X069/301

NATIONAL QUALIFICATIONS 2004

FRIDAY, 28 MAY
1.00 PM – 3.30 PM

PHYSICS
HIGHER

Read Carefully

1 All questions should be attempted.

Section A (questions 1 to 20)

2 Check that the answer sheet is for Physics Higher (Section A).

3 Answer the questions numbered 1 to 20 on the answer sheet provided.

4 Fill in the details required on the answer sheet.

5 Rough working, if required, should be done only on this question paper, or on the first two pages of the answer book provided—**not** on the answer sheet.

6 For each of the questions 1 to 20 there is only **one** correct answer and each is worth 1 mark.

7 Instructions as to how to record your answers to questions 1–20 are given on page three.

Section B (questions 21 to 30)

8 Answer questions numbered 21 to 30 in the answer book provided.

9 Fill in the details on the front of the answer book.

10 Enter the question number clearly in the margin of the answer book beside each of your answers to questions 21 to 30.

11 Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

SAB X069/301 6/16520

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
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	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
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	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.

SECTION A

For questions 1 to 20 in this section of the paper, an answer is recorded on the answer sheet by indicating the choice A, B, C, D or E by a stroke made in ink in the appropriate box of the answer sheet—see the example below.

EXAMPLE

The energy unit measured by the electricity meter in your home is the

A ampere

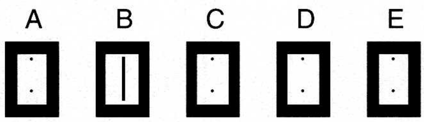
B kilowatt-hour

C watt

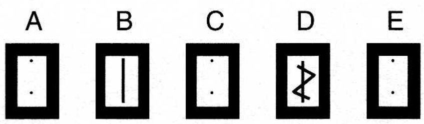
D coulomb

E volt.

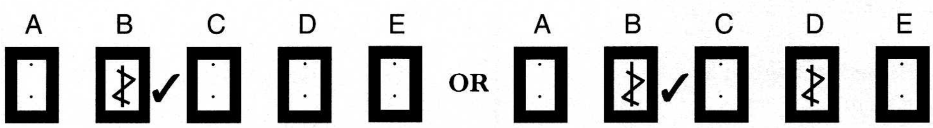
The correct answer to the question is B—kilowatt-hour. Record your answer by drawing a heavy vertical line joining the two dots in the appropriate box on your answer sheet in the column of boxes headed B. The entry on your answer sheet would now look like this:



If after you have recorded your answer you decide that you have made an error and wish to make a change, you should cancel the original answer and put a vertical stroke in the box you now consider to be correct. Thus, if you want to change an answer D to an answer B, your answer sheet would look like this:



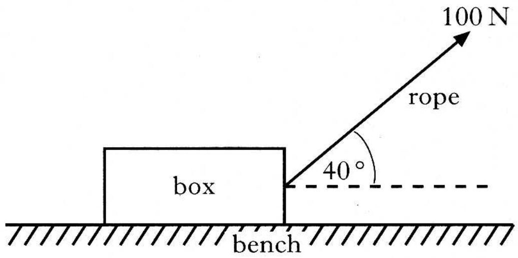
If you want to change back to an answer which has already been scored out, you should enter a tick (✓) to the RIGHT of the box of your choice, thus:



SECTION A

Answer questions 1–20 on the answer sheet.

1. A box is pulled along a level bench by a rope held at a constant angle of 40° to the horizontal as shown.



A constant force of 100 N is applied to the rope.

The box moves a distance of 10 m along the bench.

The work done on the box by the rope is

A 100 J

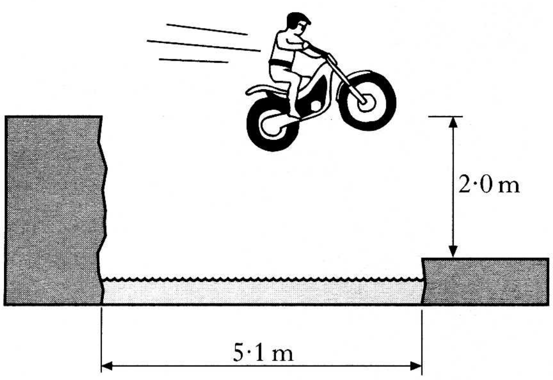
B 643 J

C 766 J

D 839 J

E 1000 J.

2. A stuntman on a motorcycle jumps a river which is 5·1 m wide. He lands on the edge of the far bank, which is 2·0 m lower than the bank from which he takes off.



His minimum horizontal speed at take off is

A $2{\cdot}0\ \text{m s}^{-1}$

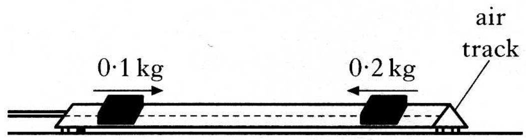
B $3{\cdot}2\ \text{m s}^{-1}$

C $5{\cdot}5\ \text{m s}^{-1}$

D $8{\cdot}0\ \text{m s}^{-1}$

E $9{\cdot}8\ \text{m s}^{-1}$.

3. A vehicle of mass 0·1 kg is moving to the right along a horizontal friction-free air track. A vehicle of mass 0·2 kg is moving to the left on the same track.



The vehicles collide and stick together.

Which of the following quantities is/are conserved in this collision?

I The total momentum

II The kinetic energy

III The total energy

A I only

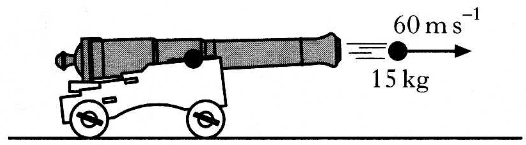
B II only

C I and II only

D I and III only

E II and III only

4. A cannon of mass 1200 kg fires a cannonball of mass 15 kg at a velocity of $60\ \text{m s}^{-1}$ East.



Assuming the force of friction is negligible, the velocity of the cannon just after firing is

A $0\ \text{m s}^{-1}$

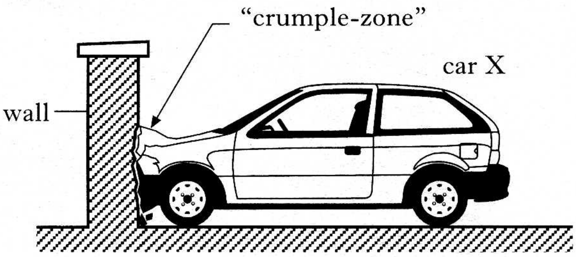
B $0{\cdot}75\ \text{m s}^{-1}$ East

C $0{\cdot}75\ \text{m s}^{-1}$ West

D $6{\cdot}0\ \text{m s}^{-1}$ East

E $6{\cdot}0\ \text{m s}^{-1}$ West.

