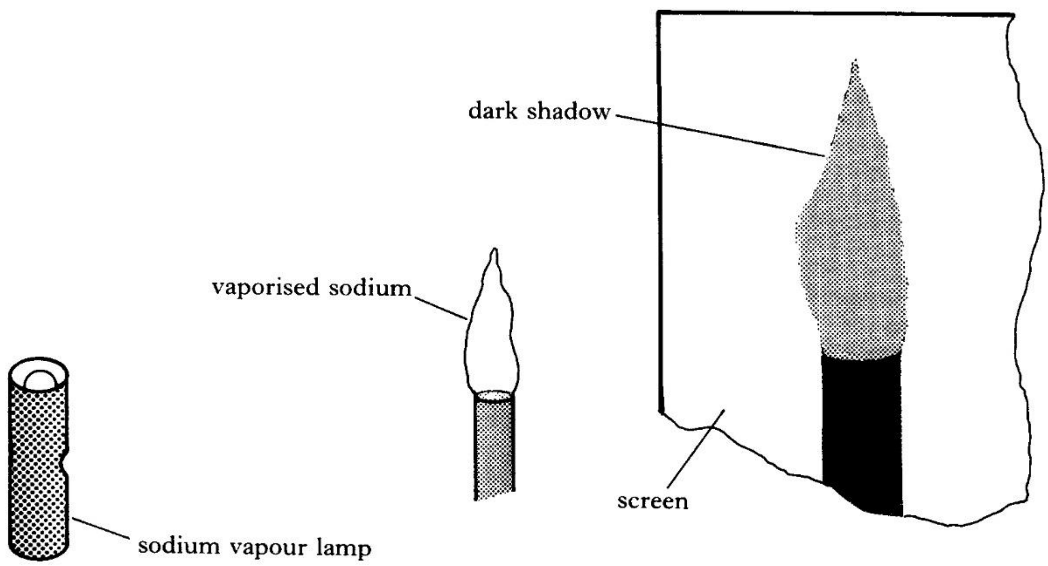
(6)

4. (a) A sodium vapour lamp emits bright yellow light when electrons make transitions from one energy level to another within the sodium atom.

(i) State whether electrons are moving to a higher or lower energy level when the light is emitted. 1

(ii) Using information provided in the data sheet, calculate the energy difference between these two electron energy levels in the sodium atom. 3

(b) A Bunsen flame contains vaporised sodium is placed between a sodium vapour lamp and a screen as shown.



(i) Explain why a dark shadow of the flame is seen on the screen. 1

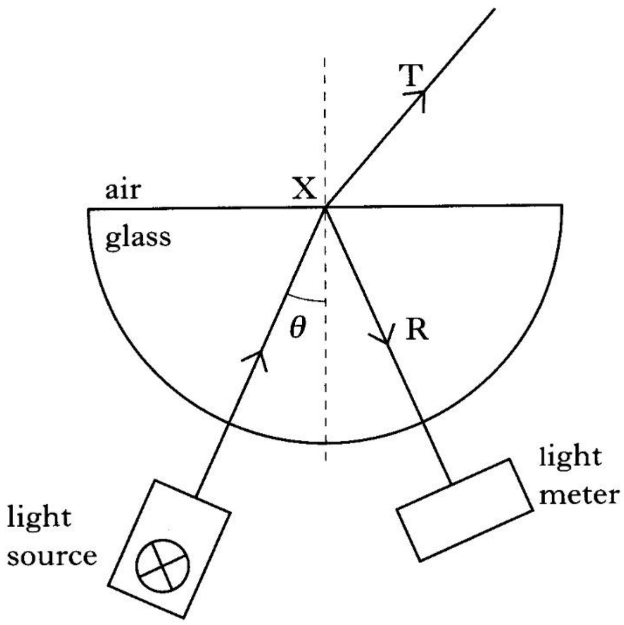
(ii) The sodium vapour lamp is replaced with a cadmium vapour lamp. Explain why there is now no dark shadow of the flame on the screen. 1

(6)

UNCERTAINTIES AND EXPERIMENTS IN P&W

1. A student is investigating the effect that a semicircular block has on a ray of monochromatic light.

   She observes that at point X the incident ray splits into two rays:
   T – a transmitted ray;
   R – a reflected ray.

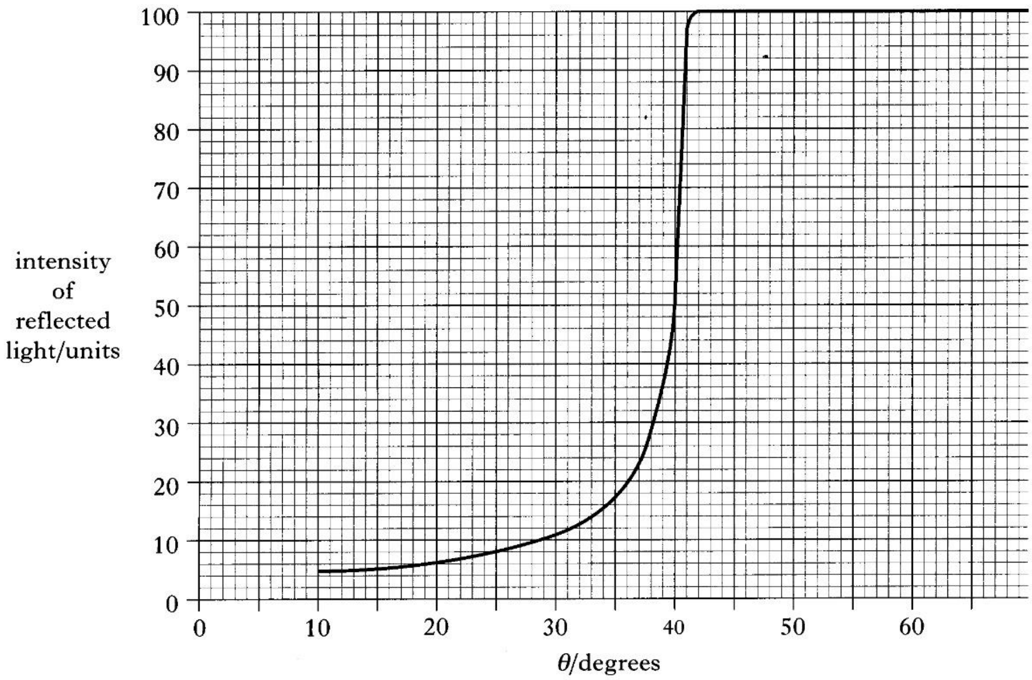


   The student uses a light meter to measure the irradiance of ray R as angle θ is changed.

   (a) State what is meant by the *irradiance* of a radiation. 1

   (b) Explain why, as angle q is changed, it is important to keep the light meter at a constant distance from point X for each measurement of irradiance. 1

(c) The graph below is obtained from the student's results.



