3220/320

SCOTTISH CERTIFICATE OF EDUCATION 1995

WEDNESDAY, 17 MAY
1.30 PM – 4.00 PM

PHYSICS (REVISED)
HIGHER GRADE
Paper II

Read carefully

1 All questions should be attempted.

2 Enter the question number clearly in the margin beside each question.

3 Any necessary data will be found in the Data Sheet on page two.

4 Care should be taken not to give an unreasonable number of significant figures in the final answers to calculations.

5 Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Examination Board.

ESB 3220/320 6/3/22810

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}	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$ C	Mass of neutron	m_n	$1{\cdot}67490 \times 10^{-27}$ kg
Gravitational acceleration	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s			

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	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49		

SPECTRAL LINES

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

Element	*Wavelength*/nm	*Colour*
Cadmium	644 509 480	Red Green 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	*Specific Heat Capacity*/ J kg^{-1} K^{-1}	*Specific Latent Heat of Fusion*/ J kg^{-1}	*Specific Latent Heat of Vaporisation*/ J kg^{-1}
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{5}$

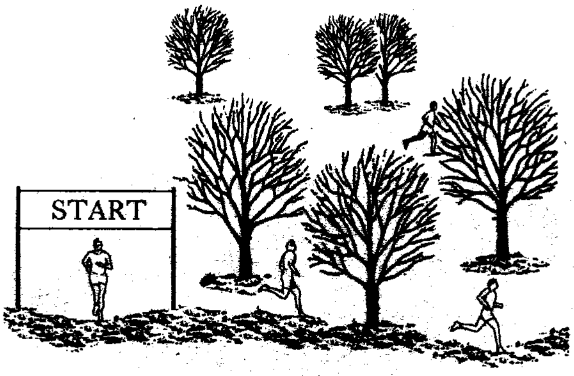
The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

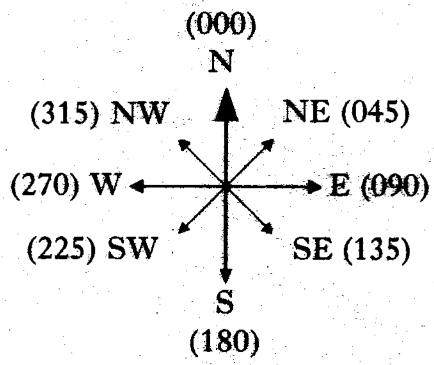
Marks

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 $3\,m\,s^{-1}$.

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

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

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

Determine the average velocity of Paul.

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

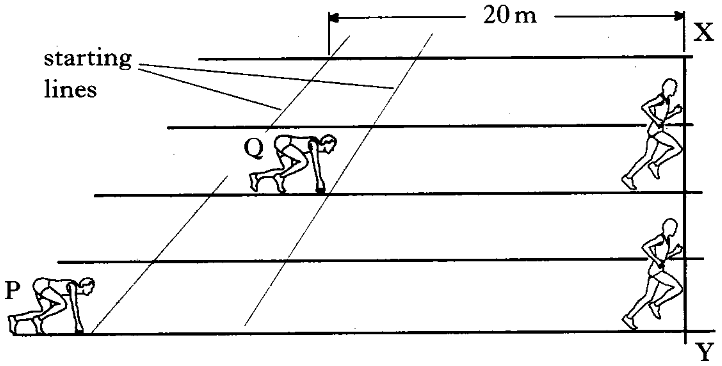
Show by calculation who is first to arrive at this control point. **9**

(10)

[Turn over

2. In a "handicap" sprint race, sprinters P and Q both start the race at the same time but from different starting lines on the track.

The handicapping is such that both sprinters reach the line XY, as shown below, at the same time.