5. Car X is designed with a "crumple-zone" so that the front of the car collapses during impact as shown.



A similar car, Y, of equal mass is built without a crumple-zone. In a safety test both cars are driven at the same speed into identical walls.

Which of the following statements is/are true during the collisions?

I The average force on car X is smaller than that on car Y.

II The time taken for car X to come to rest is greater than that for car Y.

III The change in momentum of car X is smaller than that of car Y.

A I only

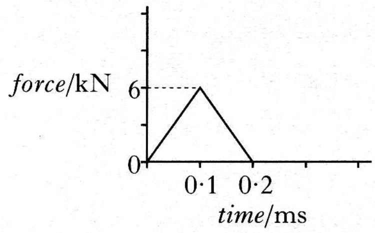
B I and II only

C I and III only

D II and III only

E I, II and III

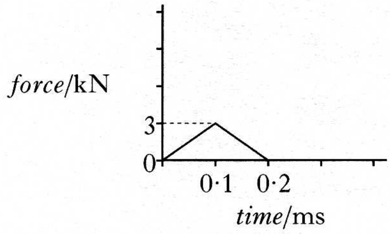
6. A golf ball, initially at rest, is hit by a club. The graph of the force of the club on the ball against time is shown.



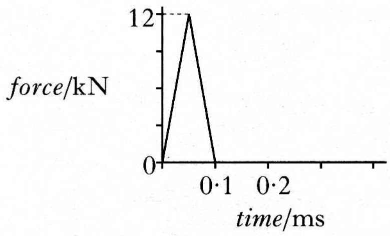
A different type of golf ball of the same size and mass is now hit with the same club. This ball moves off with the same velocity as the first ball.

Which graph shows the force of the club on the second ball against time?

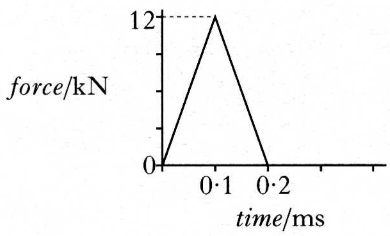
A



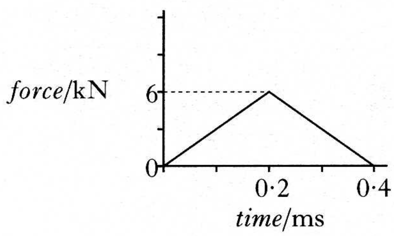
B



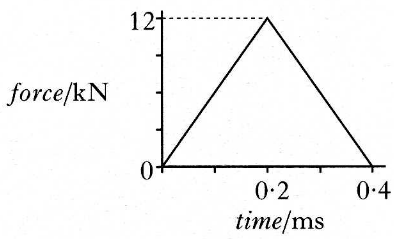
C



D



E



7. The density of steam at 100 °C is less than the density of water at 100 °C. The explanation for this is that when water changes to steam its particles

A move further apart

B move with greater speed

C have smaller mass

D are no longer joined together

E collide more often with each other.

8. In an experiment the following measurements and uncertainties are recorded.

Temperature rise	=	10 °C ± 1 °C
Heater current	=	5·0 A ± 0·2 A
Heater voltage	=	12·0 V ± 0·5 V
Time	=	100 s ± 2 s
Mass of liquid	=	1·000 kg ± 0·005 kg

The measurement which has the largest percentage uncertainty is the

A temperature rise

B heater current

C heater voltage

D time

E mass of liquid.

9. A balloon of volume of 6·0 m^3 contains a fixed mass of gas at a temperature of 300 K and a pressure of 2·0 kPa. The gas is heated to 600 K and the pressure reduced to 1·0 kPa. The new volume of the gas is

A 1·5 m^3

B 3·0 m^3

C 6·0 m^3

D 12·0 m^3

E 24·0 m^3.

10. A student writes the following statements about electric fields.

I There is a force on a charge in an electric field.

II When an electric field is applied to a conductor, the free electric charges in the conductor move.

III Work is done when a charge is moved in an electric field.

Which of the above statements is/are correct?