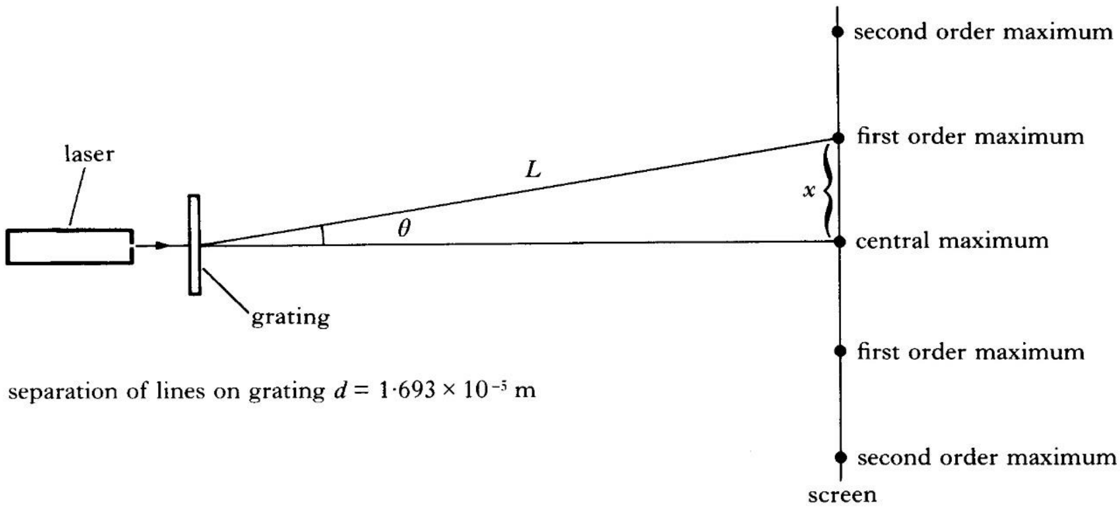
(i) What is the value of the critical angle in the glass for this light? 1

(ii) Calculate the refractive index of the glass for this light. 2

(iii) As the angle θ is increased, what happens to the irradiance of ray T? 1

(6)

2. The apparatus shown below is set up to determine the wavelength of light from a laser.



The wavelength of the light is calculated using the equations:

$\lambda = d \sin \theta$ and $\sin \theta = \frac{x}{L}$

where angle θ and distances x and L are shown in the diagram.

(a) Seven students measure the distance L with a tape measure.

Their results are as follows.

2·402 m 2·399 m 2·412 m 2·408 m 2·388 m 2·383 m 2·415 m

Calculate the mean value for L **and** the approximate random uncertainty in the mean. 2

(b) The best estimate of the distance x is (91 ± 1) mm.
Show by calculation whether L or x has the largest percentage uncertainty. 2

(c) Calculate the wavelength, in nanometres, of the laser light.
You must give your answer in the form
final value ± absolute uncertainty. 3

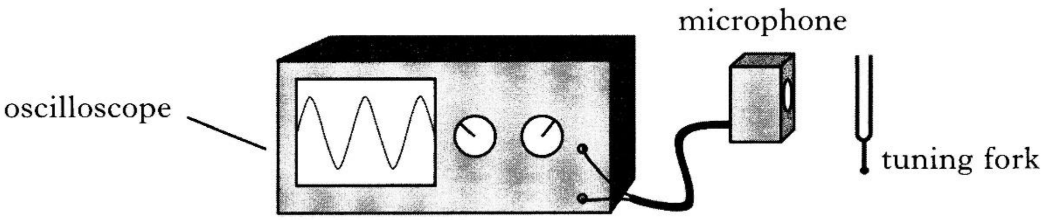
(d) Suggest an improvement which could be made so that a more accurate estimate of the wavelength could be made.
You must use only the same equipment and make the same number of measurements. 1

Electrons and energy

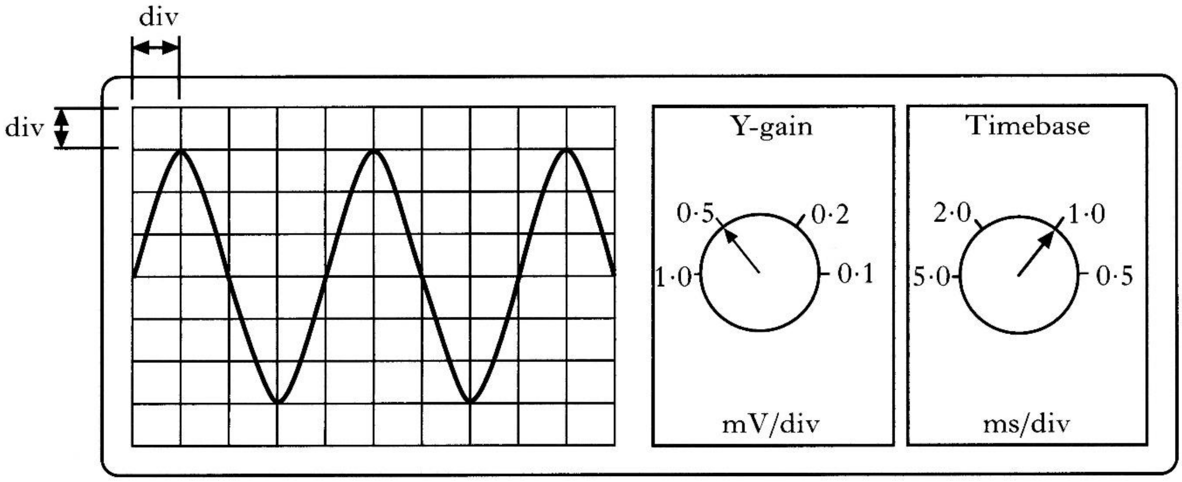
Chapter 7- Electricity

MEASURING AND MONITORING ALTERNATING CURRENT

1. A microphone is connected to the input terminals of an oscilloscope. A tuning fork is made to vibrate and held close to the microphone as shown.



The following diagram shows the trace obtained and the settings on the oscilloscope.



Calculate:

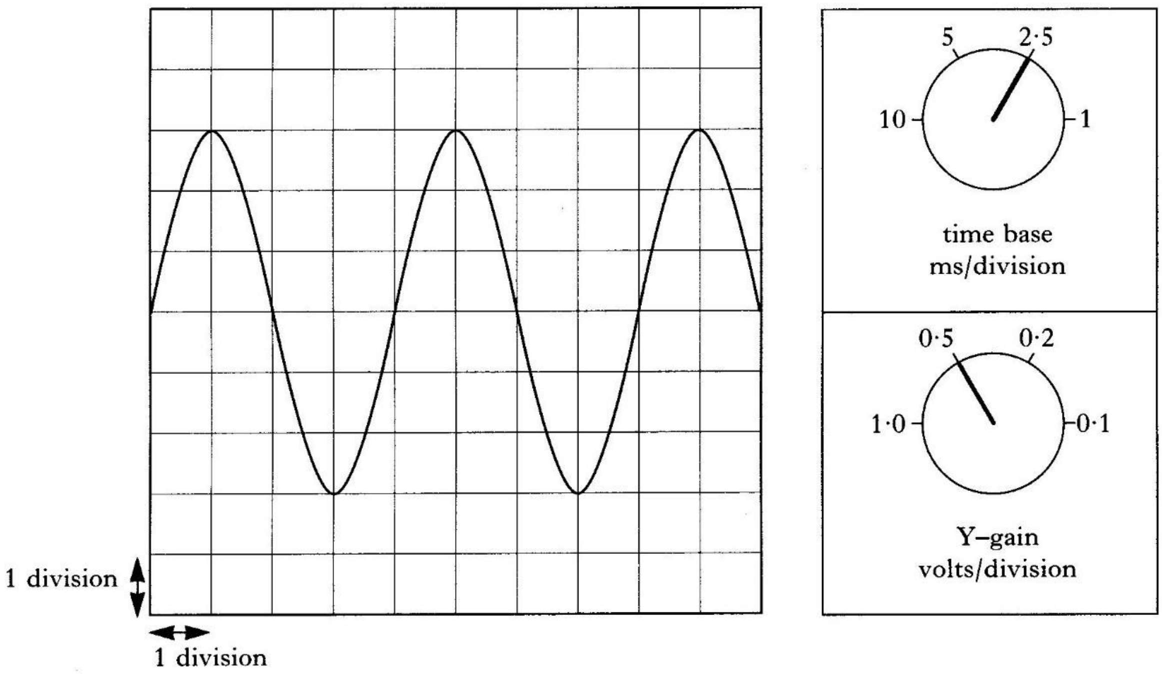
(a) the peak voltage of the signal; 1

(b) the r.m.s. voltage of the signal; 2

(c) the frequency of the signal. 2

(5)

2. The output from a signal generator is connected to the input terminals of an oscilloscope. A trace is obtained on the oscilloscope screen. The oscilloscope control settings and the trace on the oscilloscope screen are shown in the diagram below.



