X069/301

NATIONAL
QUALIFICATIONS
2007

WEDNESDAY, 16 MAY
1.00 PM – 3.30 PM

PHYSICS
HIGHER

Read Carefully

Reference may be made to the Physics Data Booklet.

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 For this section of the examination you must use an **HB pencil** and, where necessary, an eraser.

4 Check that the answer sheet you have been given has **your name**, **date of birth**, **SCN** (Scottish Candidate Number) and **Centre Name** printed on it.

Do not change any of these details.

5 If any of this information is wrong, tell the Invigilator immediately.

6 If this information is correct, **print** your name and seat number in the boxes provided.

7 There is **only one correct** answer to each question.

8 Any rough working should be done on the question paper or the rough working sheet, **not** on your answer sheet.

9 At the end of the exam, put the **answer sheet for Section A inside the front cover of your answer book**.

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

Section B (questions 21 to 31)

11 Answer the questions numbered 21 to 31 in the answer book provided.

12 **All answers must be written clearly and legibly in ink**.

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

14 Enter the question number clearly in the margin of the answer book beside each of your answers to questions 21 to 31.

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

16 Where additional paper, eg square ruled paper, is used, write your name and SCN (Scottish Candidate Number) on it and place it inside the front cover of your answer booklet.

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	656 486 434 410 397 389	Red Blue-green Blue-violet Violet Ultraviolet Ultraviolet
Sodium	589	Yellow
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
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 the answer to each question is either A, B, C, D or E. Decide what your answer is, then, using your pencil, put a horizontal line in the space provided—see the example below.

EXAMPLE

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

A kilowatt-hour

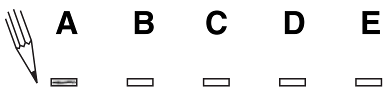
B ampere

C watt

D coulomb

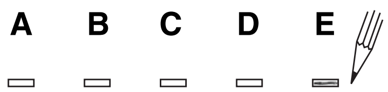
E volt.

The correct answer is **A**—kilowatt-hour. The answer **A** has been clearly marked in **pencil** with a horizontal line (see below).



Changing an answer

If you decide to change your answer, carefully erase your first answer and, using your pencil, fill in the answer you want. The answer below has been changed to **E**.



[Turn over

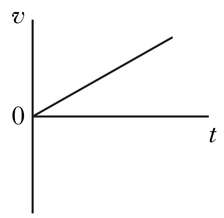
SECTION A

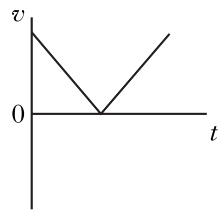
Answer questions 1–20 on the answer sheet.

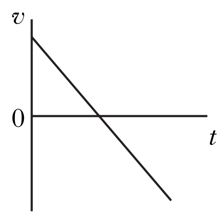
1. Which row shows both quantities classified correctly?

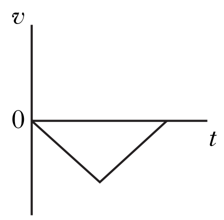
	Scalar	*Vector*
A	weight	force
B	force	mass
C	mass	distance
D	distance	momentum
E	momentum	time

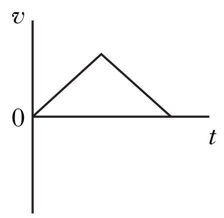
2. A ball is thrown vertically upwards and falls back to Earth. Neglecting air resistance, which velocity-time graph represents its motion?

A


B


C


D


E


3. A person stands on a weighing machine in a lift. When the lift is at rest, the reading on the machine is 700 N. The lift now descends and its speed increases at a constant rate. The reading on the machine

A is a constant value higher than 700 N

B is a constant value lower than 700 N

C continually increases from 700 N

D continually decreases from 700 N

E remains constant at 700 N.

4. Momentum can be measured in

A N kg^{-1}

B N m

C N m s^{-1}

D kg m s^{-1}

E kg m s^{-2}.

5. A cannon of mass 2000 kg fires a cannonball of mass 5·00 kg.

The cannonball leaves the cannon with a speed of $50{\cdot}0\ \text{m s}^{-1}$.

The speed of the cannon immediately after firing is

A $0{\cdot}125\ \text{m s}^{-1}$

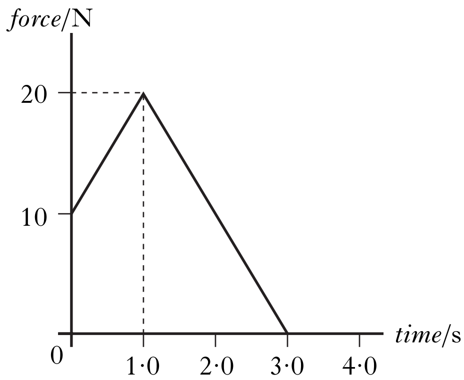
B $8{\cdot}00\ \text{m s}^{-1}$

C $39{\cdot}9\ \text{m s}^{-1}$

D $40{\cdot}1\ \text{m s}^{-1}$

E $200\ \text{m s}^{-1}$.

6. The graph shows the force acting on an object of mass 5·0 kg.



The change in the object's momentum is

A $7{\cdot}0\,\text{kg m s}^{-1}$

B $30\,\text{kg m s}^{-1}$

C $35\,\text{kg m s}^{-1}$

D $60\,\text{kg m s}^{-1}$

E $175\,\text{kg m s}^{-1}$.

