X069/12/02

NATIONAL QUALIFICATIONS 2012

MONDAY, 28 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	$3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \text{kg}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \text{C}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \text{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \text{kg}$
Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \text{J s}$			

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 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

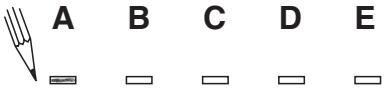
B ampere

C watt

D coulomb

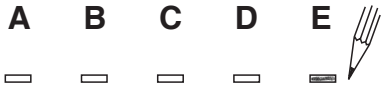
E volt.

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 of the following contains one vector and two scalar quantities?

A force, time and acceleration

B power, momentum and velocity

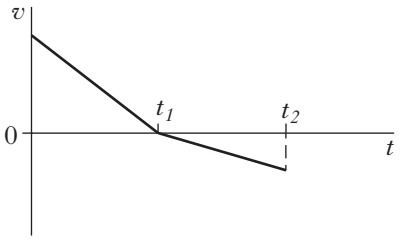
C acceleration, velocity and force

D mass, distance and speed

E acceleration, time and speed

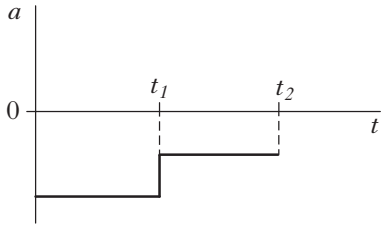
2. A trolley travels along a straight track.

The graph shows how the velocity v of the trolley varies with time t.

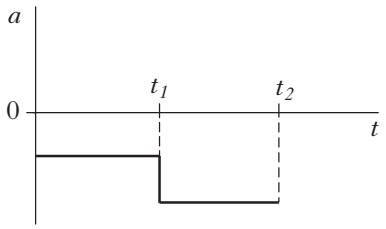


Which graph shows how the acceleration a of the trolley varies with time t?

A



B



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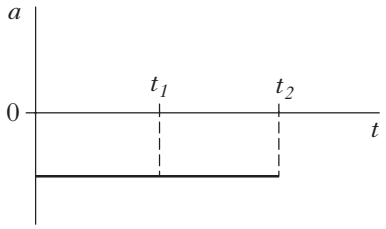
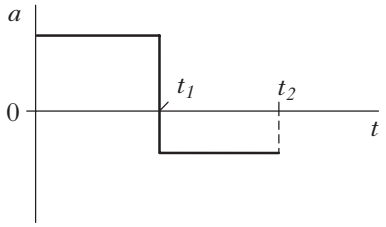
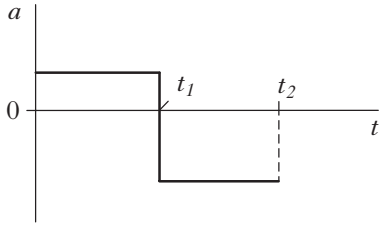


D



E



3. A rocket of mass 200 kg accelerates vertically upwards from the surface of a planet at $2{\cdot}0\,m\,s^{-2}$.

The gravitational field strength on the planet is $4{\cdot}0\,N\,kg^{-1}$.

What is the size of the force being exerted by the rocket's engines?

A 400 N

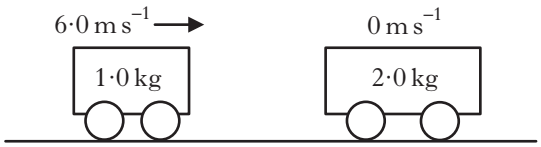
B 800 N

C 1200 N

D 2000 N

E 2400 N

4. The diagram shows the masses and velocities of two trolleys just before they collide on a level bench.



After the collision, the trolleys move along the bench joined together.

How much kinetic energy is lost in this collision?

A 0 J

B 6·0 J

C 12 J

D 18 J

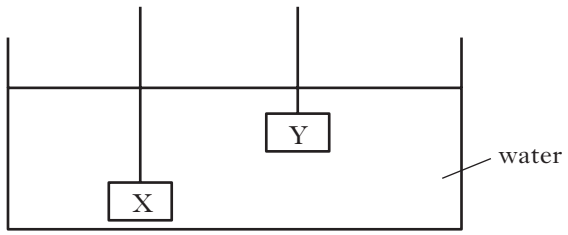
E 24 J

5. A fixed mass of gas condenses at atmospheric pressure to form a liquid.

Which row in the table shows the approximate increase in density and the approximate decrease in spacing between molecules?

	Approximate increase in density	*Approximate decrease in spacing between molecules*
A	10 times	10 times
B	10 times	1000 times
C	1000 times	10 times
D	1000 times	1000 times
E	1 000 000 times	1000 times

6. Two identical blocks are suspended in water at different depths as shown.



A student makes the following statements.

I The buoyancy force on block Y is greater than the buoyancy force on block X.

II The pressure on the bottom of block X is greater than the pressure on the bottom of block Y.

III The pressure on the top of block X is greater than the pressure on the top of block Y.

Which of the statements is/are correct?

A I only

B II only

C I and II only

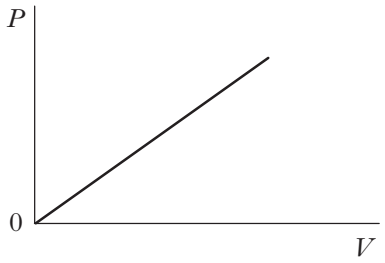
D II and III only

E I, II and III

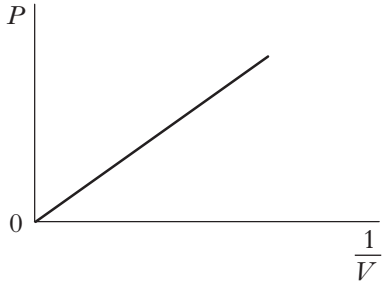
[Turn over

7. Which of the following graphs shows the relationship between the pressure P and the volume V of a fixed mass of gas at constant temperature?