A I only

B II only

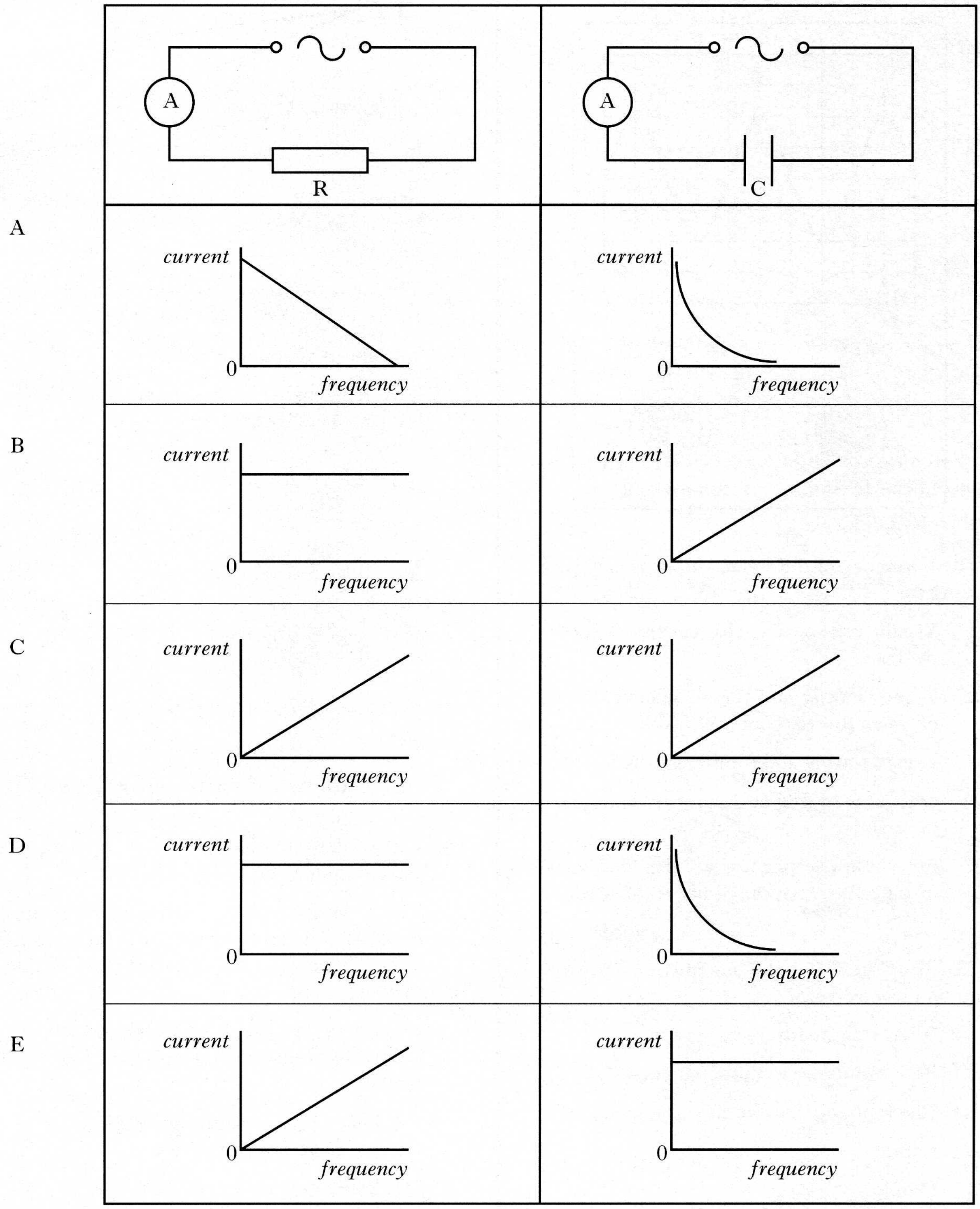
C I and II only

D I and III only

E I, II and III

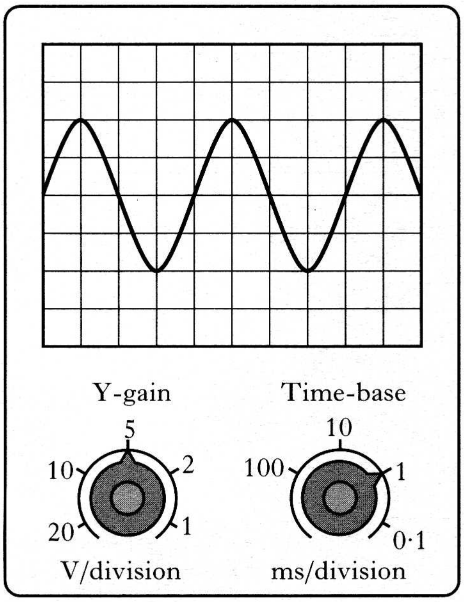
11. A resistor and a capacitor are connected to identical a.c. supplies which provide constant voltage throughout their whole frequency range.

Which of the following pairs of graphs illustrates how the current varies with frequency in the two circuits shown?



[Turn over

12. The output from a signal generator is connected to the input terminals of an oscilloscope. The trace observed on the oscilloscope screen, the Y-gain setting and the time-base setting are shown in the diagram.



The frequency of the signal shown is calculated using the

A Y-gain setting and the vertical height of the trace

B Y-gain setting and the horizontal distance between the peaks of the trace

C Y-gain setting and time-base setting

D time-base setting and the vertical height of the trace

E time-base setting and the horizontal distance between the peaks of the trace.

13. Which of the following statements is/are true for an ideal op-amp?

I It has infinite input resistance.

II Both inputs are at the same potential.

III The input current to the op-amp is zero.

A I only

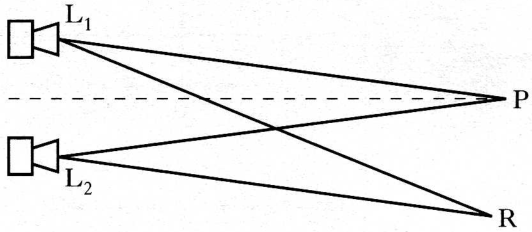
B II only

C I and II only

D II and III only

E I, II and III

14. Two identical loudspeakers, L_1 and L_2, are operated at the same frequency and in phase with each other. An interference pattern is produced.



At position P, which is the same distance from both loudspeakers, there is a maximum intensity.

The next maximum intensity is at position R, where $L_1R = 5{\cdot}6$ m and $L_2R = 5{\cdot}3$ m.

The speed of sound is $340\,\text{m}\,\text{s}^{-1}$.

The frequency of the sound emitted by the loudspeakers is given by

A $\frac{5{\cdot}6 - 5{\cdot}3}{340}$ Hz

B $\frac{340}{5{\cdot}6 + 5{\cdot}3}$ Hz

C $\frac{340}{5{\cdot}6 - 5{\cdot}3}$ Hz

D $340 \times (5{\cdot}6 - 5{\cdot}3)$ Hz

E $340 \times (5{\cdot}6 + 5{\cdot}3)$ Hz.

15. Ultraviolet radiation is incident on a clean zinc plate. Photoelectrons are ejected.

The clean zinc plate is replaced by a different metal which has a lower work function. The same intensity of ultraviolet radiation is incident on this metal.

Compared to the zinc plate, which of the following statements is/are true for the new metal?

I The maximum speed of the photoelectrons is greater.