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

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

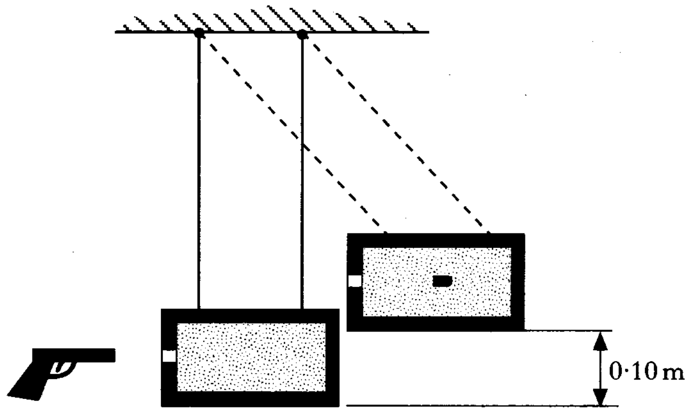
(*b*) Find the speed of **each** sprinter at this line. **3**

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

(7)

3. (*a*) A bullet of mass 25 g is fired horizontally into a sand-filled box which is suspended by long strings from the ceiling. The combined mass of the bullet, box and sand is 10 kg.

After impact, the box swings upwards to reach a maximum height as shown in the diagram.

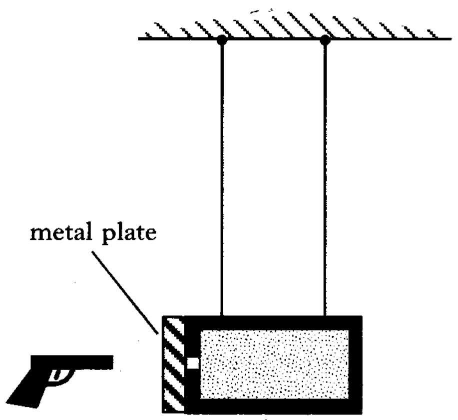


Calculate:

(i) the maximum velocity of the box after impact;

(ii) the velocity of the bullet just before impact. **5**

(*b*) The experiment is repeated with a metal plate fixed to one end of the box as shown.



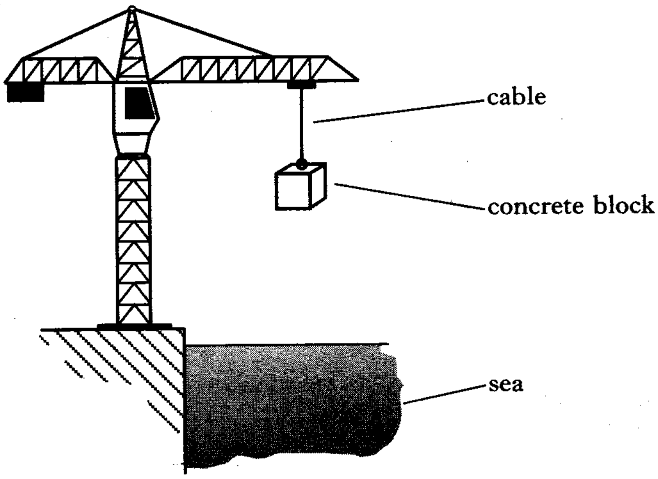
The mass of sand is reduced so that the combined mass of the sand, box and metal plate is 10 kg.

In this experiment, the bullet bounces back from the metal plate. Explain how this would affect the maximum height reached by the box compared with the maximum height reached in part (*a*). **2**

(7)

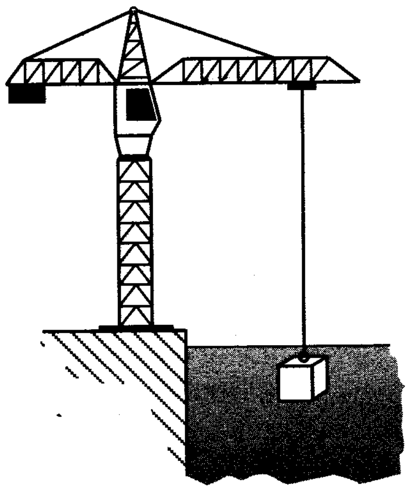
[Turn over

4. A crane is used to lower a concrete block of mass $5 \cdot 0 \times 10^3$ kg into the sea.



(*a*) The crane lowers the block towards the sea at a constant speed.
Calculate the tension in the cable supporting the block. **1**

(*b*) The crane lowers the block into the sea. The block is held stationary just below the surface of the sea as shown in the diagram below.



The tension in the cable is now $2 \cdot 9 \times 10^4$ N.

(i) Calculate the size of the buoyancy force acting on the block.