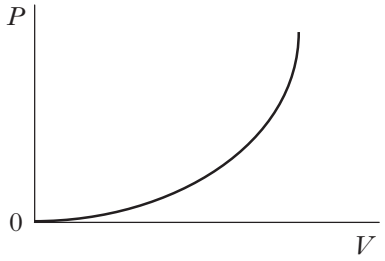
A



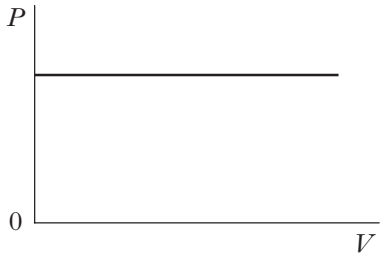
B



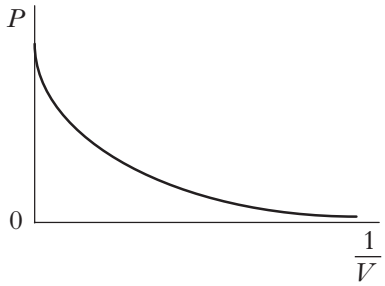
C



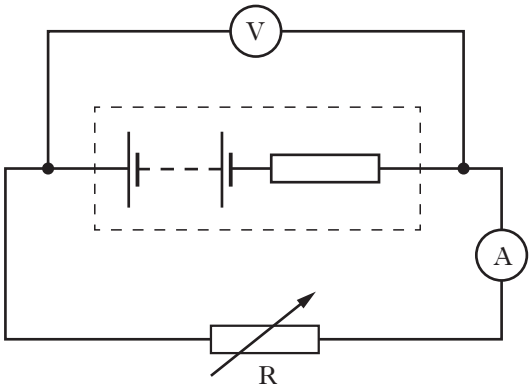
D



E

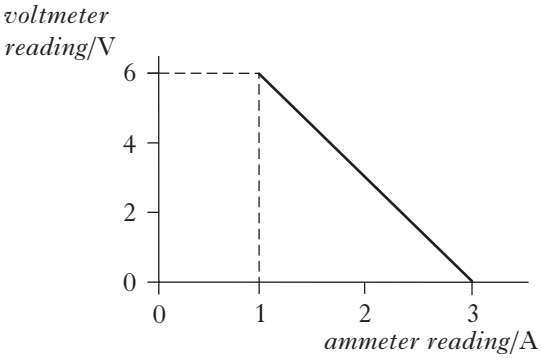


8. A circuit is set up as shown.



The variable resistor R is adjusted and a series of readings taken from the voltmeter and ammeter.

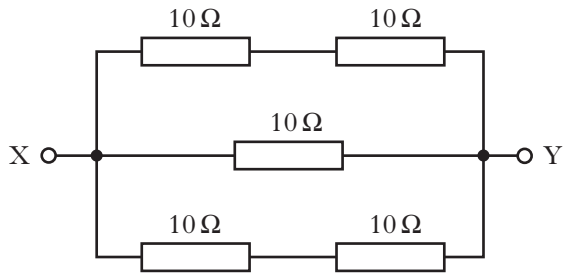
The graph shows how the voltmeter reading varies with the ammeter reading.



Which row in the table shows the values for the e.m.f. and internal resistance of the battery in the circuit?

	e.m.f./V	*internal resistance*/Ω
A	6	2
B	6	3
C	9	2
D	9	3
E	9	6

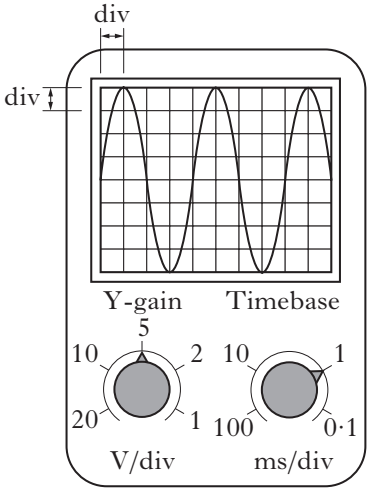
9. The diagram shows part of an electrical circuit.



What is the resistance between X and Y?

A 0·2 Ω
B 5 Ω
C 10 Ω
D 20 Ω
E 50 Ω

10. An alternating voltage is displayed on an oscilloscope screen. The Y-gain and the timebase settings are shown.



Which row in the table gives the values for the peak voltage and frequency of the signal?

	Peak voltage/V	*Frequency*/Hz
A	10	100
B	10	250
C	20	250
D	10	500
E	20	1000

11. A student carries out an experiment to find the capacitance of a capacitor. The charge on the capacitor is measured for different values of p.d. across the capacitor. The results are shown.

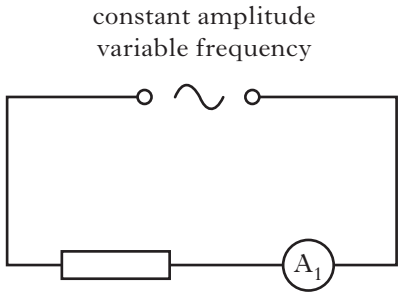
charge on capacitor/μC	*p.d. across capacitor*/V
1·9	1·0
4·6	2·0
9·6	4·0

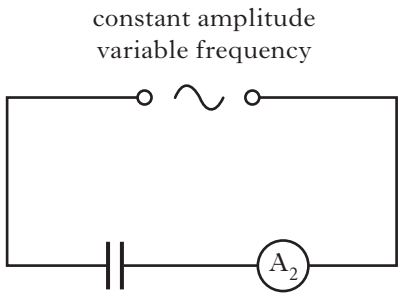
The best estimate of the capacitance is

A 1·9 μF
B 2·2 μF
C 2·3 μF
D 2·4 μF
E 2·6 μF.