7. Which of the following gives the approximate relative spacings of molecules in ice, water and water vapour?

	Spacing of molecules in ice	*Spacing of molecules in water*	*Spacing of molecules in water vapour*
A	1	1	10
B	1	3	1
C	1	3	3
D	1	10	10
E	3	1	10

8. The element of an electric kettle has a resistance of 30 Ω. The kettle is connected to a mains supply. The r.m.s. voltage of this supply is 230 V. The peak value of the current in the kettle is

A 0·13 A

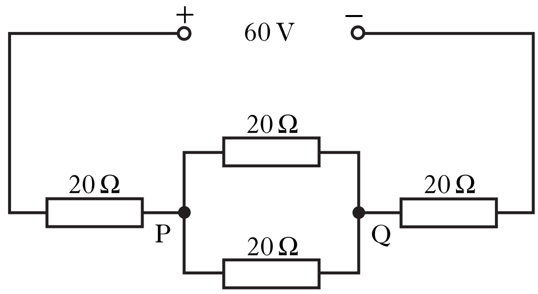
B 0·18 A

C 5·4 A

D 7·7 A

E 10·8 A .

9. Four resistors, each of resistance 20 Ω, are connected to a 60 V supply of negligible internal resistance, as shown.



The potential difference across PQ is

A 12 V

B 15 V

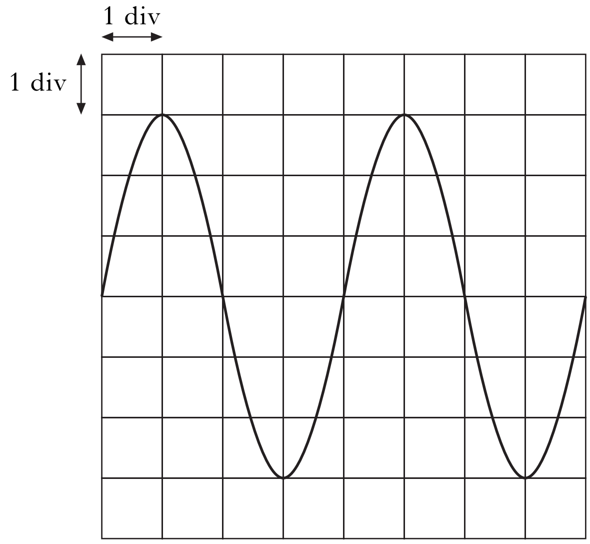
C 20 V

D 24 V

E 30 V.

10. A signal from a power supply is displayed on an oscilloscope.

The trace on the oscilloscope is shown.

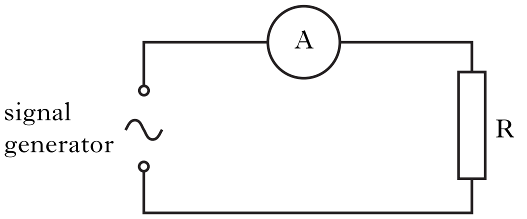


The time-base is set at 0·01 s/div and the Y-gain is set at 4·0 V/div.

Which row in the table shows the r.m.s. voltage and the frequency of the signal?

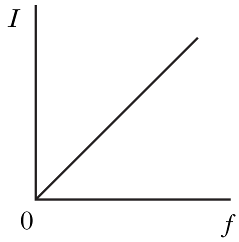
	r.m.s. voltage/V	*frequency*/Hz
A	8·5	25
B	12	25
C	24	25
D	8·5	50
E	12	50

11. A resistor and an ammeter are connected to a signal generator which has an output of constant amplitude and variable frequency.

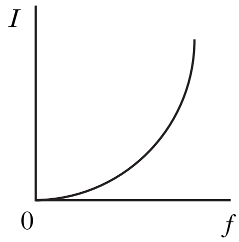


Which graph shows the relationship between the current I in the resistor and the output frequency f of the signal generator?

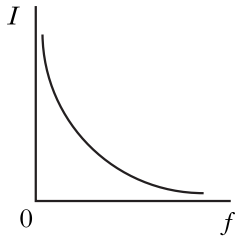
A



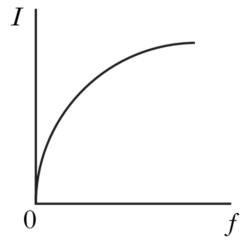
B



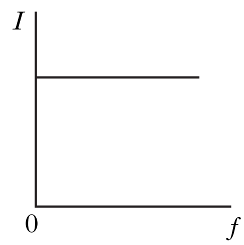
C



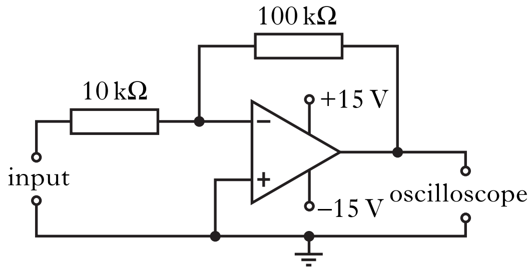
D



E



12. An oscilloscope is used to measure the frequency of the output voltage from an op-amp.



The input has a frequency of 280 Hz and a peak voltage of 0·5 V.