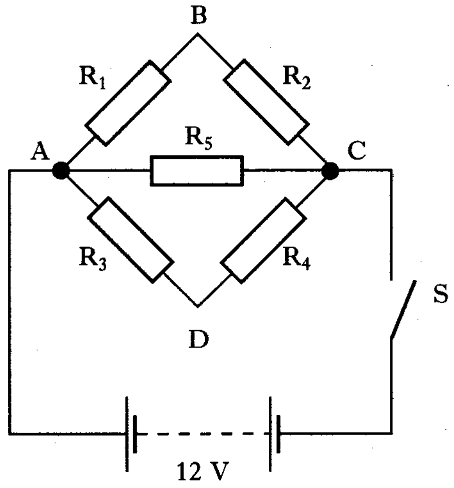
(ii) Explain how this buoyancy force is produced. **4**

(*c*) The block is now lowered to a greater depth.
What effect, if any, does this have on the tension in the cable?
Justify your answer. **2**

(7)

Marks

5. Four 10 Ω resistors R_1, R_2, R_3 and R_4 are connected in the form of a square ABCD. A fifth resistor R_5 of the same value is connected between A and C. This arrangement of resistors is connected in a circuit as shown below. The battery in the circuit has negligible internal resistance.



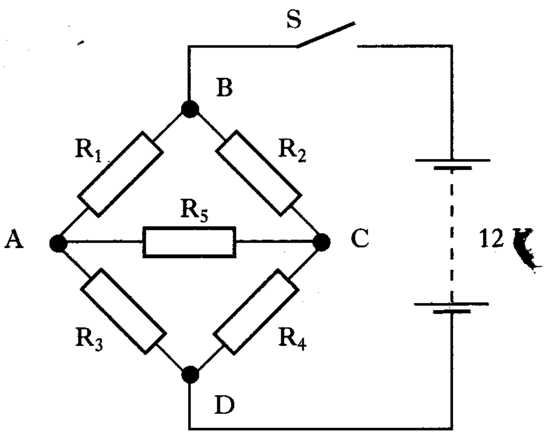
(*a*) Determine the total resistance between A and C. **2**

(*b*) The switch S is now closed.

(i) In which of the resistors is the greatest power developed?

(ii) Calculate the value of **this** power. **3**

(*c*) In a second experiment with the same resistors, the battery is connected across BD.



The switch S is now closed.

(i) Explain why there is no current in resistor R_5.

(ii) Calculate the current drawn from the battery. **4**

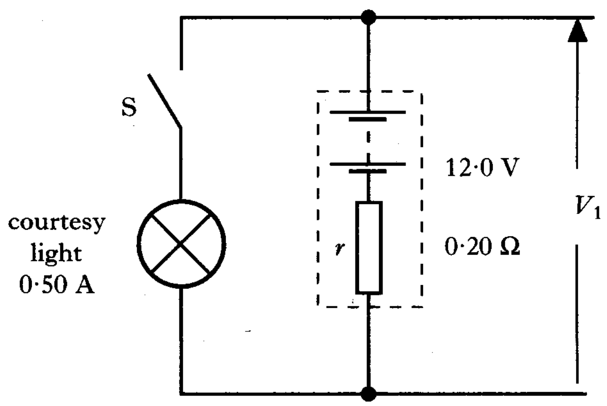
(9)

[Turn over

6. A certain car alarm system is triggered when the opening of a door of the car switches on the courtesy light.

The car alarm works by detecting the very small change in the voltage across the car battery which occurs when the courtesy light is switched on.

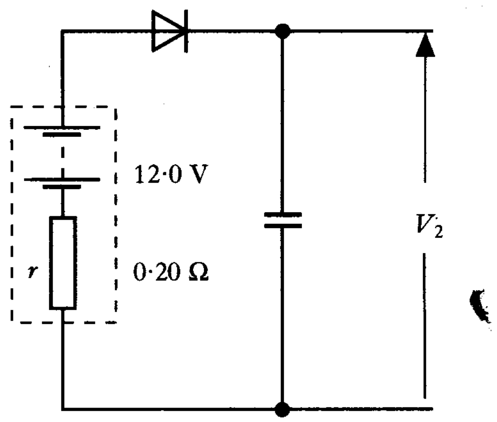
(*a*) The car battery has an e.m.f. of 12·0 V and an internal resistance r of 0·20 Ω as shown below.