[Turn over

12. The circuits below have identical a.c. supplies which are set at a frequency of 200 Hz.



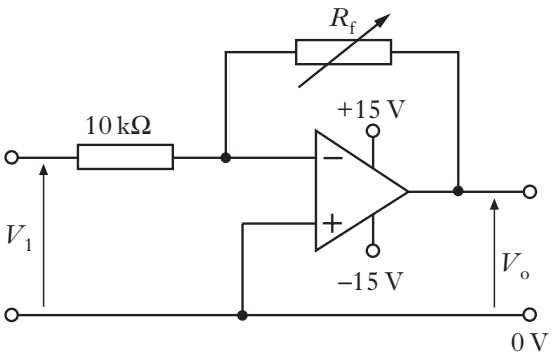


The frequency of each a.c. supply is now increased to 500 Hz.

What happens to the readings on the ammeters A_1 and A_2?

	A_1	A_2
A	increases	decreases
B	decreases	increases
C	no change	no change
D	no change	decreases
E	no change	increases

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



The resistance of R_f can be varied between 0 and 100 kΩ.

When the input voltage V_1 is +2 V a possible value of the output voltage V_o is

A +20 V

B +10 V

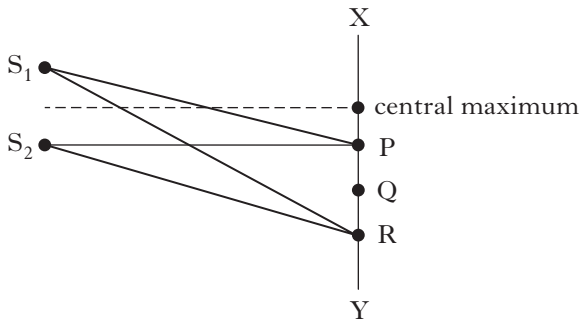
C +2 V

D −10 V

E −20 V.

14. S_1 and S_2 are sources of coherent waves.

An interference pattern is obtained between X and Y.



The first order maximum occurs at P, where S_1P = 200 mm and S_2P = 180 mm.

For the third order maximum, at R, the path difference ($S_1R - S_2R$) is

A 20 mm

B 30 mm

C 40 mm

D 50 mm

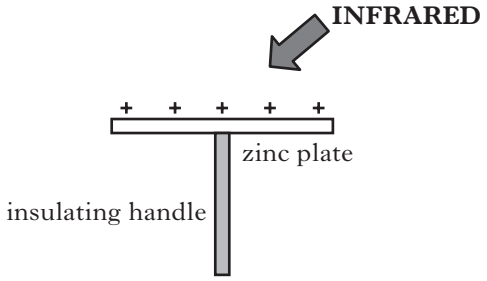
E 60 mm.

15. Clean zinc plates are mounted on insulating handles and then charged.

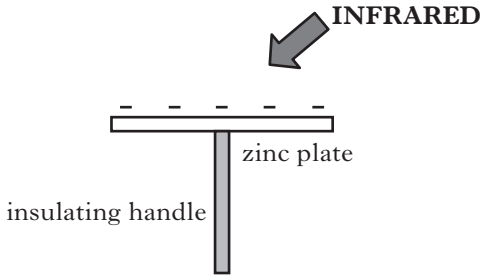
Different types of electromagnetic radiation are now incident on the plates as shown.

Which of the zinc plates is most likely to discharge due to photoelectric emission?

A



B



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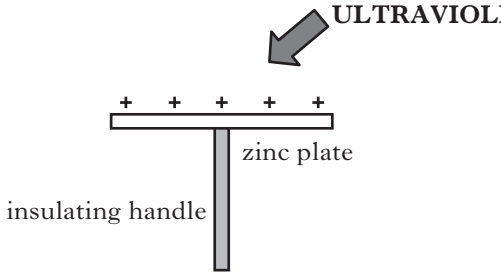

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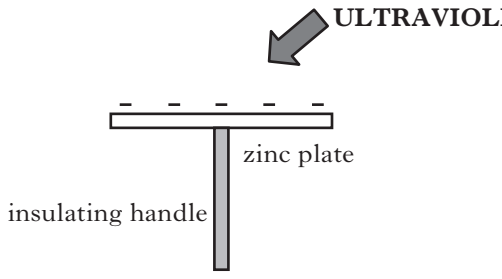
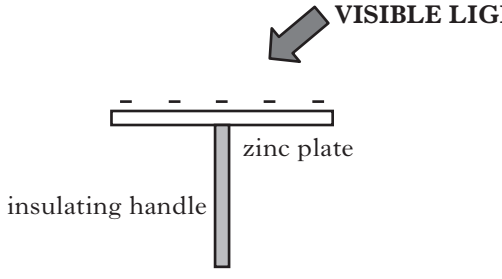


E



16. Electromagnetic radiation of frequency $9{\cdot}0 \times 10^{14}$ Hz is incident on a clean metal surface.

The work function of the metal is $5{\cdot}0 \times 10^{-19}$ J.

The maximum kinetic energy of a photoelectron released from the metal surface is

A $1{\cdot}0 \times 10^{-19}$ J

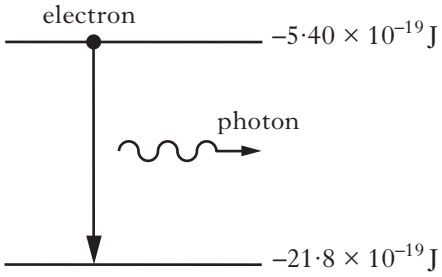
B $4{\cdot}0 \times 10^{-19}$ J

C $5{\cdot}0 \times 10^{-19}$ J

D $6{\cdot}0 \times 10^{-19}$ J

E $9{\cdot}0 \times 10^{-19}$ J.