The frequency of the output voltage is

A 28 Hz

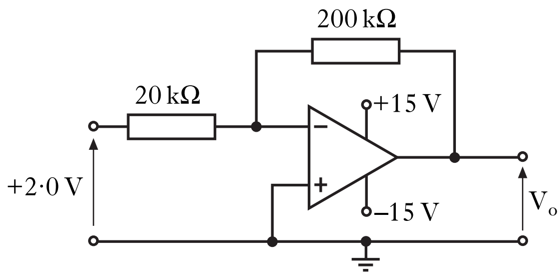
B 140 Hz

C 280 Hz

D 560 Hz

E 2800 Hz.

13. An op-amp circuit is set up as shown.



A voltage of +2·0 V is applied to the input. The voltage output, V_o, is approximately

A +20 V

B +15 V

C −2·0 V

D −15 V

E −20 V.

14. The energy of a wave depends on its

A amplitude

B period

C phase

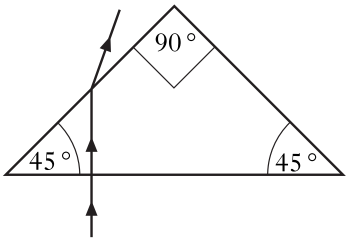
D speed

E wavelength.

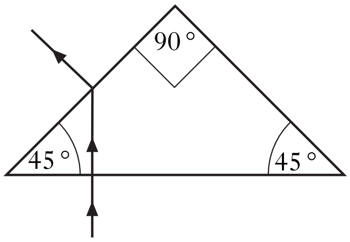
15. A ray of light travels from air into a glass prism. The refractive index of the glass is 1·50.

Which diagram shows the correct path of the ray?

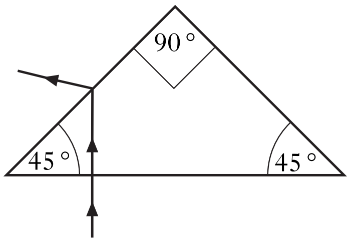
A



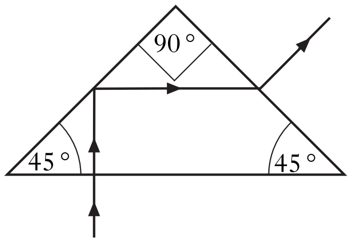
B



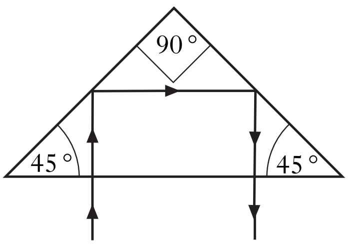
C



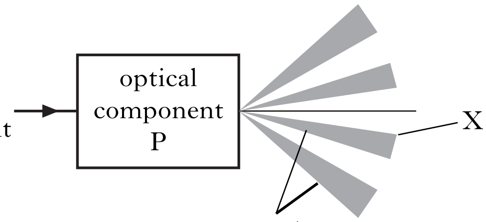
D

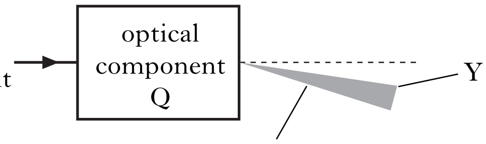


E



16. A beam of white light is passed through two optical components P and Q. Component P produces a number of spectra and component Q produces a spectrum as shown.



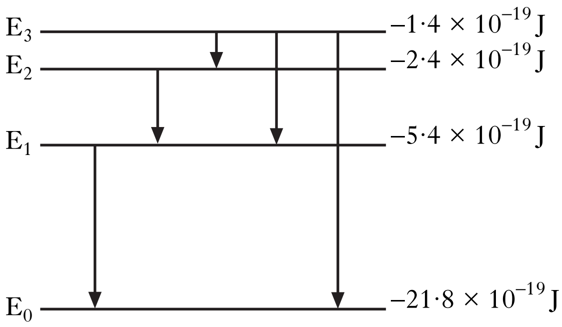


Which row in the table identifies the optical components and the colour of light seen at position X and position Y?

	Optical component P	*Colour seen at X*	*Optical component Q*	*Colour seen at Y*
A	grating	red	triangular prism	red
B	grating	red	triangular prism	violet
C	grating	violet	triangular prism	red
D	triangular prism	red	grating	violet
E	triangular prism	violet	grating	red

[Turn over

17. The diagram represents some electron transitions between energy levels in an atom.



The radiation emitted with the shortest wavelength is produced by an electron making transition

A E_1 to E_0

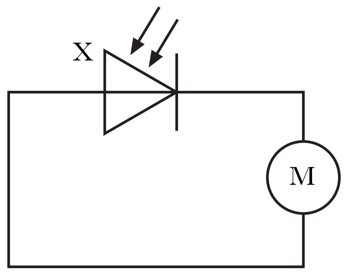
B E_2 to E_1

C E_3 to E_2

D E_3 to E_1

E E_3 to E_0.

18. In the following circuit, component X is used to drive a motor.



Which of the following gives the name of component X and its mode of operation?