(a) Calculate the frequency of the output from the signal generator. 2

(b) The frequency and amplitude of the output from the signal generator are kept constant. The time base control setting is changed to 5 ms/division.
What is the effect on the trace shown on the oscilloscope? 1

(3)

3. The peak value of an a.c. voltage is 12 V.

Calculate:

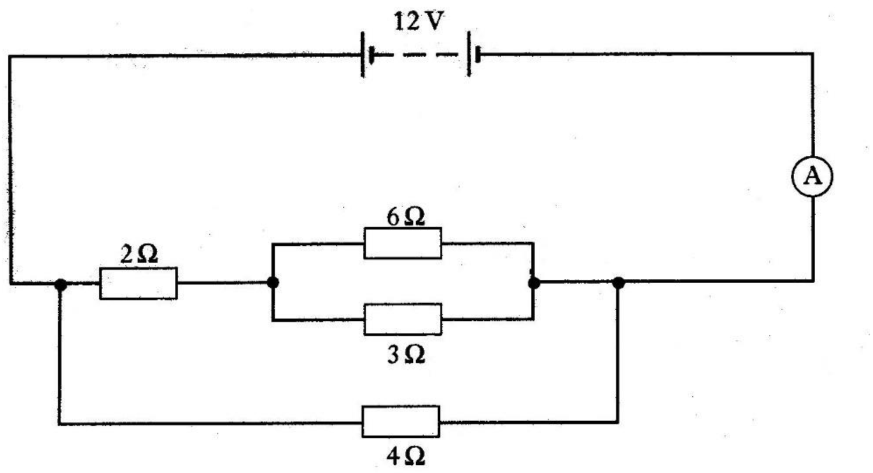
(a) the r.m.s. voltage; 2

(b) the power dissipated in a 4·0 Ω resistor by this voltage. 2

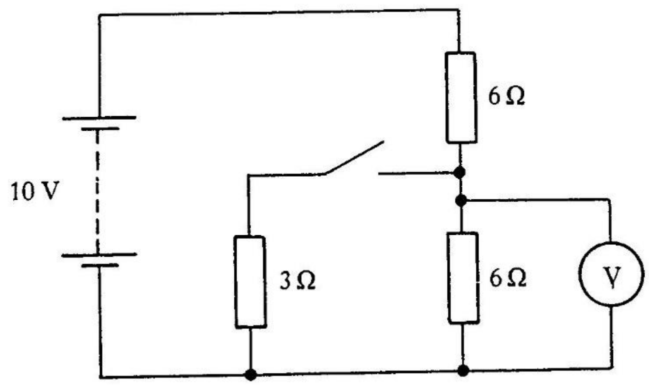
(4)

CURRENT, VOLTAGE, POWER AND RESISTANCE

1. Calculate the current in the ammeter in the circuit below. The battery has negligible internal resistance.



2. The circuit below shows resistors connected in a potential divider.



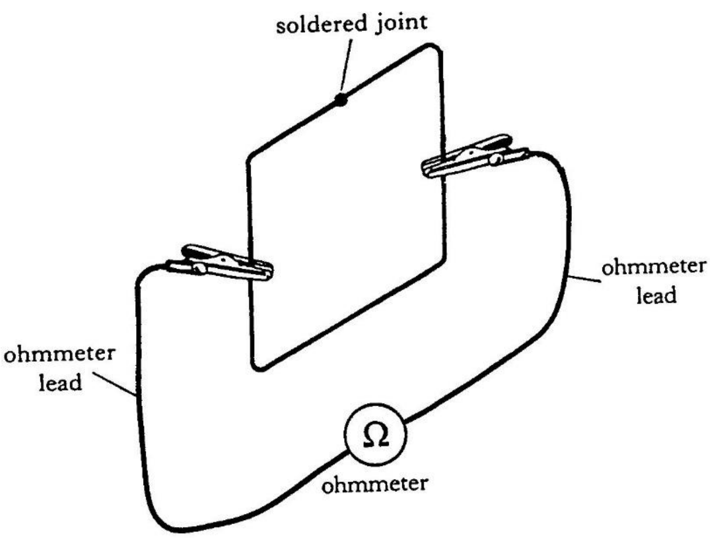
Calculate the reading on the voltmeter:

(a) when the switch is open; 2

(b) when the switch is closed. 2

(4)

4. The resistance of a length of bare uniform resistance wire is 30 Ω. The length of wire is folded into the shape of a square and the ends soldered together as shown below.



The resistance of the ohmmeter leads is negligible.

(a) Calculate the resistance displayed on the ohmmeter when it is connected as shown at the mid-points of opposite sides of the square. 2

(b) The right hand lead is now moved down to the bottom right-hand corner of the square.
State how the resistance displayed on the ohmmeter compares to that in part (a). You must justify your answer. 2

(4)

ELECTRICAL SOURCES AND INTERNAL RESISTANCE

1. (a) A supply of e.m.f. 10·0 V and internal resistance *r* is connected in a circuit as shown in Figure 1.

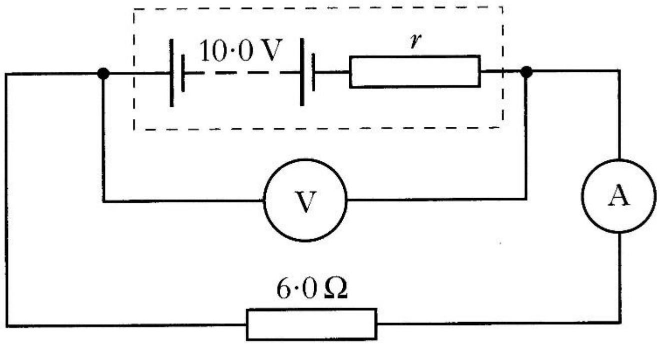


Figure 1

The meters display the following readings.

Reading on ammeter = 1·25 A
Reading on voltmeter = 7·50 V

(i) What is meant by an *e.m.f. of 10·0 V*? 1
(ii) Show that the internal resistance *r* of the supply is 2·0 Ω. 1

(b) A resistor R is connected to the circuit as shown in Figure 2.

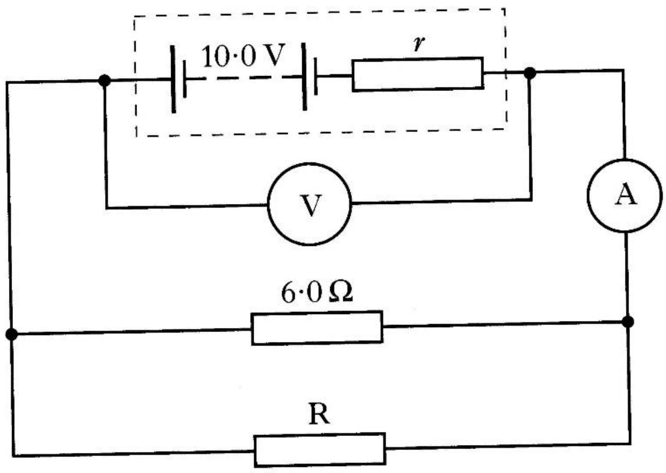


Figure 2

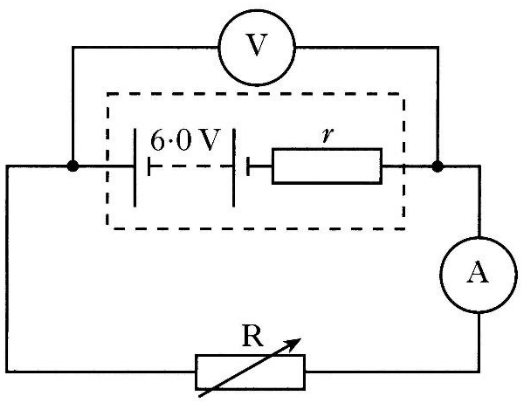
The meters now display the following readings.