17. In an atom, a photon of radiation is emitted when an electron makes a transition from a higher energy level to a lower energy level as shown.



The wavelength of the radiation emitted due to an electron transition between the two energy levels shown is

A $1{\cdot}2 \times 10^{-7}$ m

B $7{\cdot}3 \times 10^{-8}$ m

C $8{\cdot}2 \times 10^{6}$ m

D $1{\cdot}4 \times 10^{7}$ m

E $2{\cdot}5 \times 10^{15}$ m.

[Turn over

18. Which of the following statements describes a spontaneous nuclear fission reaction?

A $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{90}_{36}Kr + 2\,{}^{1}_{0}n$

B $^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$

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

D $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

E $^{216}_{84}Po \rightarrow {}^{216}_{84}Po + \gamma$

19. The statement below represents a nuclear reaction.

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

The total mass on the left hand side is $8{\cdot}347 \times 10^{-27}$ kg.

The total mass on the right hand side is $8{\cdot}316 \times 10^{-27}$ kg.

The energy released during one nuclear reaction of this type is

A $9{\cdot}30 \times 10^{-21}$ J

B $2{\cdot}79 \times 10^{-12}$ J

C $7{\cdot}51 \times 10^{-10}$ J

D $1{\cdot}50 \times 10^{-9}$ J

E $2{\cdot}79 \times 10^{15}$ J.

20. A source of gamma radiation is stored in a large container. A count rate of 160 counts per minute, after correction for background radiation, is recorded outside the container.

The container is to be shielded so that the corrected count rate at the same point outside the container is no more than 10 counts per minute.

Lead and water are available as shielding materials. For this source, the half-value thickness of lead is 11 mm and the half-value thickness of water is 110 mm.

Which of the following shielding arrangements meets the above requirements?

A 40 mm of lead only

B 33 mm of lead plus 110 mm of water

C 20 mm of lead plus 220 mm of water

D 11 mm of lead plus 275 mm of water

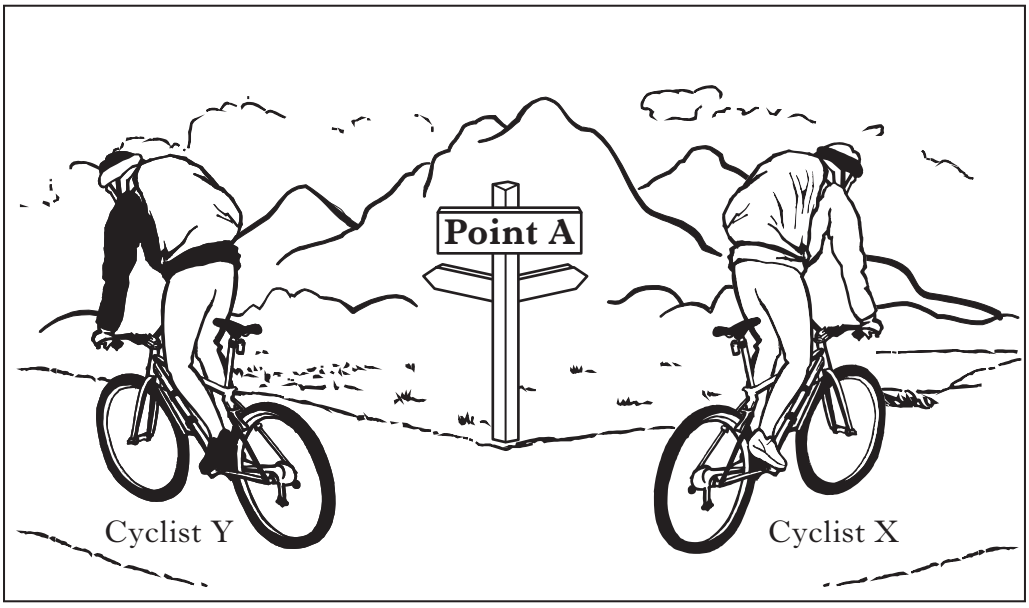
E 10 mm of lead plus 330 mm of water

SECTION B

Marks

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

21. Two cyclists choose different routes to travel from point **A** to a point **B** some distance away.



(*a*) Cyclist X travels 12 km due East (bearing 090). He then turns onto a bearing of 200 (20 ° West of South) and travels a further 15 km to arrive at **B**. He takes 1 hour 15 minutes to travel from **A** to **B**.

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

(ii) Calculate the average velocity of cyclist X for the journey from **A** to **B**. **2**

(*b*) Cyclist Y travels a total distance of 33 km by following a different route from **A** to **B** at an average speed of 22 km h^{-1}.

(i) State the displacement of cyclist Y on completing this route. **1**

(ii) Calculate the average velocity of cyclist Y for the journey from **A** to **B**. **3**

(8)

[Turn over

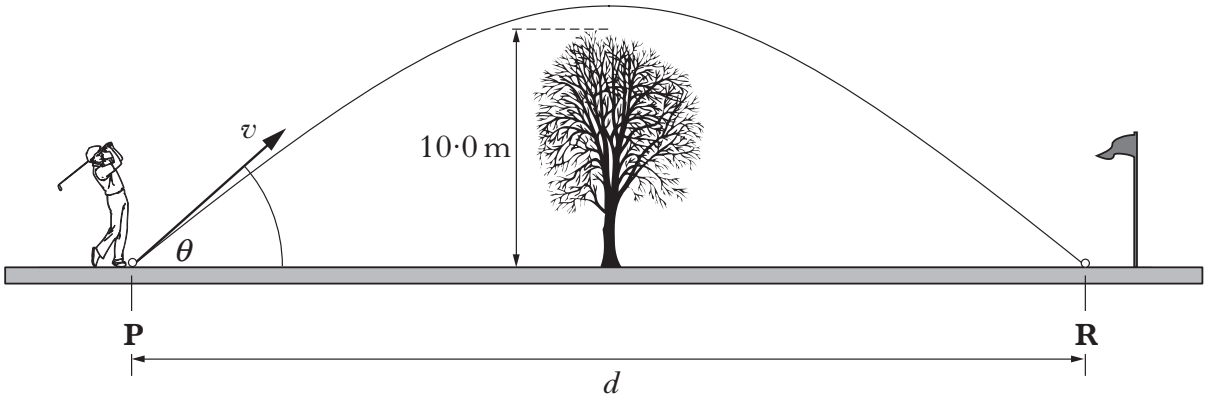
Marks

22. A golfer hits a ball from point **P**. The ball leaves the club with a velocity v at an angle of θ to the horizontal.