	Name of component X	*Mode of operation*
A	light-emitting diode	photoconductive
B	light-emitting diode	photovoltaic
C	photodiode	photoconductive
D	photodiode	photovoltaic
E	op-amp	inverting

19. The classical experiment on the scattering of alpha particles from a thin gold foil suggested that

A positive charges were evenly distributed throughout the atom

B atomic nuclei were very small and positively charged

C neutrons existed in the nucleus

D alpha particles were helium nuclei

E alpha particles were hydrogen nuclei.

20. A radioactive source produces a count rate of 2400 counts per second in a detector. When a lead plate of thickness 36 mm is placed between the source and the detector the count rate falls to 300 counts per second.

The half-value thickness of lead for this radiation is

A 4·5 mm

B 12 mm

C 36 mm

D 108 mm

E 288 mm.

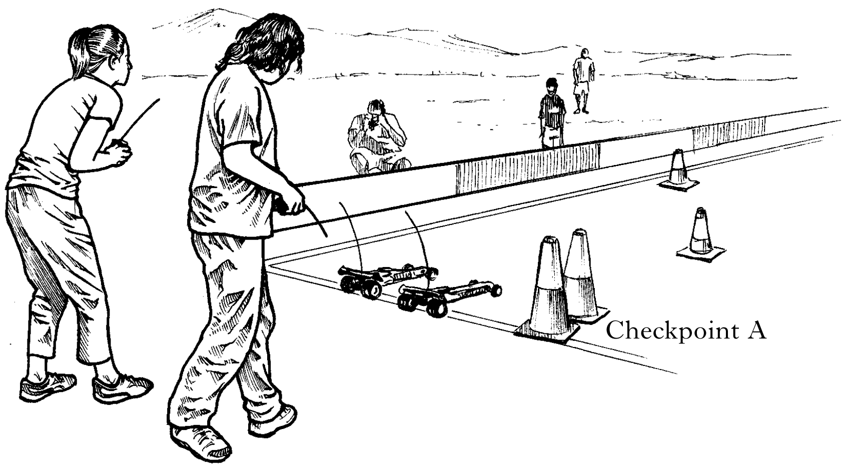
[Turn over for SECTION B on *Page ten*

SECTION B

Write your answers to questions 21 to 31 in the answer book.

Marks

21. Competitors are racing remote control cars. The cars have to be driven over a precise route between checkpoints.



Each car is to travel from checkpoint A to checkpoint B by following these instructions.

"Drive 150 m due North, then drive 250 m on a bearing of 60° East of North (060)."

Car X takes 1 minute 6 seconds to follow these instructions exactly.

(*a*) By scale drawing or otherwise, find the displacement of checkpoint B from checkpoint A. **2**

(*b*) Calculate the average velocity of car X from checkpoint A to checkpoint B. **2**

(*c*) Car Y leaves A at the same time as car X.

Car Y follows exactly the same route at an average speed of $6{\cdot}5\,\mathrm{m\,s^{-1}}$.

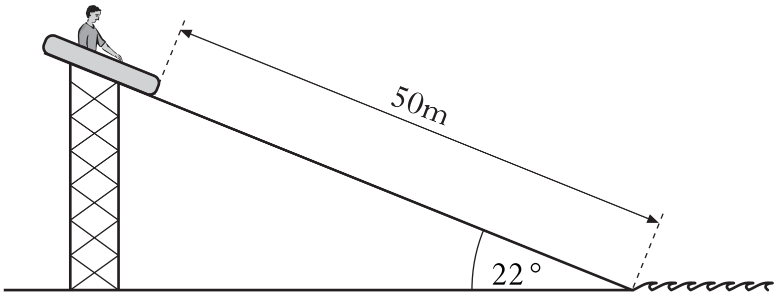
Which car arrives first at checkpoint B?

Justify your answer with a calculation. **2**

(*d*) State the displacement of checkpoint A from checkpoint B. **1**

(7)

22. A fairground ride consists of rafts which slide down a slope into water.



The slope is at an angle of 22° to the horizontal. Each raft has a mass of 8·0 kg. The length of the slope is 50 m.

A child of mass 52 kg sits in a raft at the top of the slope. The raft is released from rest. The child and raft slide together down the slope into the water. The force of friction between the raft and slope remains constant at 180 N.

(*a*) Calculate the component of weight, in newtons, of the child and raft down the slope. **1**

(*b*) Show by calculation that the acceleration of the child and raft down the slope is 0·67 m s^{-2}. **2**

(*c*) Calculate the speed of the child and raft at the bottom of the slope. **2**

(*d*) A second child of smaller mass is released from rest in an identical raft at the same starting point. The force of friction is the same as before.

How does the speed of this child and raft at the bottom of the slope compare with the answer to part (*c*)?

Justify your answer. **2**

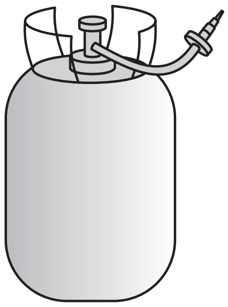
(7)

[Turn over

Marks

23. A rigid cylinder contains $8{\cdot}0 \times 10^{-2}\,\text{m}^3$ of helium gas at a pressure of $750\,\text{kPa}$. Gas is released from the cylinder to fill party balloons.

rigid cylinder



party balloons

During the filling process, the temperature remains constant. When filled, each balloon holds $0{\cdot}020\,\text{m}^3$ of helium gas at a pressure of $125\,\text{kPa}$.