Reading on ammeter = 2·0 A
Reading on voltmeter = 6·0 V

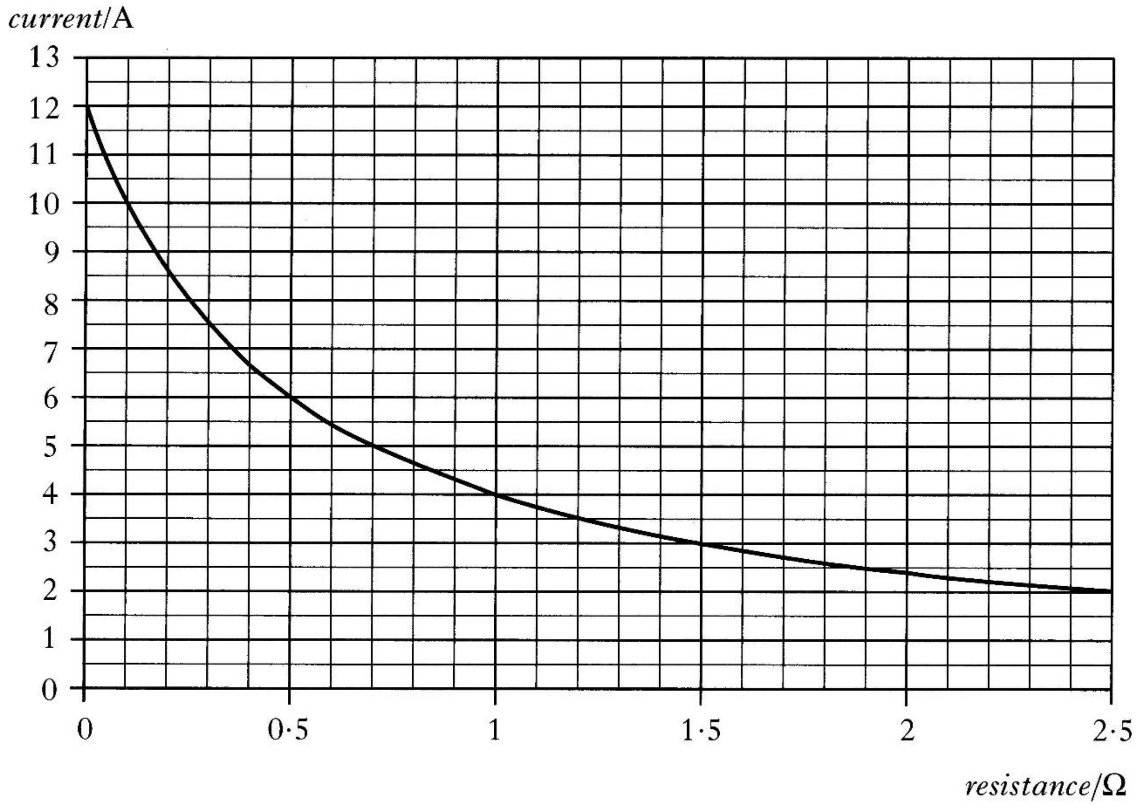
(i) Explain why the reading on the voltmeter has decreased. 2
(ii) Calculate the resistance of resistor R. 3

(7)

2. A battery of e.m.f. 6·0 V and internal resistance r is connected to a variable resistor R as shown.



The graph shows how the current in the circuit changes as the resistance R increases.



(a) Use information from the graph to calculate:

(i) the lost volts in the circuit when the resistance of R is 1·5 Ω; 2

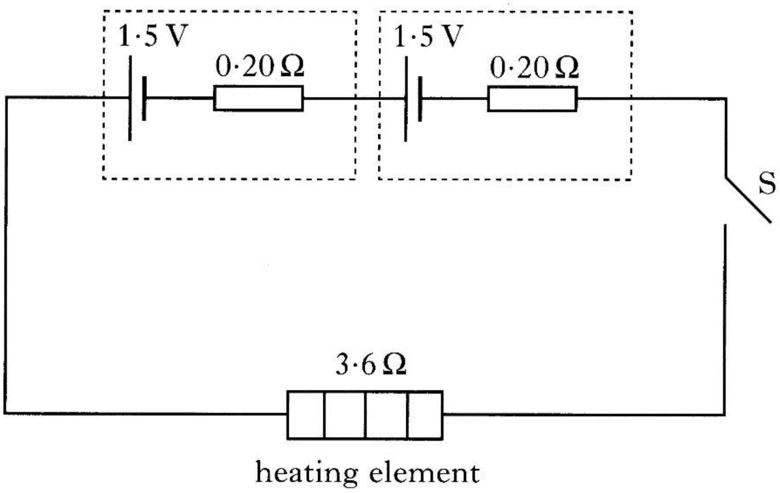
(ii) the internal resistance r of the battery. 2

(b) The resistance of R is now increased.
What effect, if any, does this have on the lost volts?
You must justify your answer. 2

(6)

3. Electrically heated gloves are used by skiers and climbers to provide extra warmth.

(a) Each glove has a heating element of resistance 3·6 Ω.
Two cells, each of e.m.f. 1·5 V and internal resistance 0·20 Ω, are used to operate the heating element.



Switch S is closed.

(i) Determine the value of the total circuit resistance. 1

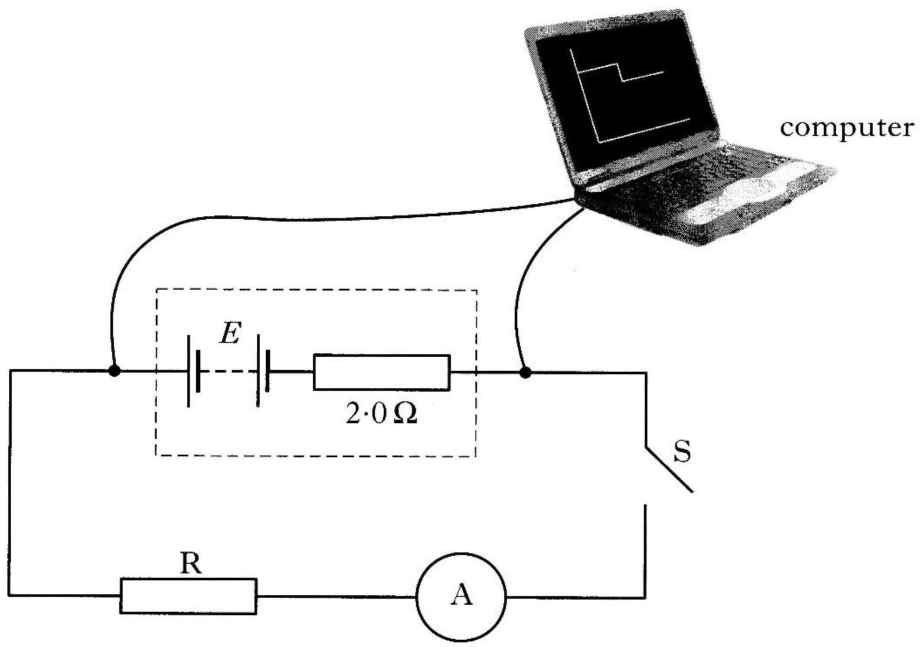
(ii) Calculate the current in the heating element. 2

(iii) Calculate the power output of the heating element. 2

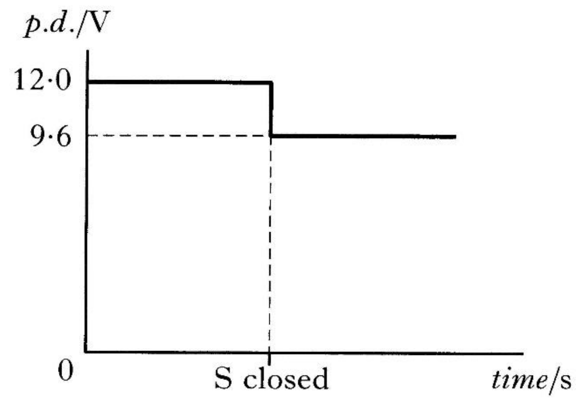
(b) When in use, the internal resistance of each cell gradually increases.
What effect, if any, does this have on the power output of the heating element?
Justify your answer. 2

(7)

4. A power supply of e.m.f. E and internal resistance 2·0 Ω is connected as shown.



The computer connected to the apparatus displays a graph of potential difference against time.
The graph shows the potential difference across the terminals of the power supply for a short time before and after switch S is closed.