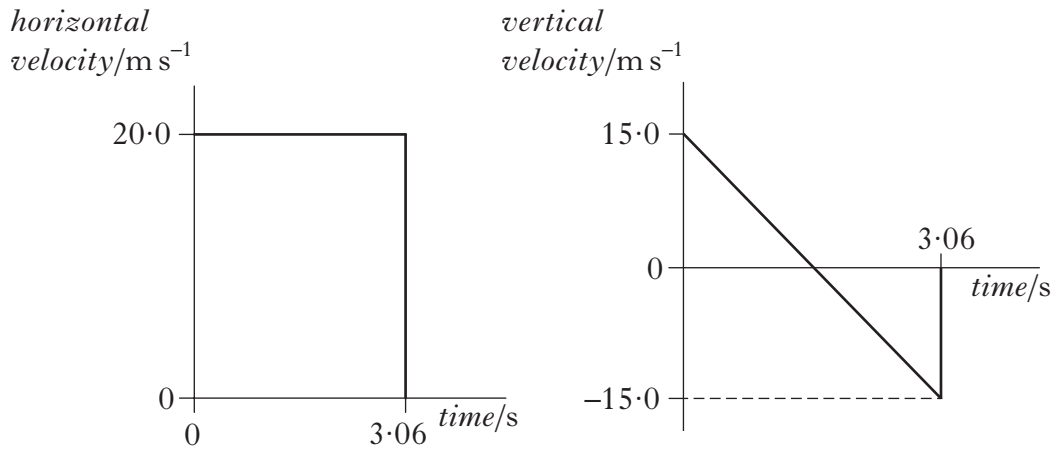
The ball travels through the air and lands at point **R**.

Midway between **P** and **R** there is a tree of height 10·0 m.

not to scale



(*a*) The horizontal and vertical components of the ball's velocity during its flight are shown.



The effects of air resistance can be ignored.

Calculate:

(i) the horizontal distance d; **1**

(ii) the maximum height of the ball above the ground. **2**

(*b*) When the effects of air resistance are **not** ignored, the golf ball follows a different path.

Is the ball more or less likely to hit the tree?

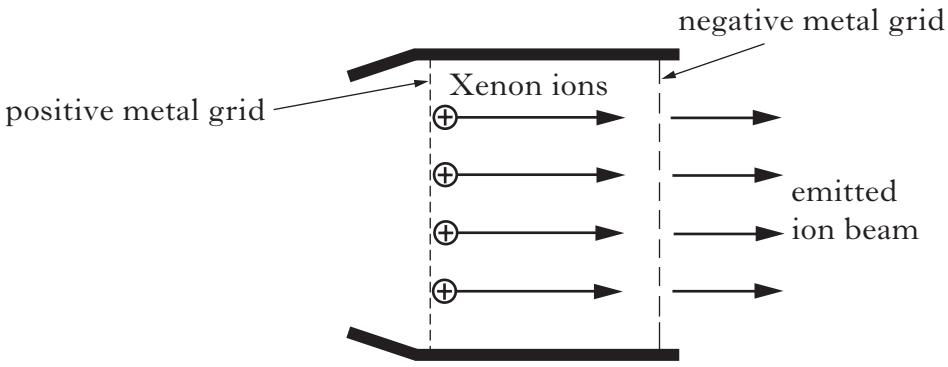
You must justify your answer. **2**

(5)

Marks

23. An ion propulsion engine can be used to propel spacecraft to areas of deep space.

A simplified diagram of a Xenon ion engine is shown.



The Xenon ions are accelerated as they pass through an electric field between the charged metal grids. The emitted ion beam causes a force on the spacecraft in the opposite direction.

The spacecraft has a total mass of 750 kg.

The mass of a Xenon ion is $2{\cdot}18 \times 10^{-25}$ kg and its charge is $1{\cdot}60 \times 10^{-19}$ C. The potential difference between the charged metal grids is 1·22 kV.

(*a*) (i) Show that the work done on a Xenon ion as it moves through the electric field is $1{\cdot}95 \times 10^{-16}$ J. **1**

(ii) Assuming the ions are accelerated from rest, calculate the speed of a Xenon ion as it leaves the engine. **2**

(*b*) The ion beam exerts a constant force of 0·070 N on the spacecraft. Calculate the change in speed of the spacecraft during a 60 second period of time. **2**

(*c*) A different ion propulsion engine uses Krypton ions which have a smaller mass than Xenon ions. The Krypton engine emits the same number of ions per second at the same speed as the Xenon engine.

Which of the two engines produces a greater force?