(*a*) Calculate the total volume of the helium gas when it is at a pressure of 125 kPa. **2**

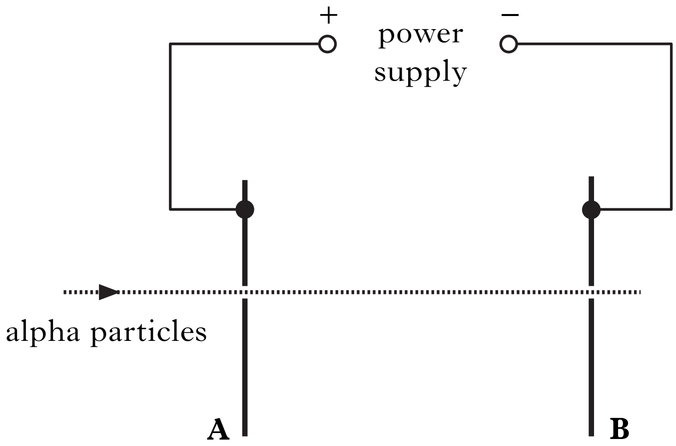
(*b*) Determine the maximum number of balloons which can be fully inflated by releasing gas from the cylinder. **2**

(*c*) State how the density of the helium gas in an inflated balloon compares to the initial density of the helium gas inside the cylinder.

Justify your answer. **2**

(6)

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



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

(*a*) When the alpha particle reaches plate B, its kinetic energy has increased to $3{\cdot}05 \times 10^{-14}\,\mathrm{J}$.

Show that the work done on the alpha particle as it moves from plate A to plate B is $8{\cdot}1 \times 10^{-15}\,\mathrm{J}$. **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.

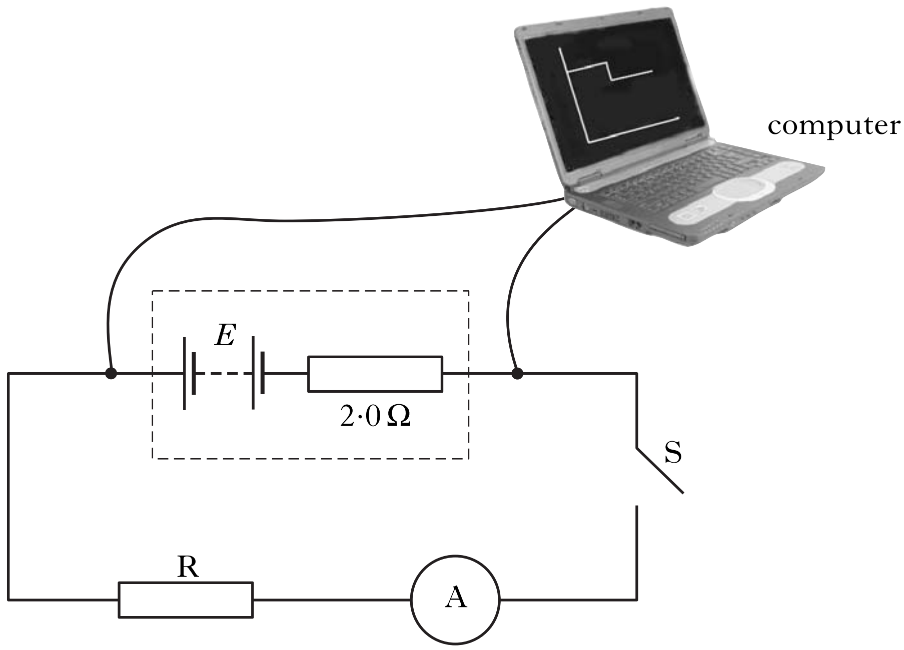
How does the increase in the kinetic energy of an electron compare with the increase in kinetic energy of the alpha particle in part (*a*)?

Justify your answer. **2**

(6)

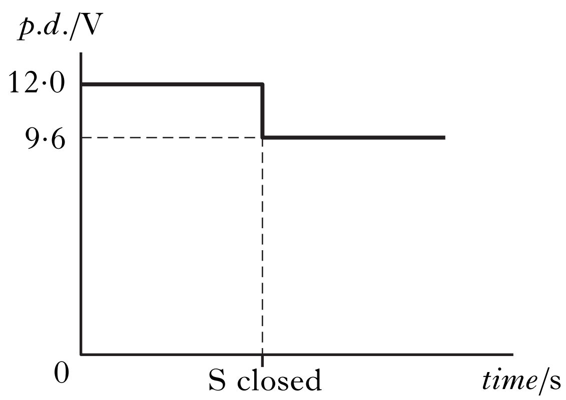
[Turn over

25. A power supply of e.m.f. E and internal resistance $2{\cdot}0\,\Omega$ 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**