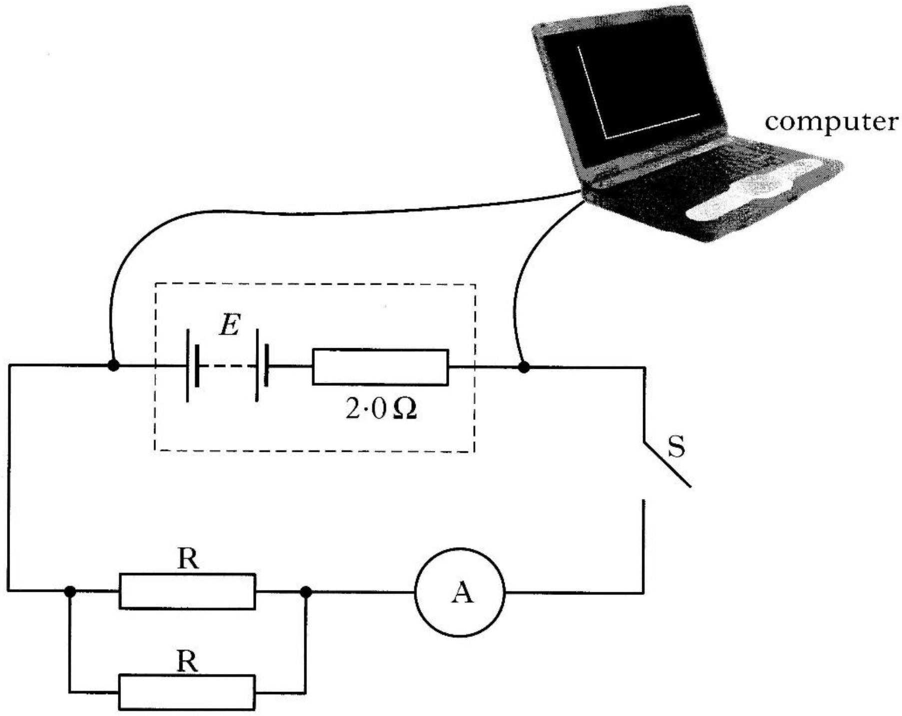
(a) State the e.m.f. of the power supply. 1

(b) Calculate:

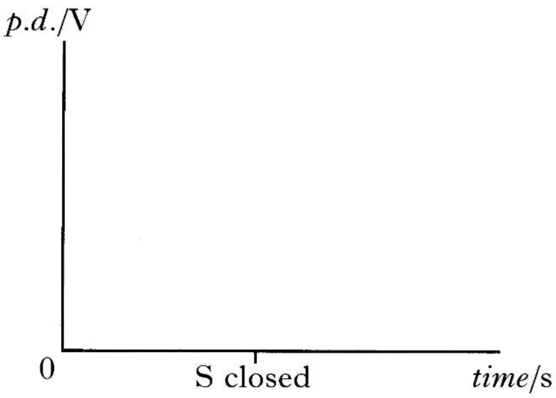
(i) the reading on the ammeter after switch S is closed; 2

(ii) the resistance of resistor R. 1

(c) Switch S is opened. A second identical resistor is now connected in parallel with R as shown.



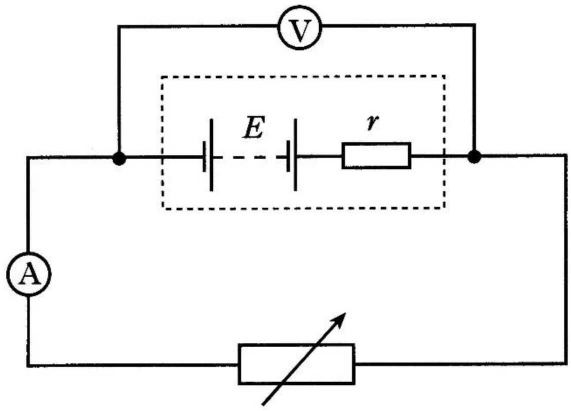
The computer is again connected in order to display a graph of potential difference against time.



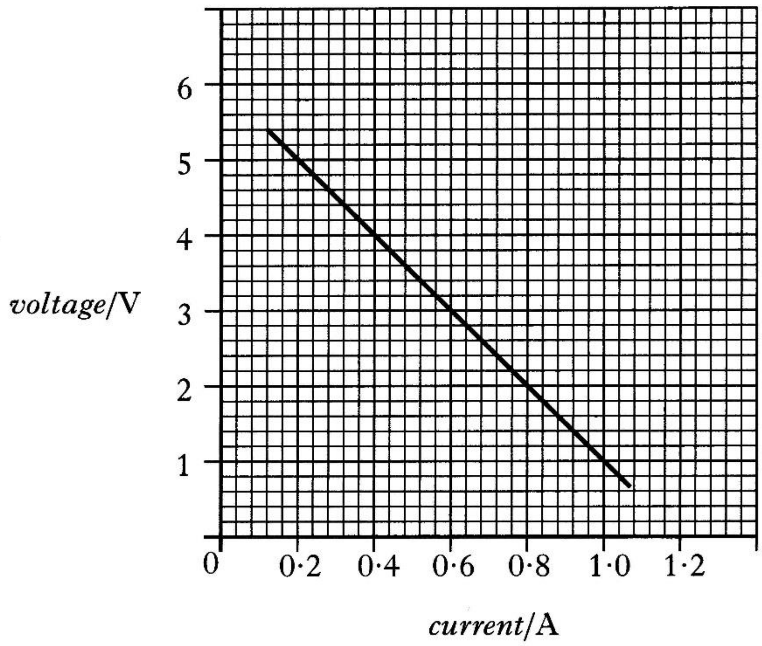
Copy and complete the new graph of potential difference against time showing the values of potential difference before and after switch S is closed. 2

(6)

5. A student sets up the following circuit to find the e.m.f. *E* and the internal resistance *r* of a battery.



Readings from the voltmeter and ammeter are used to plot the following graph.

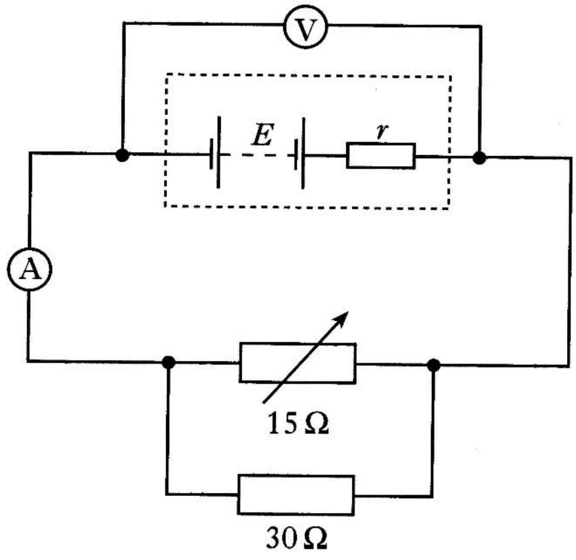


(a) What is meant by the term *e.m.f.*? 1

(b) (i) Use the graph to determine:
(A) the e.m.f.; 1
(B) the internal resistance of the battery. 2

(ii) Show that the variable resistor has a value of 15 Ω when the current is 0·30 A. 1

(c) Without adjusting the variable resistor, a 30 Ω resistor is connected in parallel with it.