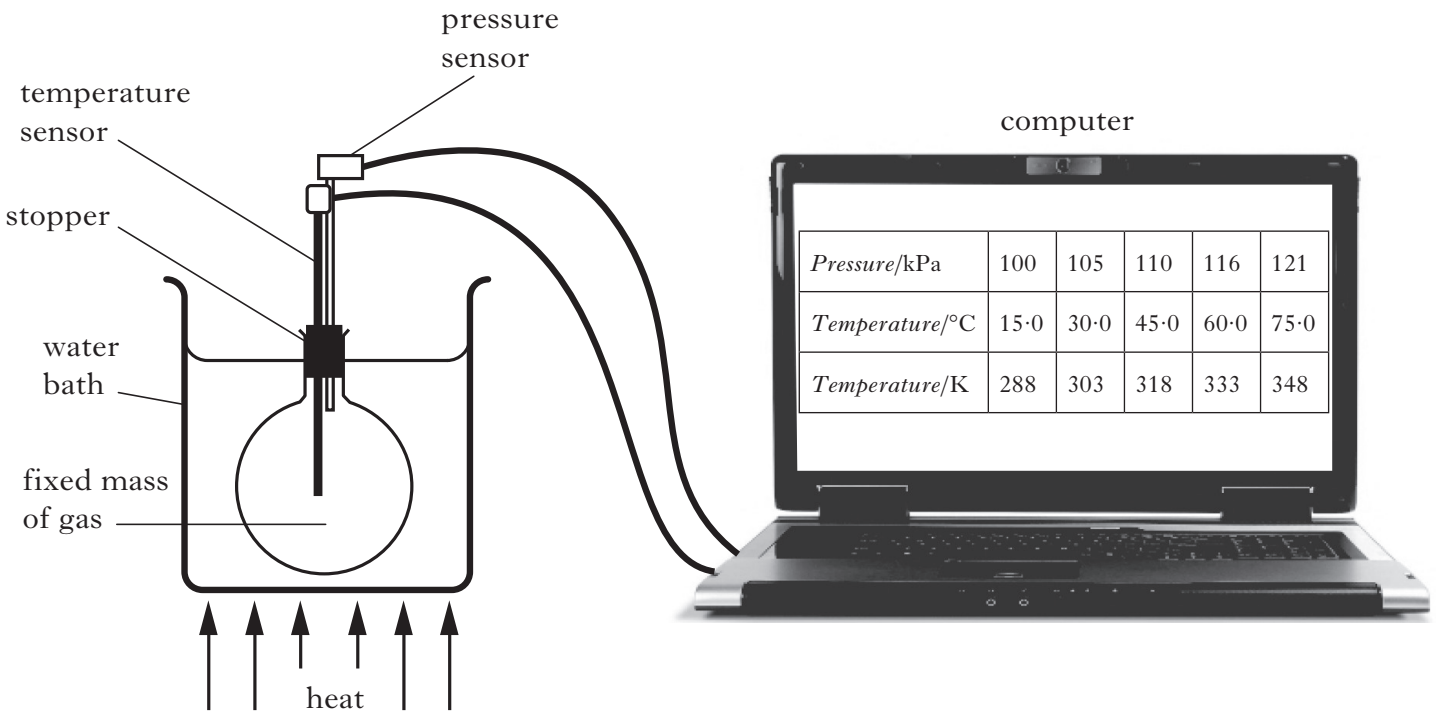
Justify your answer. **2**

(7)

[Turn over

Marks

24. A student carries out an experiment to investigate the relationship between the pressure and temperature of a fixed mass of gas. The apparatus used is shown.



The pressure and temperature of the gas are recorded using sensors connected to a computer. The gas is heated slowly in the water bath and a series of readings is taken.

The volume of the gas remains constant during the experiment.

The results are shown.

Pressure/kPa	100	105	110	116	121
Temperature/°C	15·0	30·0	45·0	60·0	75·0
Temperature/K	288	303	318	333	348

(*a*) Using **all** the relevant data, establish the relationship between the pressure and the temperature of the gas. **2**

(*b*) Use the kinetic model to explain the change in pressure as the temperature of the gas increases. **2**

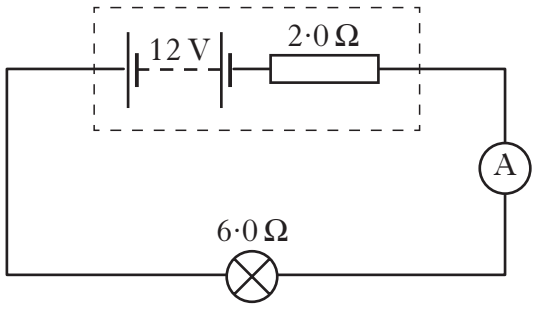
(*c*) Explain why the level of water in the water bath should be above the bottom of the stopper. **1**

(5)

Marks

25. A student carries out two experiments using different power supplies connected to a lamp of resistance 6·0 Ω.

(*a*) In the first experiment the lamp is connected to a power supply of e.m.f. 12 V and internal resistance 2·0 Ω as shown.



Calculate:

(i) the reading on the ammeter; **2**

(ii) the lost volts; **1**

(iii) the output power of the lamp. **2**

(*b*) In the second experiment the lamp is connected to a different power supply. This supply has the same e.m.f. as the supply in part (*a*) but a different value of internal resistance.

The output power of the lamp is now greater.

Assuming the resistance of the lamp has not changed, is the internal resistance of the new power supply less than, equal to, or greater than the internal resistance of the original supply?