II The maximum kinetic energy of the photoelectrons is greater.

III There are more photoelectrons ejected per second.

A I only

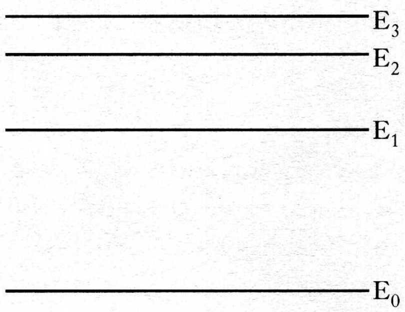
B II only

C III only

D I and II only

E I, II and III

16. An atom has the energy levels shown.



Electron transitions occur between all of these levels to produce emission lines in the spectrum of this atom.

How many emission lines are produced by transitions between these energy levels?

A 3

B 4

C 5

D 6

E 7

17. Materials are "doped" to produce n-type semiconductor material.

In n-type semiconductor material

A the majority charge carriers are electrons

B the majority charge carriers are neutrons

C the majority charge carriers are protons

D there are more protons than neutrons

E there are more electrons than neutrons.

18. A student writes the following statements about the decay of radionuclides.

I During alpha emission a particle consisting of 2 protons and 4 neutrons is emitted from a nucleus.

II During beta emission a fast moving electron is emitted from a nucleus.

III During gamma emission a high energy photon is emitted from a nucleus.

Which of these statements is/are true?

A II only

B I and II only

C I and III only

D II and III only

E I, II and III

19. A radiation technician works 150 hours each month in an area exposed to radiation from a neutron beam. The quality factor for this radiation is 3. The technician receives an absorbed dose rate of $10\,\mu Gy\,h^{-1}$ from this radiation.

In a period of 5 months the total dose equivalent received by the technician is

A $2{\cdot}50 \times 10^{-2}$ Sv

B $2{\cdot}25 \times 10^{-2}$ Sv

C $1{\cdot}50 \times 10^{-2}$ Sv

D $1{\cdot}00 \times 10^{-2}$ Sv

E $0{\cdot}75 \times 10^{-2}$ Sv.

20. A Geiger counter records a corrected count-rate of 1000 counts per second when it is placed a distance of 400 mm from a radioactive source.

A sheet of metal is placed between the source and the counter. The half value thickness of the metal for radiation from the source is 20 mm.

The corrected count-rate is now 125 counts per second.

The thickness of the metal sheet is

A 25 mm

B 40 mm

C 60 mm

D 80 mm

E 160 mm.

[Turn over

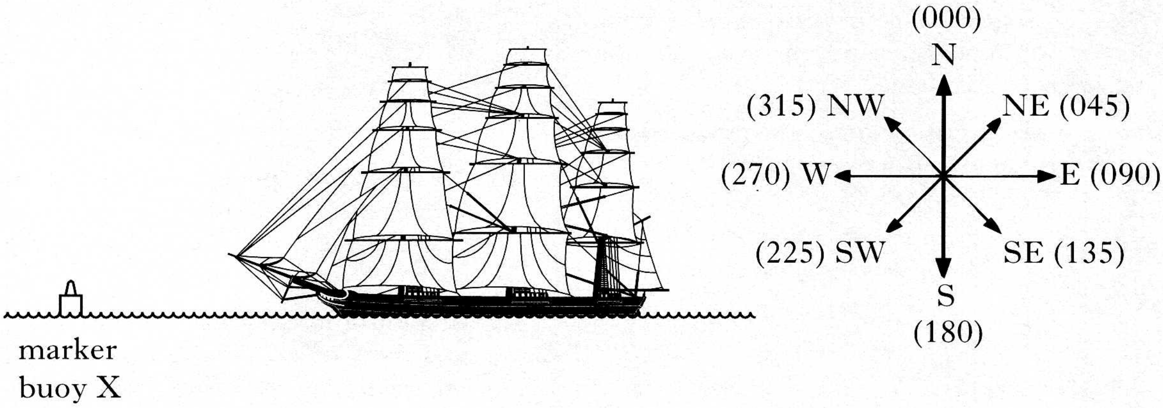
SECTION B

Write your answers to questions 21 to 30 in the answer book.

Marks

21. (*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 $10{\cdot}0\,\text{km}\,\text{h}^{-1}$, then changes course to 20° West of North (340). The Mir continues on this new course for 1½ hours at a speed of $8{\cdot}0\,\text{km}\,\text{h}^{-1}$ until it passes marker buoy Y.



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

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

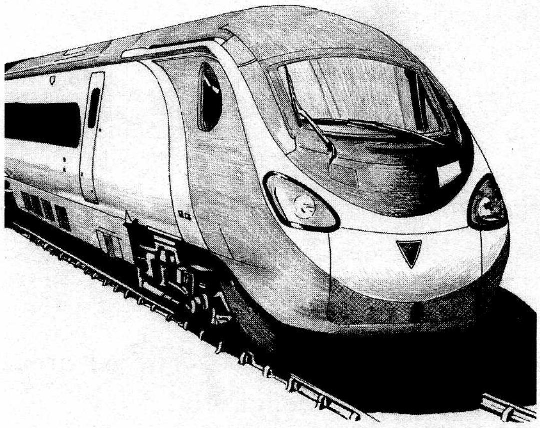
(iii) Calculate the average velocity, in $\text{km}\,\text{h}^{-1}$, of the Mir between marker buoys X and Y. **6**

(*c*) A second ship, the Leeuvin, passes marker buoy X 15 minutes after the Mir and sails directly for marker buoy Y at a speed of $7{\cdot}5\,\text{km}\,\text{h}^{-1}$.

Show by calculation which ship first passes marker buoy Y. **2**

(9)

22. A train of mass $7{\cdot}5 \times 10^5$ kg is travelling at $60\,\text{m}\,\text{s}^{-1}$ along a straight horizontal track.