When the car door is opened, the switch S closes and the courtesy light draws a current of 0·50 A from the battery.

Show that the voltage V_1 across the battery falls to 11·9 V when the switch S is closed. **2**

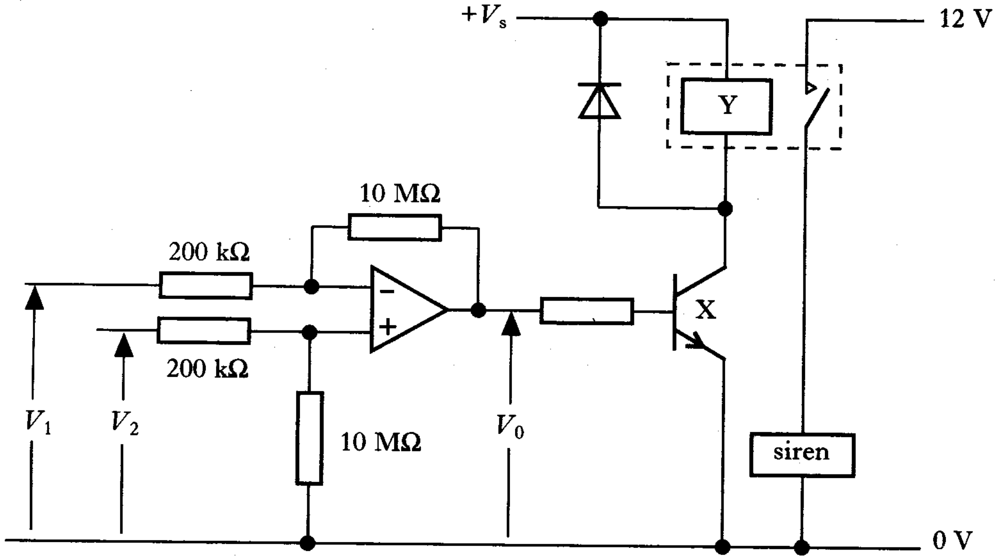
(*b*) A capacitor and diode are **also** connected across the battery, as shown below, to provide a voltage V_2 of 12·0 V across the capacitor.



Explain why the voltage V_2 across the capacitor does not decrease from 12·0 V immediately after the car door is opened and the courtesy light comes on. **1**

6. **(continued)**

(*c*) The voltages V_1 and V_2 obtained from the above circuits are then applied simultaneously as input voltages to the op-amp circuit shown below.



(i) In what mode is the op-amp being used in this circuit?

(ii) State the gain equation of the op-amp when operating in the mode shown above.

(iii) Hence calculate the output voltage V_0:

(A) while the car door is closed;

(B) when the car door is opened. **5**

(*d*) (i) Name the components labelled X and Y in the above circuit.

(ii) Describe how the output voltage V_0 of the op-amp can set off the siren of the car alarm.

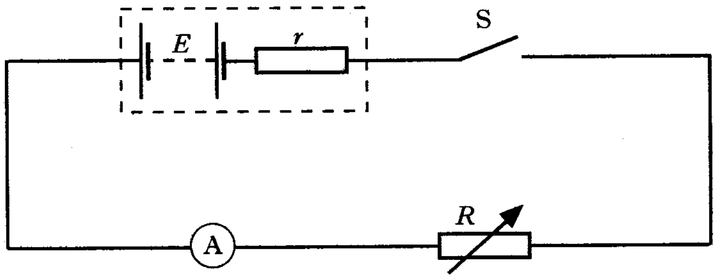
Indicate in your answer the purpose of components X and Y. **4**

(12)