Calculate the new reading on the ammeter. 2

(7)

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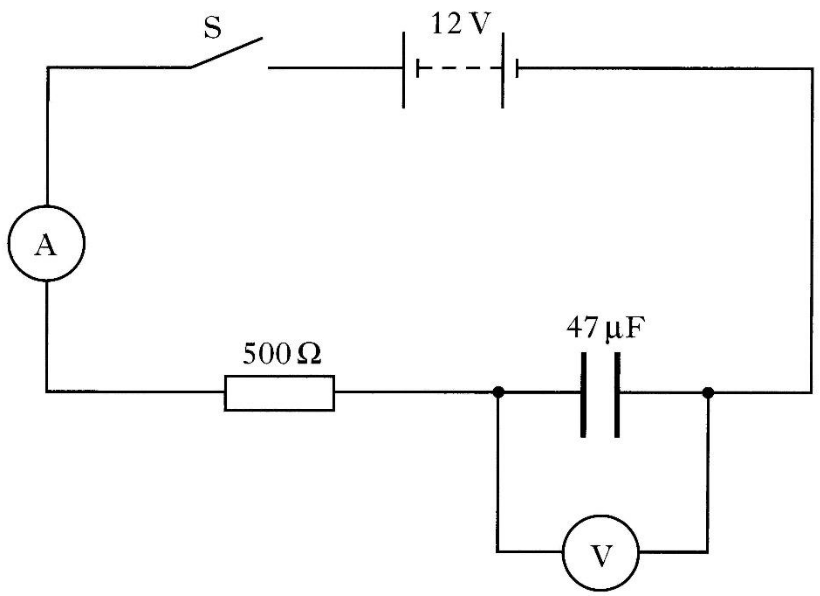
CAPACITORS

1. A 12 volt battery of negligible internal resistance is connected in a circuit as shown.



The capacitor is initially uncharged. Switch S is then closed and the capacitor starts to charge.

(a) Sketch a graph of the current against time from the instant switch S is closed. Numerical values are not required. 1

(b) At one instant during the charging of the capacitor the reading on the ammeter is 5·0 mA.
Calculate the reading on the voltmeter at this instant. 3

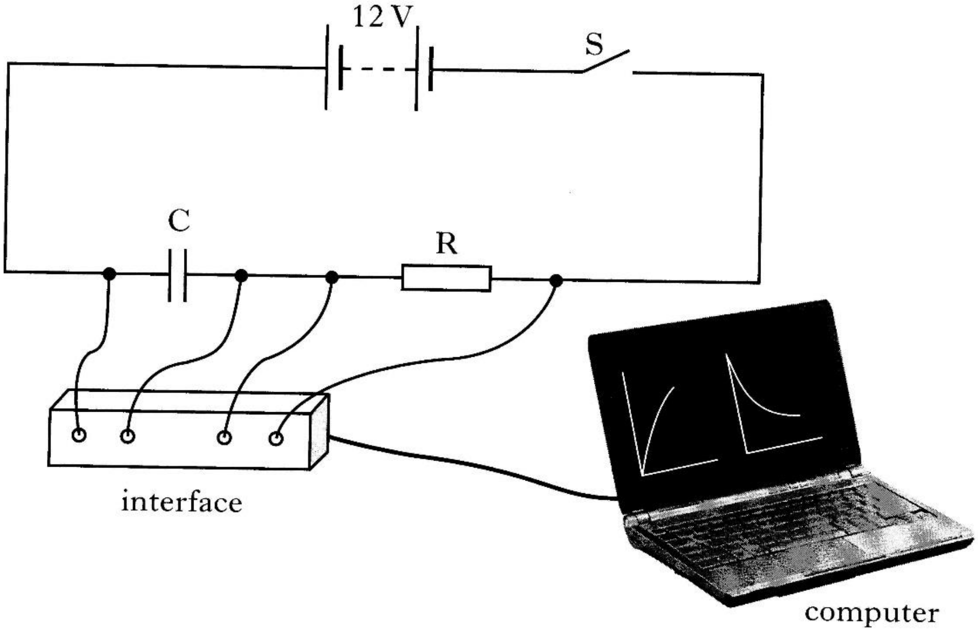
(c) Calculate the **maximum** energy stored in the capacitor in this circuit. 2

(d) The 500 Ω resistor is now replaced with a 2·0 kΩ resistor.
What effect, if any, does this have on the maximum energy stored in the capacitor?
Justify your answer. 2

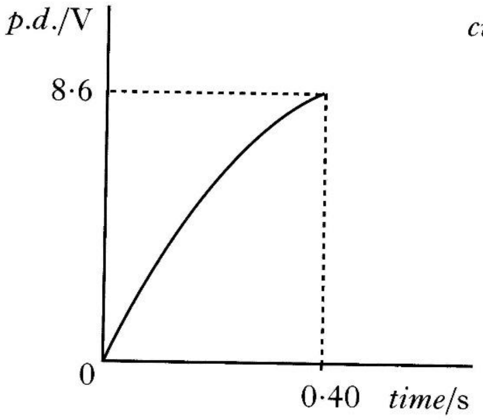
(8)

2. (a) State what is meant by the term *capacitance*. 1

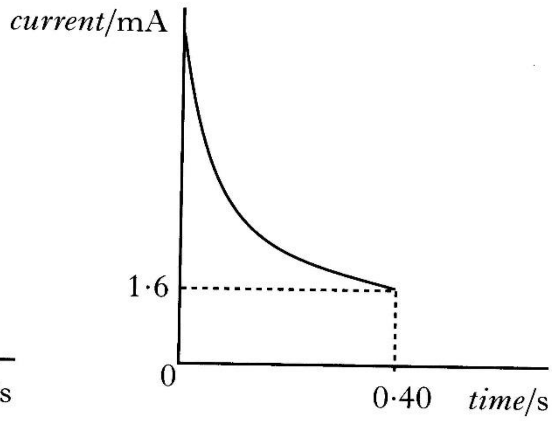
(b) An uncharged capacitor, C, is connected in a circuit as shown.



The 12 V battery has negligible internal resistance.
Switch S is closed and the capacitor begins to change.
The interface measures the current in the circuit and the potential difference (p.d.) across the capacitor. These measurements are displayed as graphs on the computer.
Graph 1 shows the p.d. across the capacitor for the first 0·40 s of charging.
Graph 2 shows the current in the circuit for the first 0·40 s of charging.



Graph 1



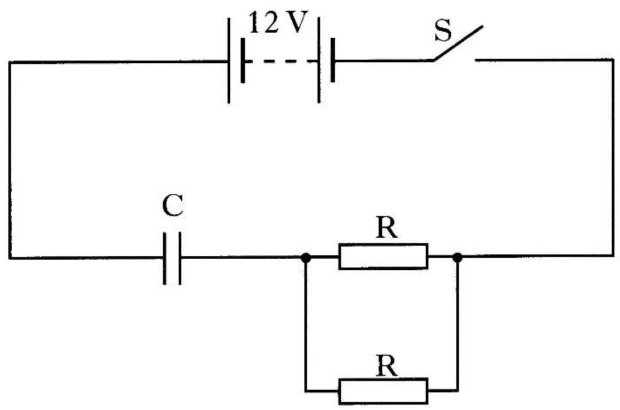
Graph 2

(i) Determine the p.d. **across resistor R** at 0·40 s. 1

(ii) Calculate the resistance R. 2

(iii) The capacitor takes 2·2 s to charge fully.
At that time it stores 10·8 mJ of energy.
Calculate the capacitance of the capacitor. 3

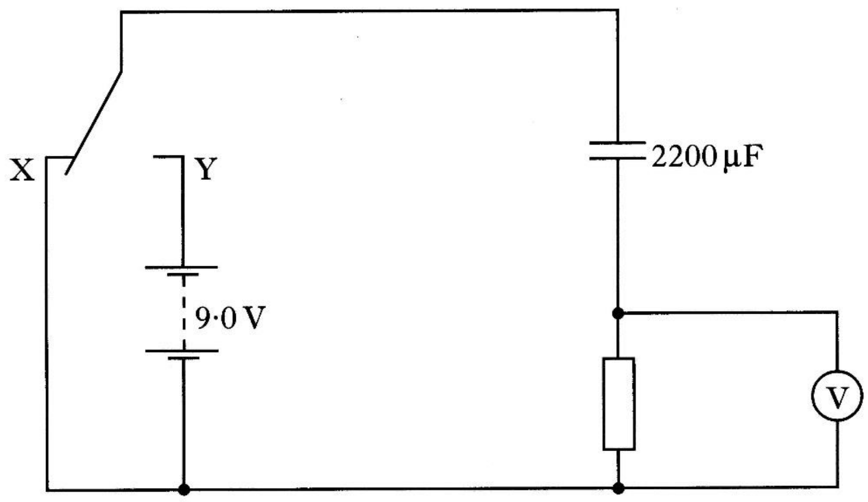
(c) The capacitor is now discharged.
A second, identical resistor is connected in the circuit as shown.