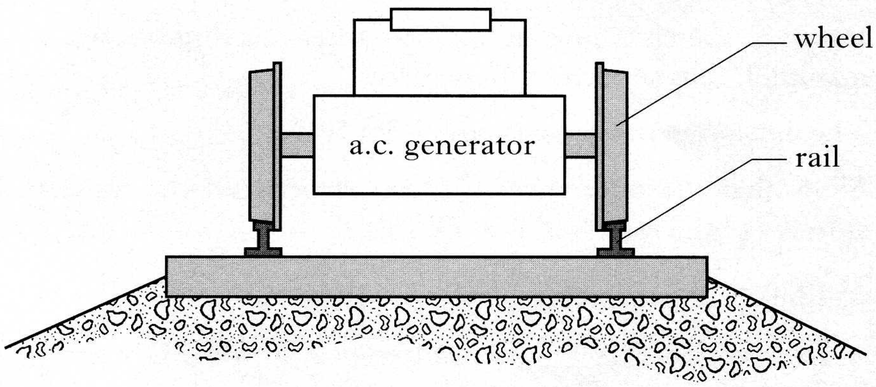


The brakes are applied and the train decelerates uniformly to rest in a time of 40 s.

(*a*) (i) Calculate the distance the train travels between the brakes being applied and the train coming to rest.

(ii) Calculate the force required to bring the train to rest in this time. **4**

(*b*) Part of the train's braking system consists of an electrical circuit as shown in the diagram.



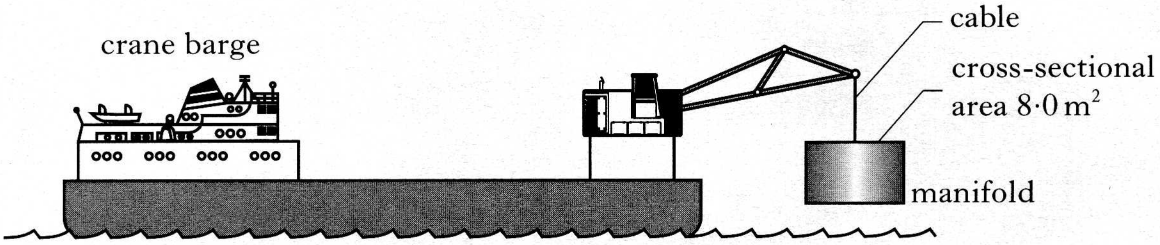
While the train is braking, the wheels drive an a.c. generator which changes kinetic energy into electrical energy. This electrical energy is changed into heat in a resistor. The r.m.s. current in the resistor is $2{\cdot}5 \times 10^3$ A and the resistor produces 8·5 MJ of heat each second.

Calculate the peak voltage across the resistor. **3**

(7)

[Turn over

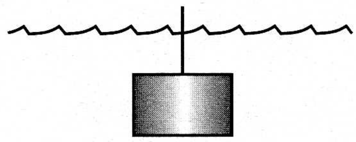
23. A crane barge is used to place part of an oil well, called a manifold, on the seabed.



The manifold is a cylinder of uniform cross-sectional area $8{\cdot}0\,m^2$ and mass $5{\cdot}0 \times 10^4$ kg. The mass of the cable may be ignored.

(*a*) Calculate the tension in the cable when the manifold is held stationary above the surface of the water. **1**

(*b*) The manifold is lowered into the water and then held stationary just below the surface as shown.



(i) Draw a sketch showing all the forces acting vertically on the manifold. Name each of these forces.

(ii) The tension in the cable is now $2{\cdot}5 \times 10^5$ N.

Show that the difference in pressure between the top and bottom surfaces of the manifold is $3{\cdot}0 \times 10^4$ Pa. **4**

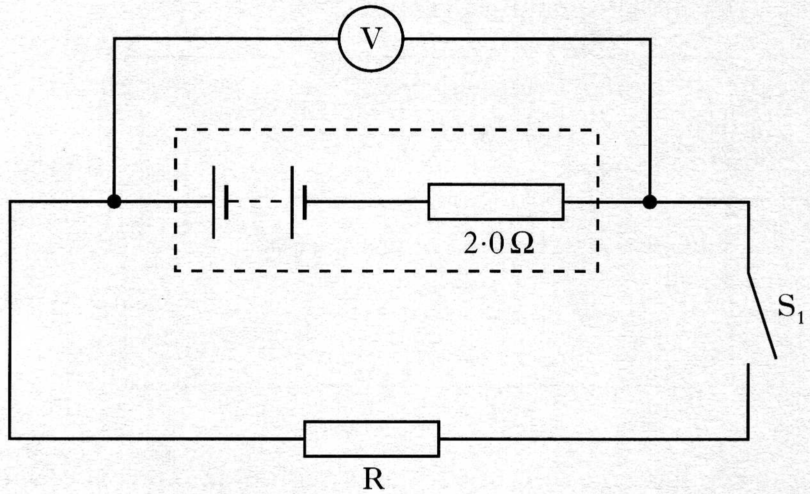
(*c*) The manifold is now lowered to a greater depth.

What effect does this have on the difference in pressure between the top and bottom surfaces of the manifold?

You must justify your answer. **2**

(7)

24. A student sets up the circuit shown.



The internal resistance of the battery is 2·0 Ω.

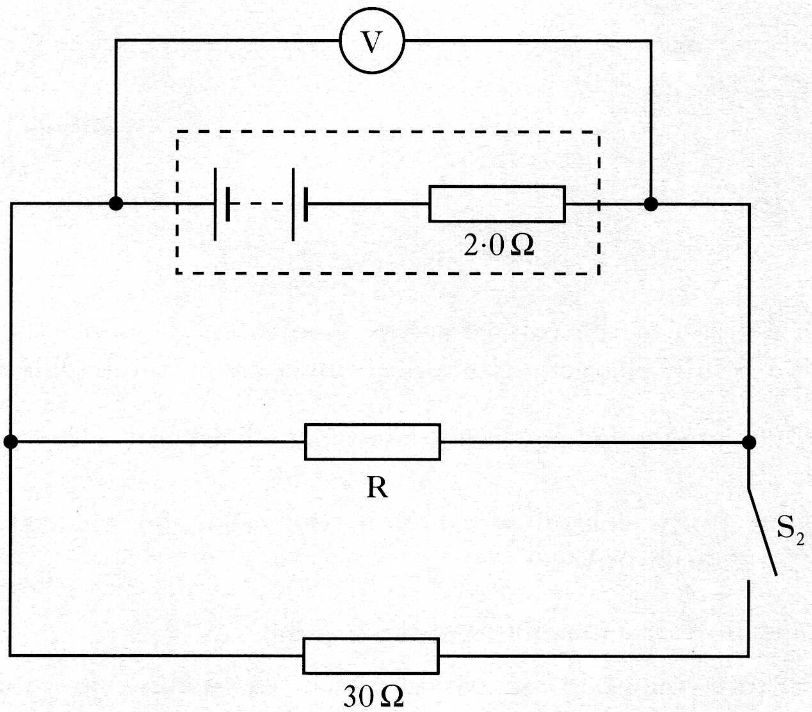
With S_1 open, the student notes that the reading on the voltmeter is 9·0 V.