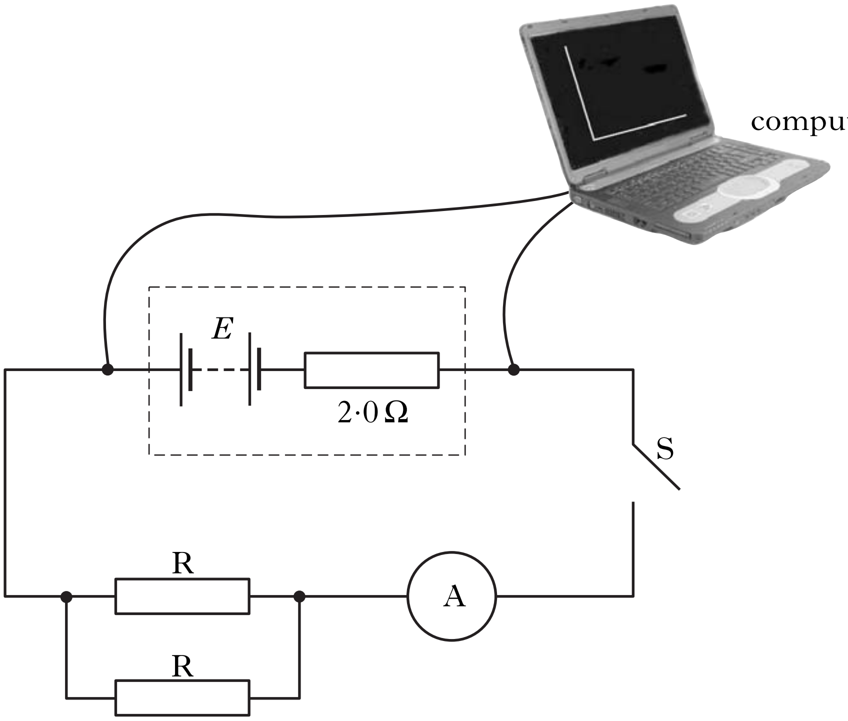
(b) Calculate:

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

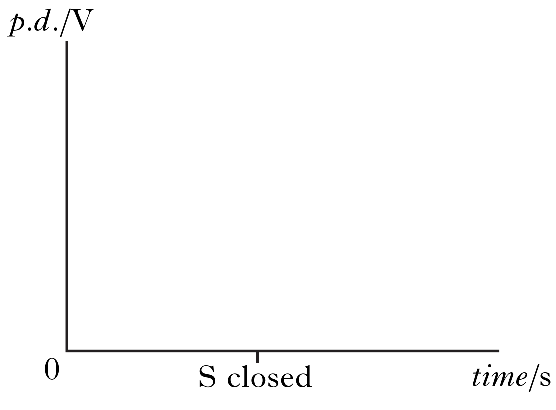
(ii) the resistance of resistor R. **1**

25. (continued)

(*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.

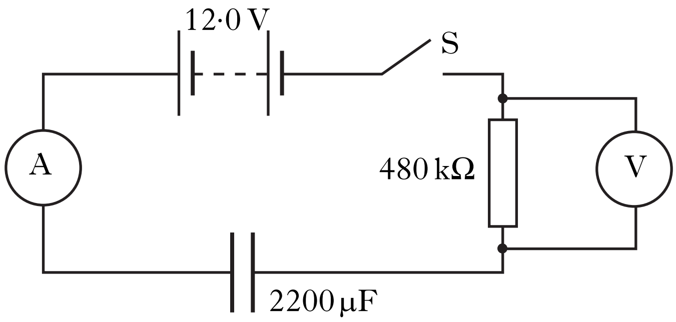


Copy and complete the new graph of potential difference against time showing the values of potential difference before and after switch S is closed. **2**

(6)

[Turn over

26. An uncharged 2200 μF capacitor is connected in a circuit as shown.



The battery has negligible internal resistance.

(*a*) Switch S is closed. Calculate the initial charging current. **2**

(*b*) At one instant during the charging process the potential difference **across the resistor** is 3·8 V.

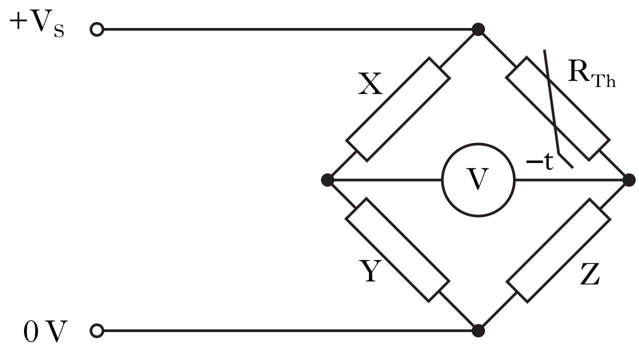
Calculate the charge stored in the capacitor at this instant. **3**

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

(7)