[Turn over

Marks

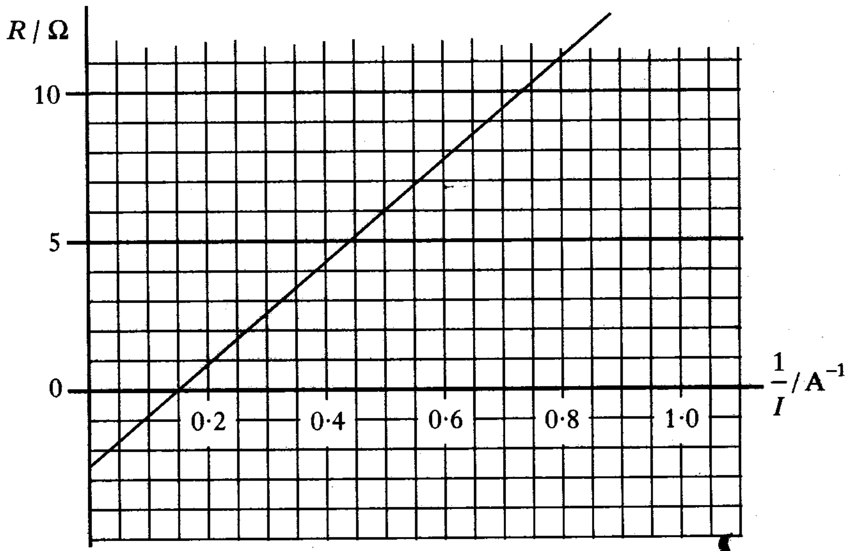
7. The circuit below is used to determine the internal resistance r of a battery of e.m.f. E.



The variable resistor provides known values of resistance R.
For each value of resistance R, the switch S is closed and the current I is noted.

For each current, the value of $\frac{1}{I}$ is calculated.

In one such experiment, the following graph of R against $\frac{1}{I}$ is obtained.



(*a*) Conservation of energy applied to the complete circuit gives the following relationship.

$$E = I(R + r)$$

Show that this relationship can be written in the form

$$R = \frac{E}{I} - r\ .$$ 1

(*b*) Use information from the graph to find:

(i) the internal resistance of the battery;

(ii) the e.m.f. of the battery. 3

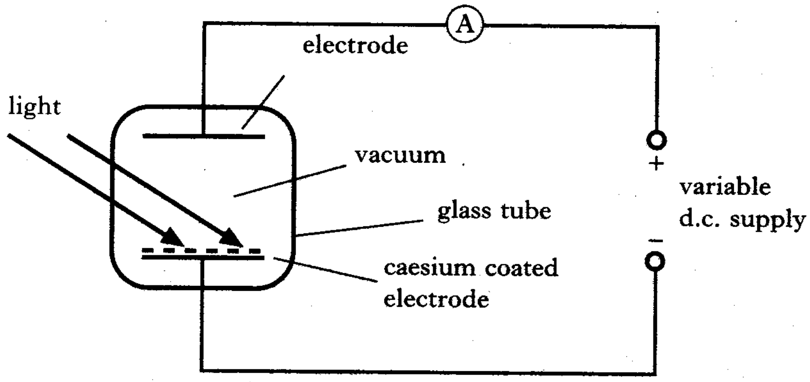
(*c*) The battery is accidentally short-circuited.
Calculate the current in the battery when this happens. 2

(6)

Marks

8. (*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.

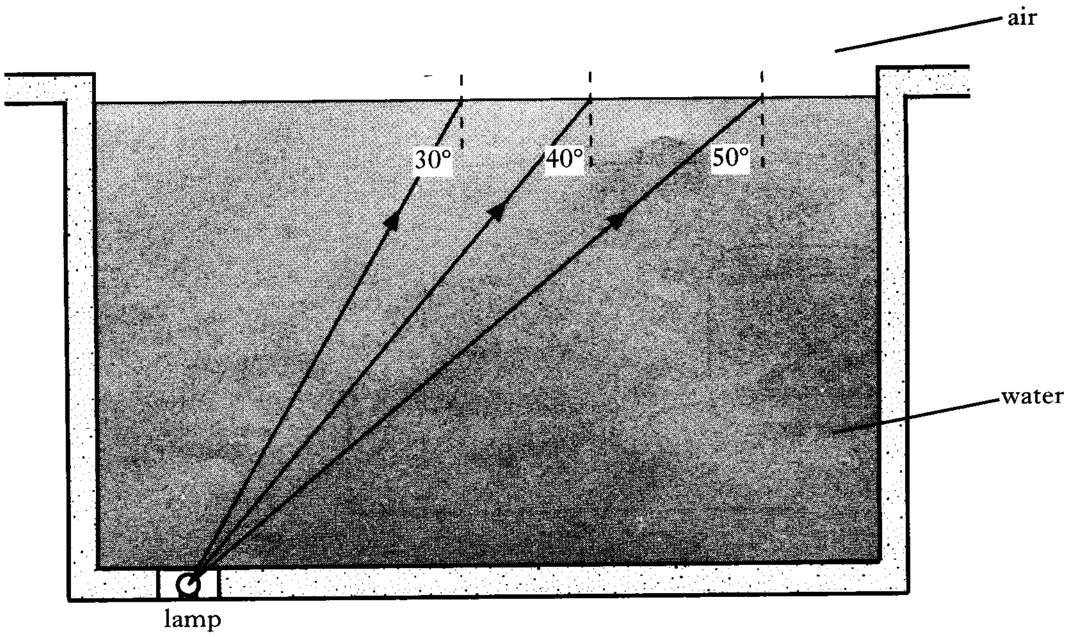
(ii) An electron leaves the caesium coated electrode with this maximum kinetic energy.
Calculate its kinetic energy as it reaches the upper electrode when the p.d. across the electrodes is 0·8 V. **6**