The student closes S_1 and notes that the reading on the voltmeter is now 7·8 V.

(*a*) (i) Calculate the resistance of resistor R.

(ii) Explain why the reading on the voltmeter decreases when S_1 is closed. **4**

(*b*) The student adds a 30 Ω resistor and a switch S_2 to the circuit as shown.



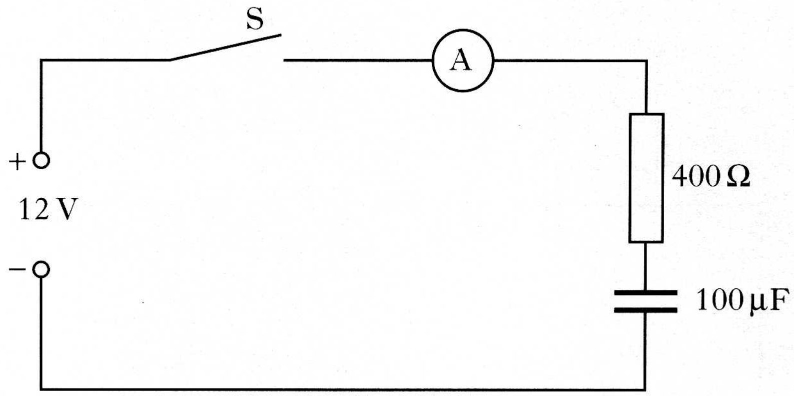
The student now closes S_2.

Explain what happens to the reading on the voltmeter. **2**

(6)

Marks

25. 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.

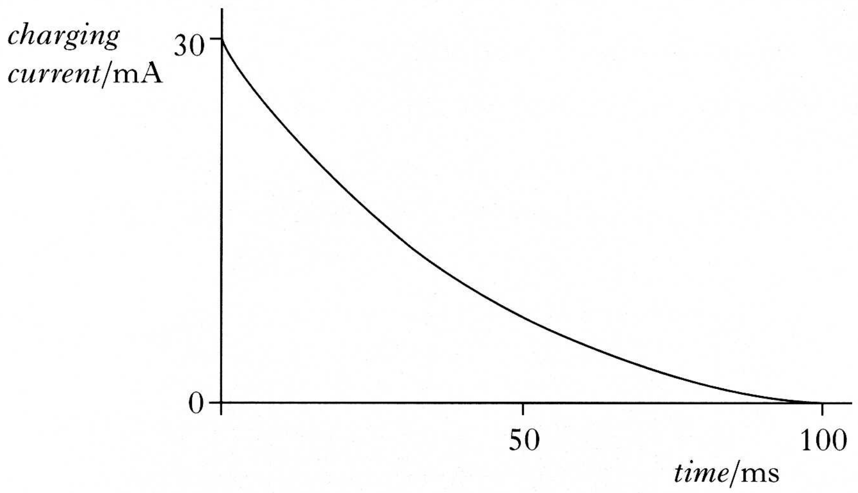


figure 1

(*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.

(ii) How much energy is stored in the capacitor when the charging current is 20 mA? **4**

(*c*) The capacitor has a maximum working voltage of 12 V.

Suggest **one** change to this circuit which would allow an initial charging current of greater than 30 mA. **1**

25. (continued)

(*d*) The $100\,\mu F$ capacitor is now replaced by an uncharged capacitor of unknown capacitance and the experiment is repeated. The graph of charging current against time for this capacitor is shown in figure 2.