Marks

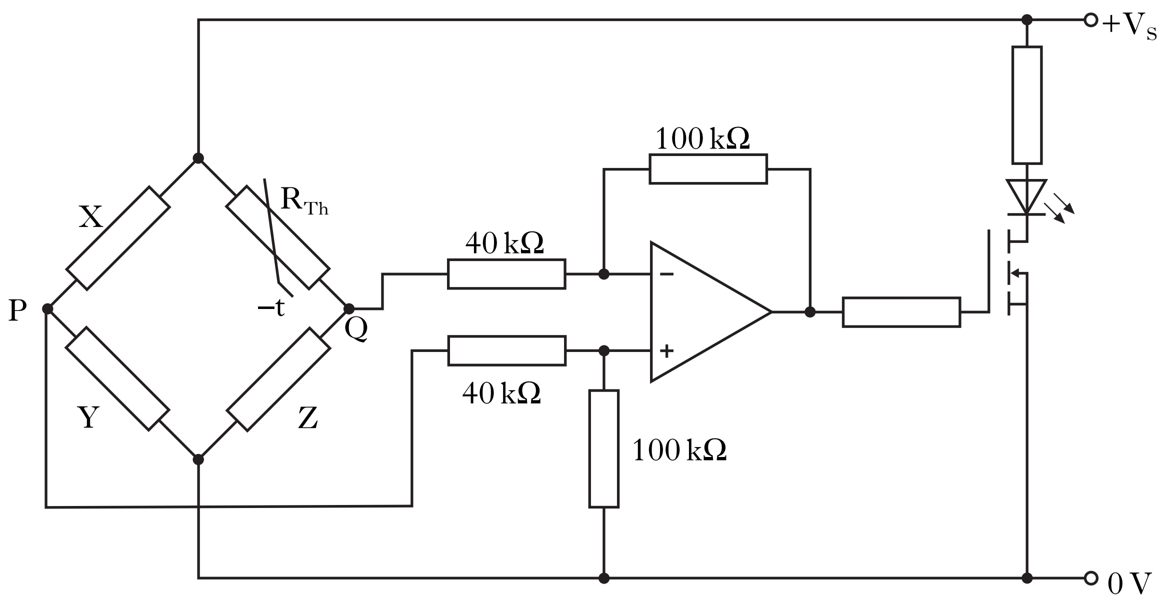
27. A Wheatstone bridge is used to measure the resistance of a thermistor as its temperature changes.



(*a*) The bridge is balanced when X = 2·2 kΩ, Y = 5·0 kΩ and Z = 750 Ω.

Calculate the resistance of the thermistor, R_{Th}, when the bridge is balanced. **2**

(*b*) A student uses this bridge in a circuit to light an LED when the temperature in a greenhouse falls below a certain level.



(i) In which mode is the op-amp being used? **1**

(ii) As the temperature of the thermistor falls, its resistance increases.

Explain how this whole circuit operates to cause the LED to light when the temperature falls. **2**

(iii) At a certain temperature the output voltage of the op-amp is 3·0 V.

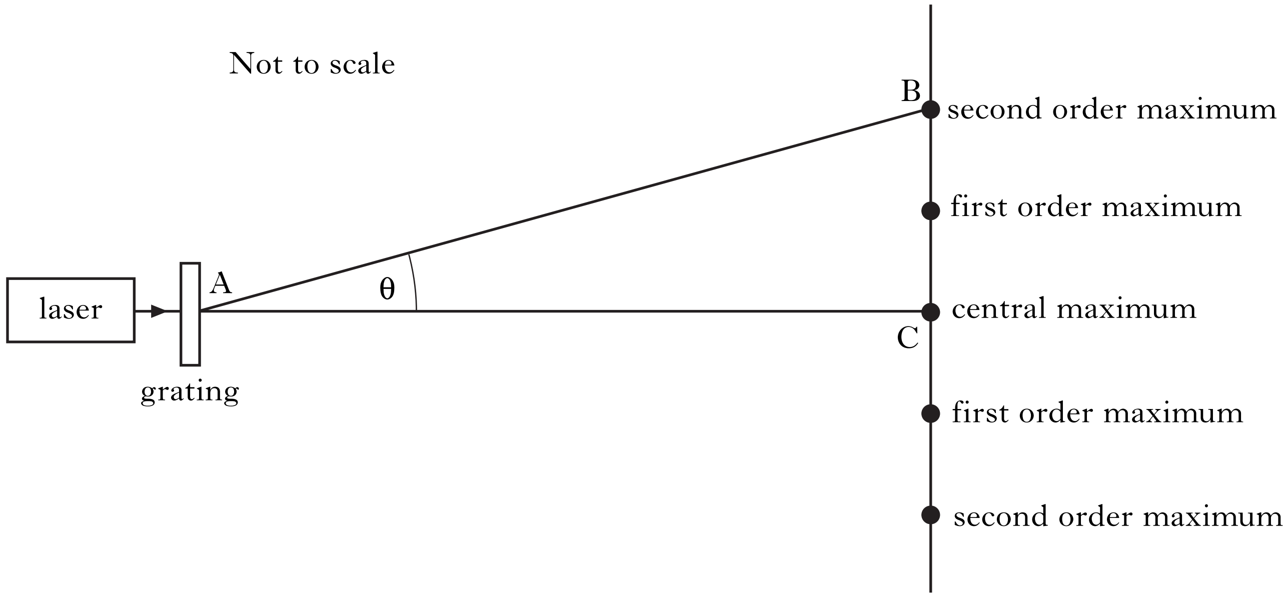
Calculate the potential difference between P and Q at this temperature. **2**

(7)

[Turn over

Marks

28. An experiment to determine the wavelength of light from a laser is shown.



A **second** order maximum is observed at point B.

(*a*) Explain in terms of waves how a maximum is formed. **1**

(*b*) Distance AB is measured six times.

The results are shown.

1·11 m   1·08 m   1·10 m   1·13 m   1·11 m   1·07 m

(i) Calculate:

(A) the mean value for distance AB; **1**

(B) the approximate random uncertainty in this value. **1**

(ii) Distance BC is measured as (270 ± 10) mm.

Show whether AB or BC has the larger percentage uncertainty. **2**

(iii) The spacing between the lines on the grating is $4{\cdot}00 \times 10^{-6}$ m.

Calculate the wavelength of the light from the laser.