(*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)

[Turn over

9. A swimming pool is illuminated by a lamp built into the bottom of the pool.



Three rays of light from the same point in the lamp are incident on the water-air boundary with angles of incidence of 30°, 40° and 50°, as shown above.

The refractive index of the water in the pool is 1·33.

(*a*) Draw a diagram to show clearly what happens to each ray at the boundary. Indicate on your diagram the sizes of appropriate angles.

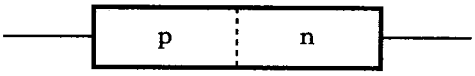
All necessary calculations must be shown. **5**

(*b*) An observer stands at the side of the pool and looks into the water.

Explain, with the aid of a diagram, why the image of the lamp appears to be at a shallower depth than the bottom of the pool. **2**

(7)

10. (*a*) The diagram below represents the p–n junction of a light emitting diode (LED).

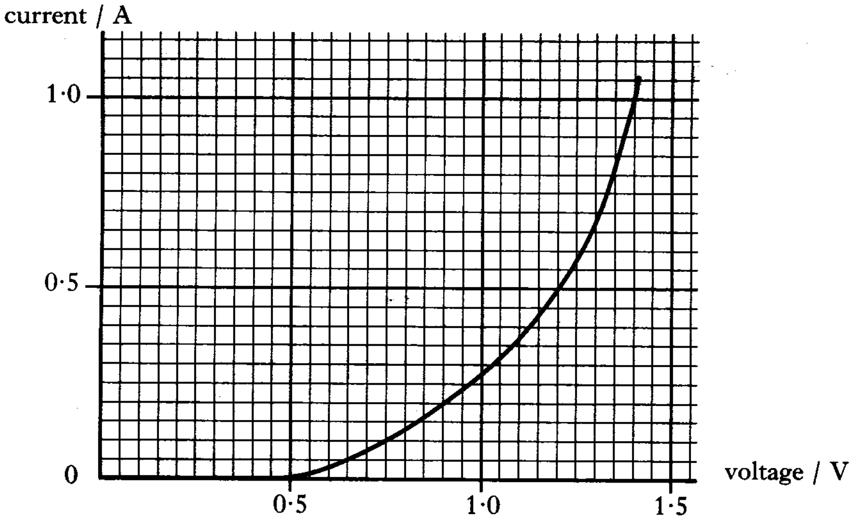


(i) Draw a diagram showing the above p–n junction connected to a battery so that the junction is forward biased.

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

(iii) Describe how the charge carriers in the light emitting diode enable light to be produced. **5**

(*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 this diode to conduct?

(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. **3**

(8)

[Turn over

Marks

11. 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.

mass of ${}^{3}_{1}\text{H} = 5\cdot00890 \times 10^{-27}$ kg
mass of ${}^{2}_{1}\text{H} = 3\cdot34441 \times 10^{-27}$ kg
mass of ${}^{4}_{2}\text{He} = 6\cdot64632 \times 10^{-27}$ kg
mass of ${}^{1}_{0}\text{n} = 1\cdot67490 \times 10^{-27}$ 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)

[*END OF QUESTION PAPER*]