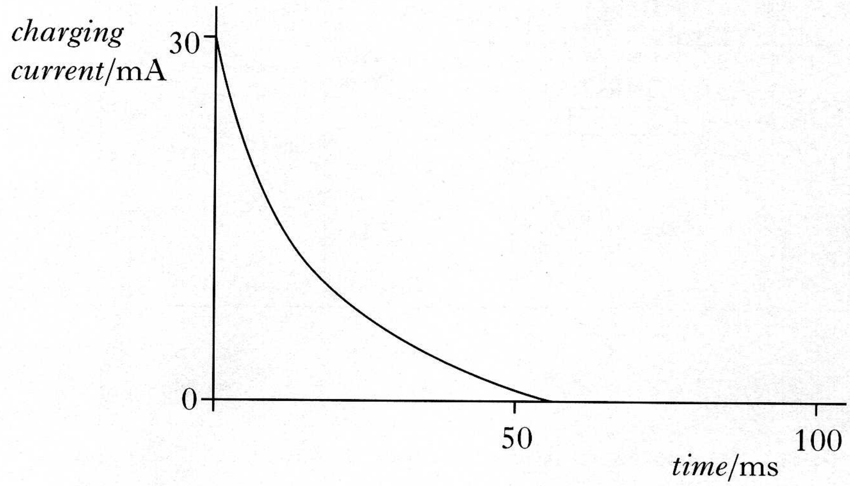


figure 2

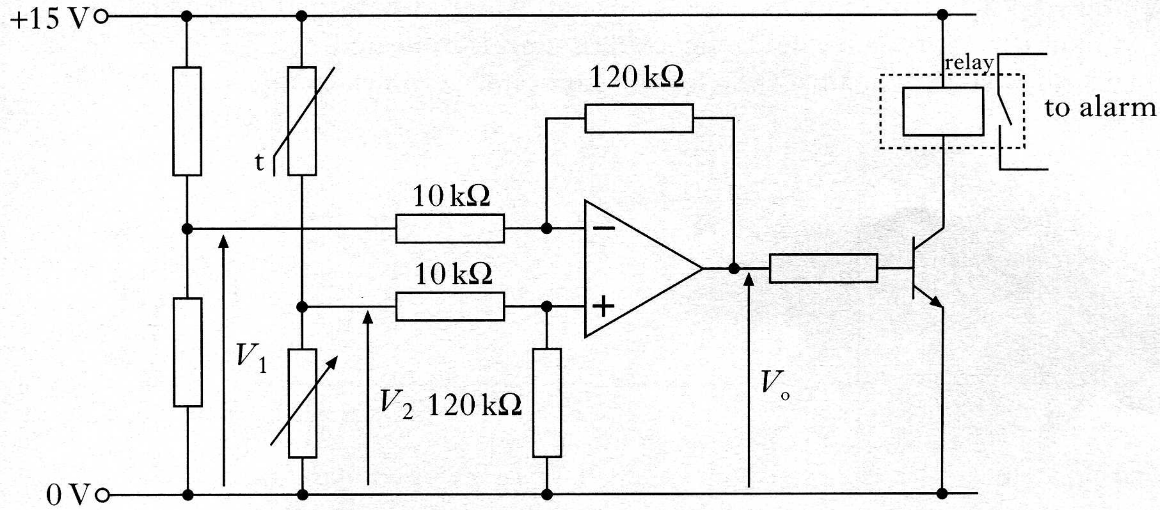
By comparing figure 2 with figure 1, determine whether the capacitance of this capacitor is greater than, equal to or less than $100\,\mu F$.

You must justify your answer. **2**

(9)

[Turn over

26. The circuit shown is designed for an alarm system.



Voltage V_1 is 7·50 V.

When the temperature increases, the resistance of the thermistor decreases.

(*a*) At a temperature of 35 °C, voltage V_2 is 7·52 V.

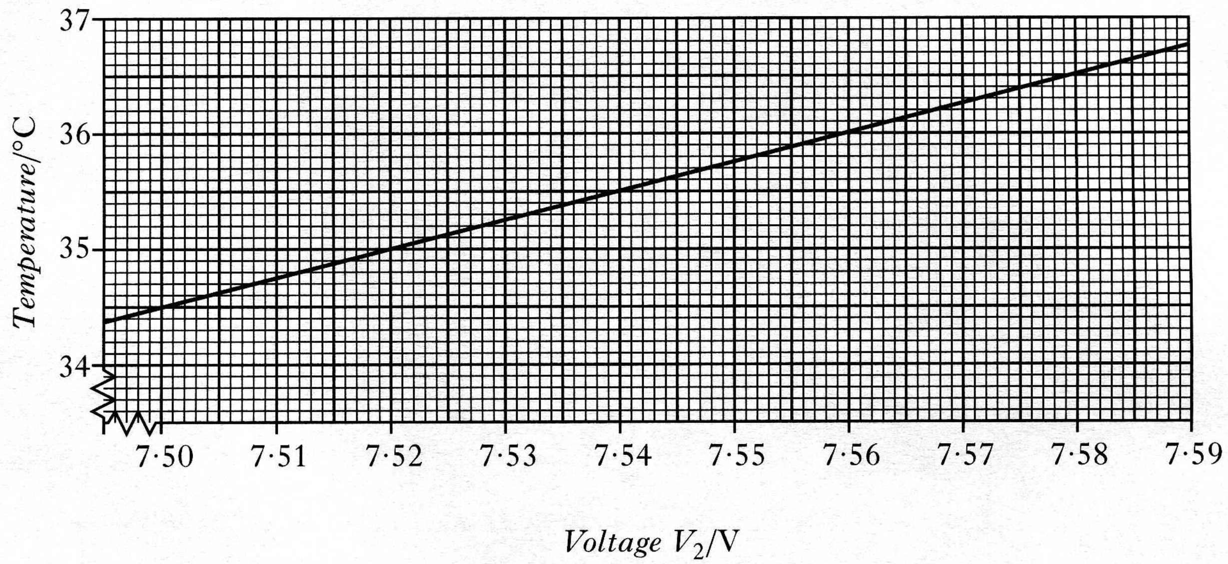
Calculate the output voltage V_o at this temperature. **2**

(*b*) When the temperature rises, V_o increases and the alarm switches on.

Explain how the circuit operates to switch on the alarm. **2**

(*c*) The alarm is on when V_o is greater than or equal to 0·72 V.

The graph of the temperature against voltage V_2 is shown.

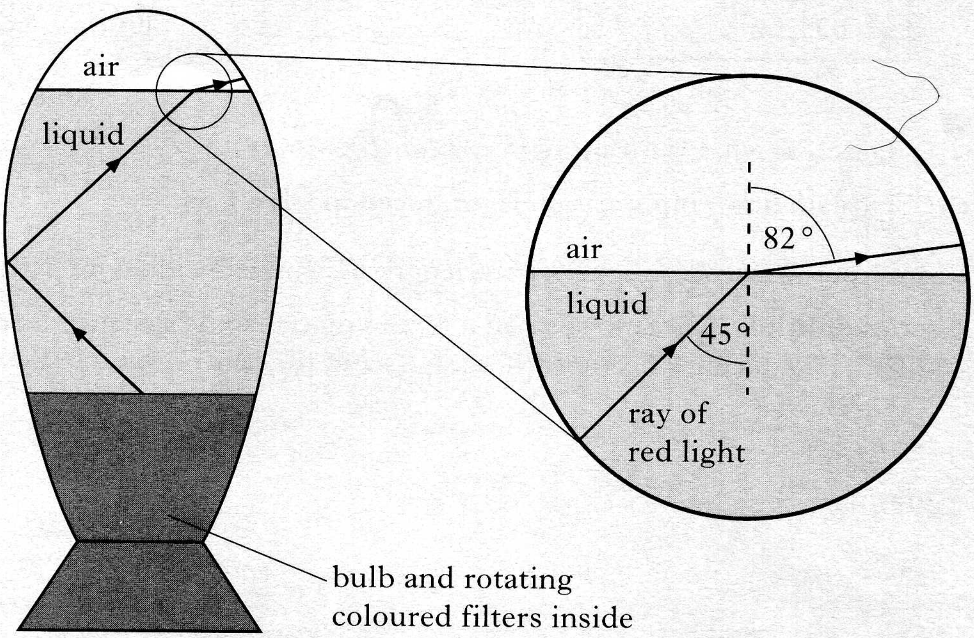


Using information from the graph, determine the minimum temperature at which the alarm switches on. **2**

(6)

27. 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.