Switch S is closed.
Is the time taken for the capacitor to fully charge less than, equal to, or greater than the time taken to fully charge in part (b)?
Justify your answer. 2

(9)

3 A student investigates the charging and discharging of a 2200 μF capacitor using the circuit shown.



The 9·0 V battery has negligible internal resistance.
Initially the capacitor is uncharged and the switch is at position X.
The switch is then moved to position Y and the capacitor charges fully in 1·5 s.

(a) (i) Sketch a graph of the p.d. across the **resistor** against time while the capacitor charges. Appropriate numerical values are required on both axes. 2

(ii) The resistor is replaced with one of higher resistance. Explain how this affects the time taken to fully charge the capacitor. 1

(iii) At one instant during the charging of the capacitor the reading on the voltmeter is 4·0 V. Calculate the charge stored by the capacitor at this instant. 3

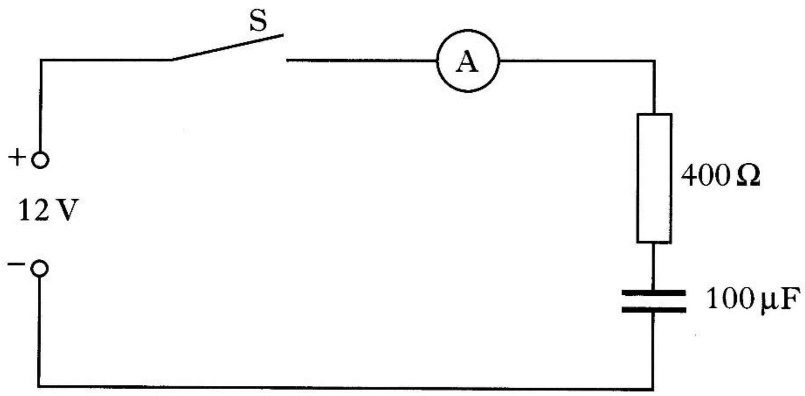
(b) Using the same circuit in a later investigation the resistor has a resistance of 100 kΩ. The switch is in **position Y** and the capacitor is fully charged.

(i) Calculate the maximum energy stored in the capacitor. 2

(ii) The switch is moved to position X. Calculate the maximum current in the resistor. 2

(10)

4. In an experiment, the circuit shown is used to investigate the charging of a capacitor.



The power supply has an e.m.f. of 12 V and negligible internal resistance. The capacitor is initially uncharged.
Switch S is closed and the current measured during charging. The graph of charging current against time is shown in figure 1.

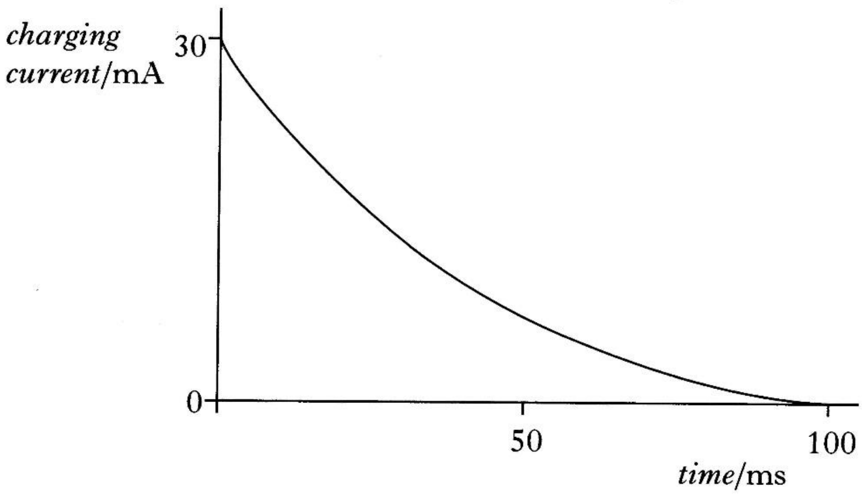


figure 1

(a) Sketch a graph of the voltage across the capacitor against time until the capacitor is fully charged. Numerical values are required on both axes. 2

(b) (i) Calculate the voltage across the capacitor when the charging current is 20 mA. 2

(ii) How much energy is stored in the capacitor when the charging current is 20 mA. 2

(c) The capacitor has a maximum working voltage 12 V.
Suggest **one** change to this circuit which would allow an initial charging current of greater than 30 mA. 1

(d) The 100 μF capacitor is now replaced with an uncharged capacitor of unknown capacitance and the experiment repeated. The graph of charging current against time for this capacitor is shown in figure 2.

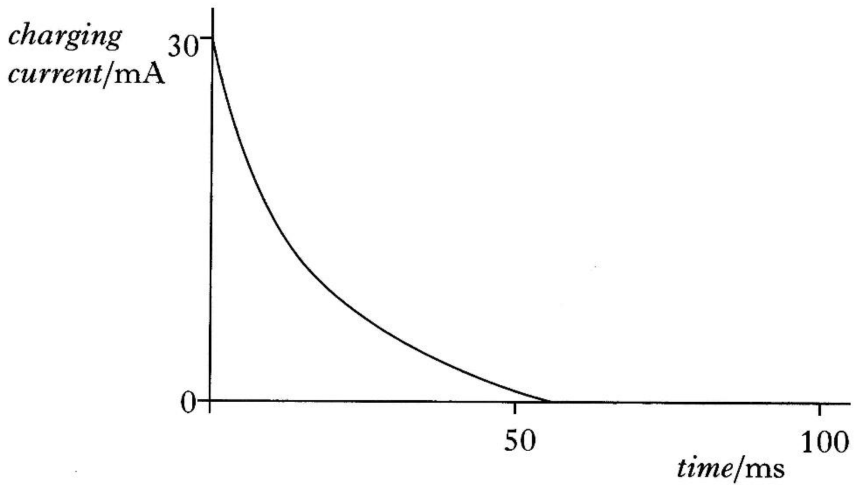


figure 2

By comparing figure 2 with figure 1, determine whether the capacitance of this capacitor is greater than, equal to or less than 100 μF.
You must justify your answer. 2

(9)

5. You are given a capacitor, a battery, a resistor, a switch. a cathode ray oscilloscope and connecting wires.

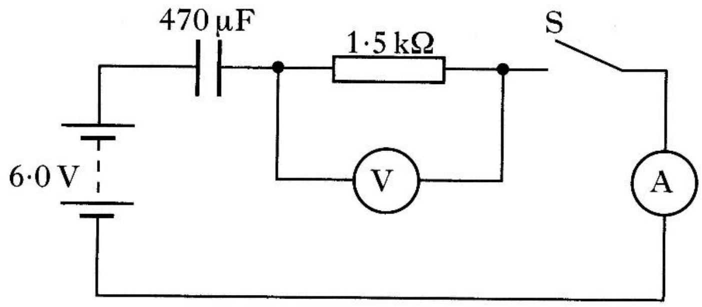
You are asked to set up a circuit which would allow you to look at the variation of current as the capacitor is charged up through the resistor.