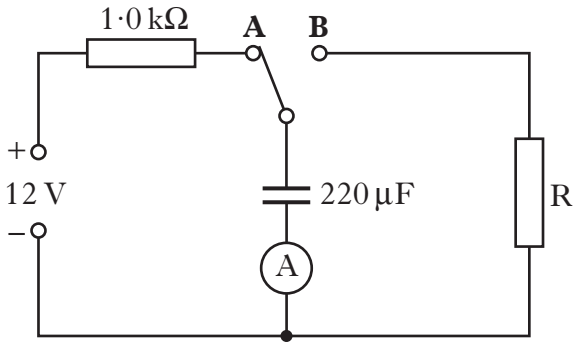
Justify your answer. **2**

(7)

[Turn over

Marks

26. The charging and discharging of a capacitor are investigated using the circuit shown.



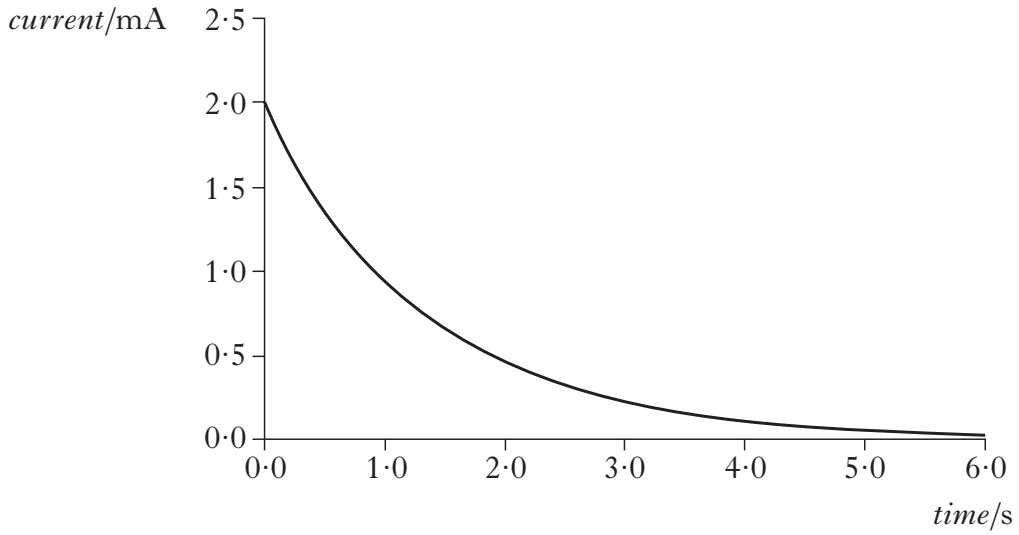
The power supply has an e.m.f. of 12 V and negligible internal resistance. The capacitor is initially uncharged.

(*a*) The switch is connected to **A** and the capacitor starts to charge. Sketch a graph showing how the voltage across the plates of the capacitor varies with time. Your graph should start from the moment the switch is connected to **A** until the capacitor is fully charged.

Numerical values are only required on the voltage axis. **2**

(*b*) The capacitor is now discharged by moving the switch to **B**.

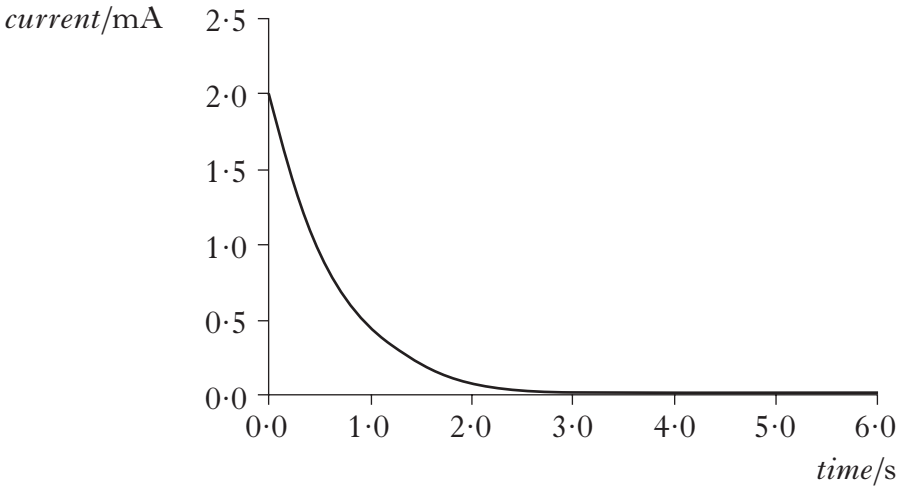
The graph of current against time as the capacitor discharges is shown.



Calculate the resistance of R. **2**

(*c*) The 220 μF capacitor is now replaced with one of different value. This new capacitor is fully charged by moving the switch to **A**. It is then discharged by moving the switch to **B**.

The graph of current against time as this capacitor discharges is shown.



(i) Explain why the value of the initial discharging current remains the same as in part (*b*). **1**

(ii) How does the capacitance of this capacitor compare with the capacitance of the original 220 μF capacitor?

You must justify your answer. **2**

(7)