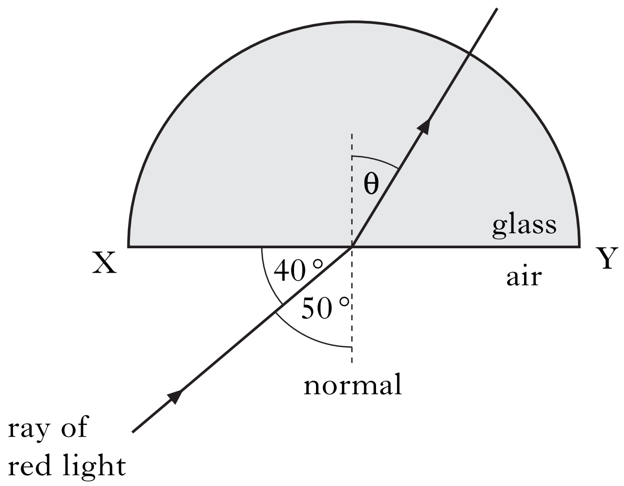
Express your answer in the form

wavelength ± **absolute** uncertainty **3**

(8)

Marks

29. A ray of red light is incident on a semicircular block of glass at the mid point of XY as shown.



The refractive index of the block is 1·50 for this red light.

(*a*) Calculate angle θ shown on the diagram. **2**

(*b*) The wavelength of the red light **in the glass** is 420 nm.

Calculate the wavelength of the light in air. **2**

(*c*) The ray of red light is replaced by a ray of blue light incident at the same angle. The blue light enters the block at the same point.

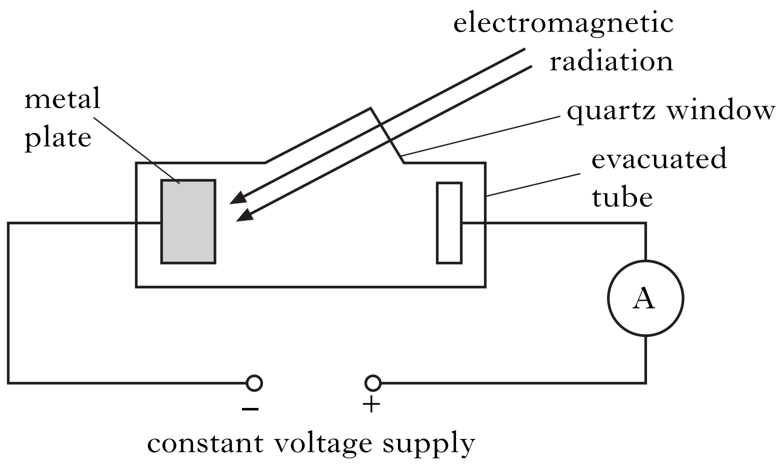
Explain why the path taken by the blue light in the block is different to that taken by the red light. **1**

(5)

[Turn over

Marks

30. A metal plate emits electrons when certain wavelengths of electromagnetic radiation are incident on it.



When light of wavelength 605 nm is incident on the metal plate, electrons are released with zero kinetic energy.

(*a*) Show that the work function of this metal is $3{\cdot}29 \times 10^{-19}$ J. **2**

(*b*) The wavelength of the incident radiation is now altered. Photons of energy $5{\cdot}12 \times 10^{-19}$ J are incident on the metal plate.

(i) Calculate the maximum kinetic energy of the electrons just as they leave the metal plate. **1**

(ii) The irradiance of this radiation on the metal plate is now decreased.

State the effect this has on the ammeter reading.

Justify your answer. **2**

(5)

31. (*a*) The following statement represents a nuclear reaction.

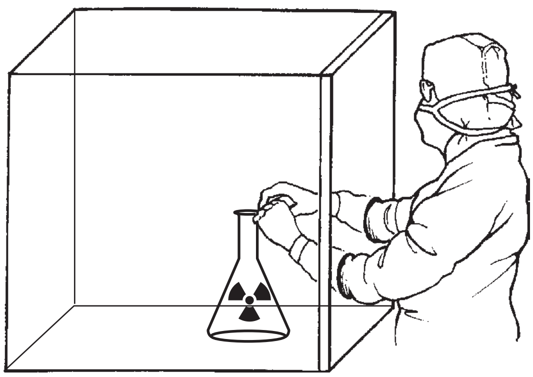
$$^{240}_{94}\text{Pu} \longrightarrow {}^{236}_{92}\text{U} \quad + \quad {}^{4}_{2}\text{He}$$

The table shows the masses of the particles involved in this reaction.

Particle	*Mass*/kg
$^{240}_{94}\text{Pu}$	$398{\cdot}626 \times 10^{-27}$
$^{236}_{92}\text{U}$	$391{\cdot}970 \times 10^{-27}$
$^{4}_{2}\text{He}$	$6{\cdot}645 \times 10^{-27}$

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

(*b*) A technician is working with a radioactive source as shown.



The technician's hands receive an absorbed dose at a rate of $4{\cdot}0\,\mu\text{Gy}\,\text{h}^{-1}$ for 2 hours. The radiation from the source has a radiation weighting factor of 3. Calculate the equivalent dose received by the technician's hands. **3**

(6)

[*END OF QUESTION PAPER*]

[BLANK PAGE]

[BLANK PAGE]