(a) Draw a diagram of your circuit. 2

(b) Sketch a graph showing the variation of current while the capacitor is charging. 1

(3)

6. (a The following diagram shows a circuit that is used to investigate the charging of a capacitor.



The capacitor is initially uncharged.
The capacitor has a capacitance of 470 μF and the resistor has a resistance of 1·5 kΩ.
The battery has an e.m.f. of 6·0 V and a negligible internal resistance.

(i) Switch S is now closed. What is the initial current in the circuit? 2

(ii) How much energy is stored in the capacitor when it is fully charged? 2

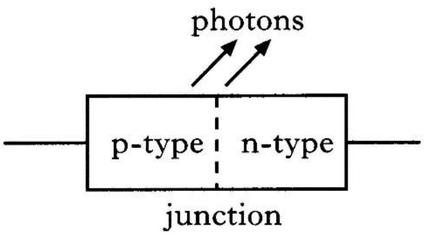
(iii) What change could be made to this circuit to ensure that the **same** capacitor stored **more** energy? 1

(b) A capacitor is used to provide the energy for an electronic flash in a camera.
When the flash is fired, $6{\cdot}35 \times 10^{-3}$ J of the stored energy is emitted as light.
The mean value of the frequency of photons of light from the flash is $5{\cdot}80 \times 10^{14}$ Hz.
Calculate the number of photons emitted in each flash of light. 3

(8)

P&N JUNCTIONS

1. An LED consists of a p-n junction as shown.



(a) Copy the diagram and add a battery so that the p-n junction is forward-biased. 1

(b) Using the terms *electrons*, *holes* and *photons*, explain how light is produced at the p-n junction of the LED. 1

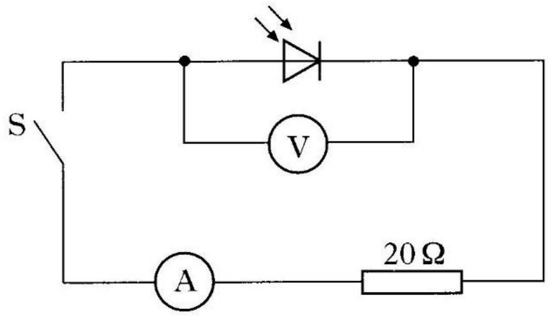
(c) The LED emits photons, of energy $3{\cdot}68 \times 10^{-19}$ J.

(i) Calculate the wavelength of a photon of light from this LED. 2

(ii) Calculate the minimum potential difference across the p-n junction when it emits photons. 2

(6)

2. A photodiode is connected in a circuit as shown below.



Switch S is open.
Light is shone on to the photodiode.
A reading is obtained on the voltmeter.

(a) (i) State the mode in which the photodiode is operating. 1

(ii) Describe the effect of light on the material of which the photodiode is made. 1

(iii) The irradiance of the light on the photodiode is increased. What happens to the reading on the voltmeter? 1

(b) Light of a constant irradiance is shone on the photodiode in the circuit shown above.
The following measurements are obtained with switch S open and then with switch S closed.

	S open	S closed
reading on voltmeter/V	0·508	0·040
reading on ammeter/mA	0·00	2·00

(i) What is the value of the e.m.f. produced by the photodiode for this light irradiance? 1

(ii) Calculate the internal resistance of the photodiode for this light irradiance. 2

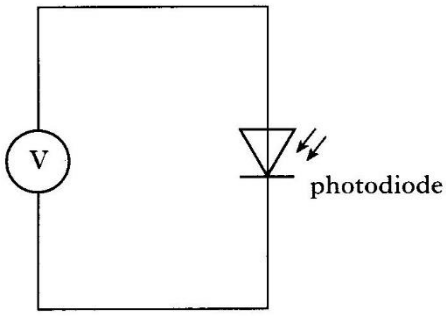
(c) In the circuit above, the 20 Ω resistor is now replaced with a 10 Ω resistor.
The irradiance of the light is unchanged.
The following measurements are obtained.

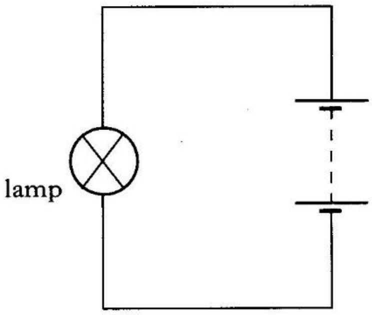
	S open	S closed
reading on voltmeter/V	0·508	0·021

Explain why the reading on the voltmeter, when S is closed, is smaller than the corresponding reading in part (b). 2

(8)

3.. The diagram shows a photodiode connected to a voltmeter. A lamp is used to shine light onto the photodiode.

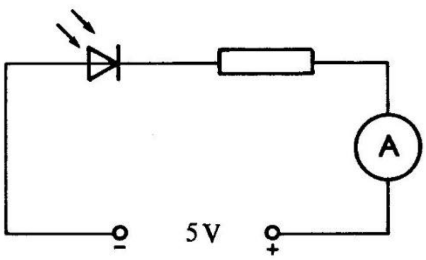




The reading on the voltmeter is 0·5 V.
The lamp is now moved closer to the photodiode.
Using the terms **photons**, **electrons** and **holes**, explain why the voltmeter reading changes. 2

(2)

4. The circuit below shows a photodiode connected in series with a resistor and an ammeter. The power supply has an output voltage 5 V and negligible internal resistance.



In a darkened room, there is no current in the circuit.
When light strikes the photodiode, there is a current in the circuit.

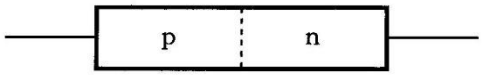
(a) Describe the effect of light on the material of which the photodiode is made. 1

(b) In which mode is the photodiode operating? 1

(c) When the photodiode is placed 1·0 m from a small lamp, the current in the circuit is 3·0 μA.
Calculate the current in the circuit when the photodiode is placed 0·75 m from the same lamp. 3

(5)

4. (a) The diagram below represents the p-n junction of a light emitting diode (LED).

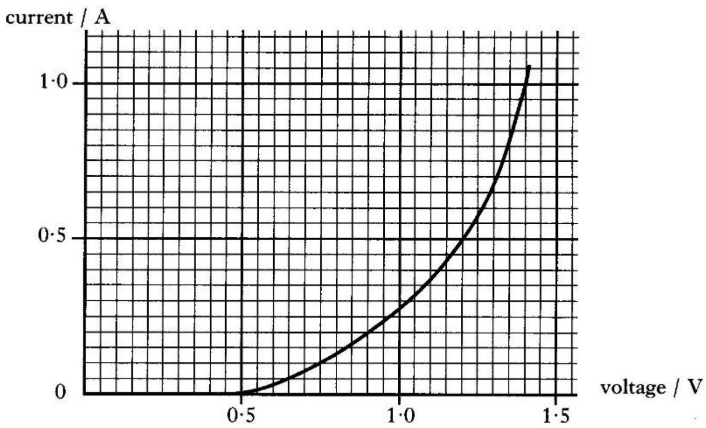


(i) Draw a diagram showing the above p-n junction connected to a battery so that the junction is forward biased. 1

(ii) When the junction is forwarded biased, there is a current in the diode. Describe the movement of charge carriers which produces this current. 2

(iii) Describe how the charge carriers in the light emitting diode enable light to be produced. 2

(b) The following graph shows the variation of current with voltage for a diode when it is forward biased.



(i) What is the minimum voltage required for the diode to conduct. 1

(ii) What happens to the resistance of the diode as the voltage is increased above this minimum value?
Use information from the graph to justify your answer. 2

UNCERTAINTIES IN ELECTRICITY

1. Measurements of the p.d. across a resistor and the current in the resistor give the following results.

p.d. = (30·00 ± 0·03) V
current = (2·00 ± 0·01) A

Use these results to calculate the resistance of the resistor and express your answer in the form

resistance ± uncertainty 3