(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 explain your answer. **3**

(*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 values of all appropriate angles.

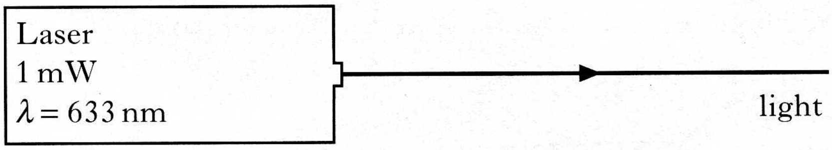
All relevant calculations must be shown. **3**

(6)

[Turn over

Marks

28. The term LASER is short for "Light Amplification by the Stimulated Emission of Radiation".

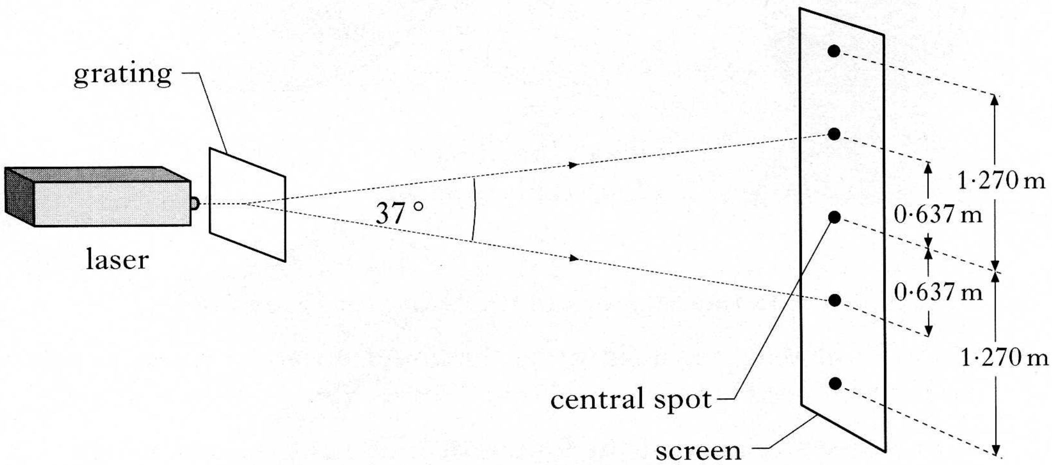


(*a*) (i) Describe what is meant by *Stimulated Emission.*

(ii) Explain how amplification is produced in a laser. **3**

(*b*) In an experiment, laser light of wavelength 633 nm is incident on a grating.

A series of bright spots are seen on a screen placed some distance from the grating. The distance between these spots and the central spot is shown.



Calculate the number of lines per metre on the grating. **3**

(*c*) The laser is replaced with another laser and the experiment repeated. With this laser the bright spots are closer together.

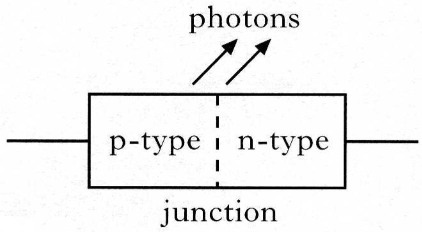
How does the wavelength of the light from this laser compare with that from the original laser?

You must justify your answer. **2**

(8)

Marks

29. 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.

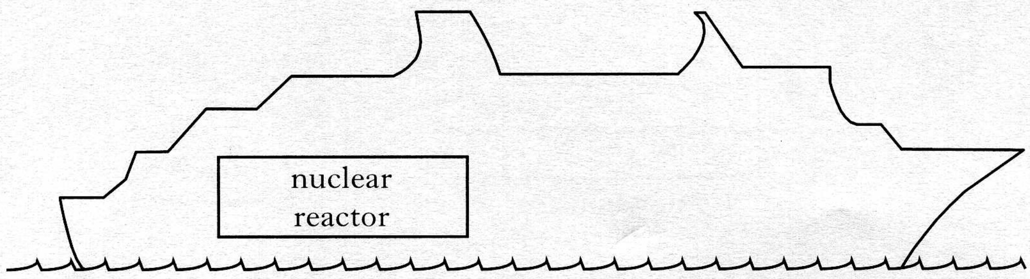
(ii) Calculate the minimum potential difference across the p-n junction when it emits photons. **4**

(6)

[Turn over for Question 30 on *Page twenty*

Marks

30. A ship is powered by a nuclear reactor.



One reaction that takes place in the core of the nuclear reactor is represented by the statement below.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{58}Ce + ^{94}_{40}Zr + 2^{1}_{0}n + 6^{0}_{-1}e$$

(*a*) The symbol for the Uranium nucleus is $^{235}_{92}U$.

What information about the nucleus is provided by the following numbers?

(i) 92

(ii) 235 **2**

(*b*) Describe how neutrons produced during the reaction can cause further nuclear reactions. **1**

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

Particles	*Mass*/kg
$^{235}_{92}U$	$390{\cdot}173 \times 10^{-27}$
$^{140}_{58}Ce$	$232{\cdot}242 \times 10^{-27}$
$^{94}_{40}Zr$	$155{\cdot}884 \times 10^{-27}$
$^{1}_{0}n$	$1{\cdot}675 \times 10^{-27}$
$^{0}_{-1}e$	negligible

Calculate the energy released in the reaction. **3**

(6)

[*END OF QUESTION PAPER*]