[Turn over

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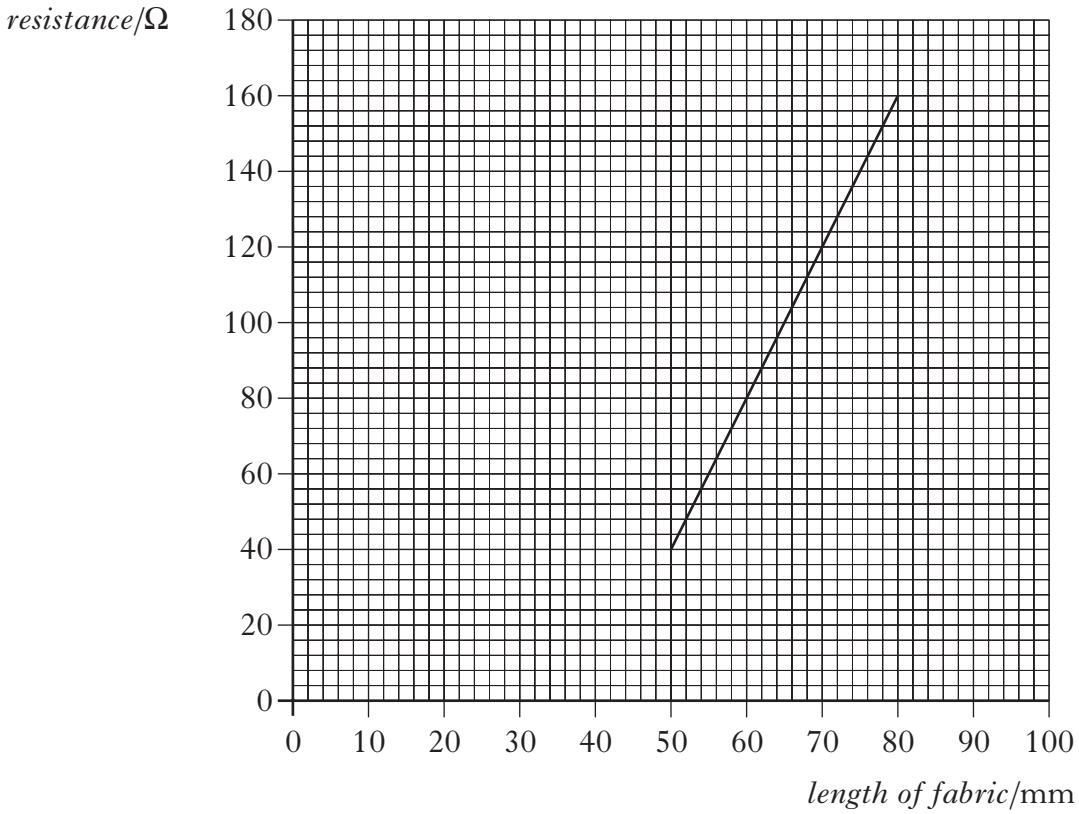
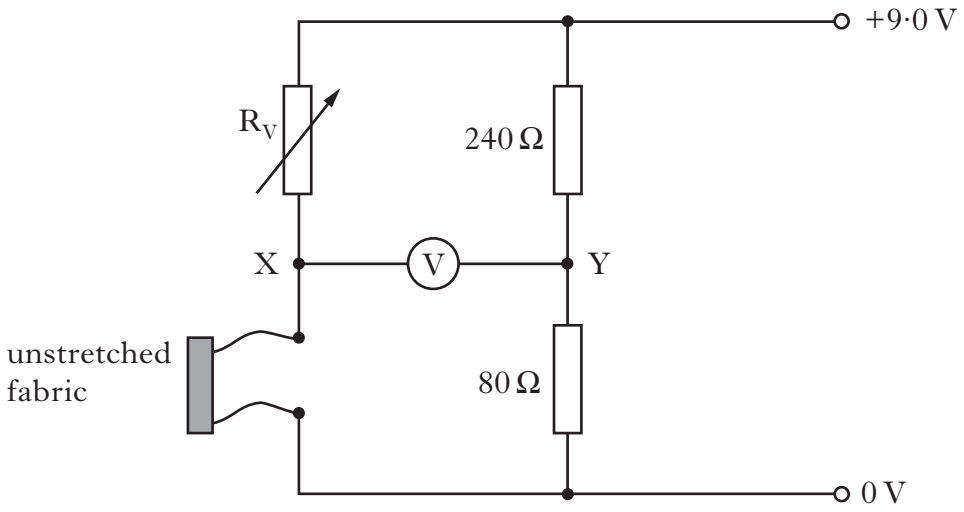
Marks

27. A fabric has been developed for use as a sensor in a breathing rate monitor. The graph shows how the resistance of a 50 mm length of this fabric changes as it is stretched.



A sample of the fabric of unstretched length 50 mm is connected in a Wheatstone bridge circuit.

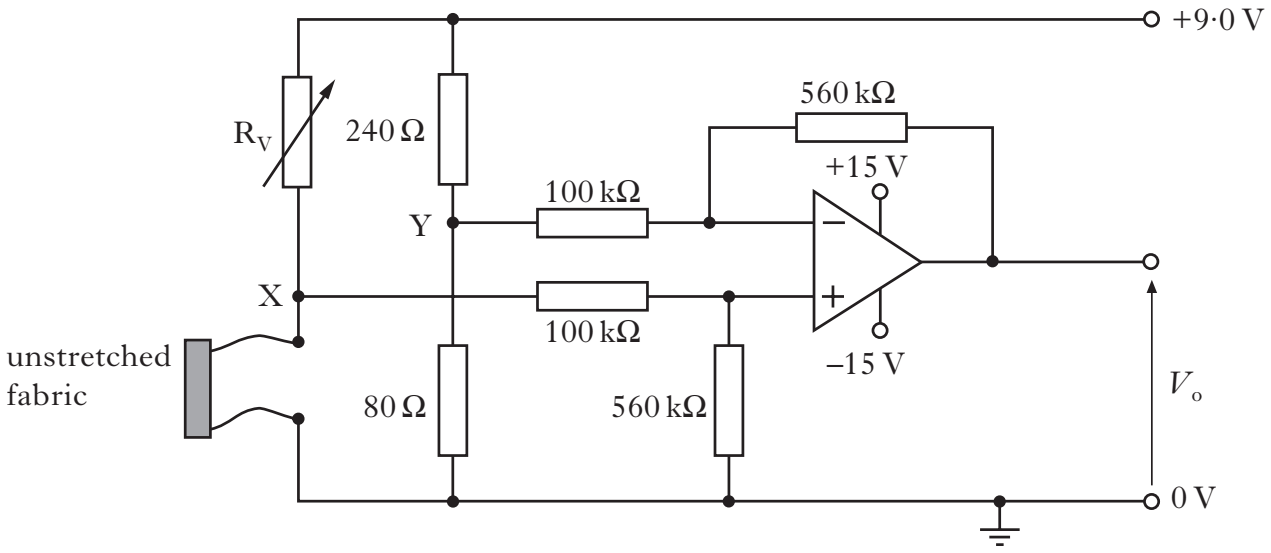


(*a*) The variable resistor R_V is adjusted until the bridge is balanced.

Show that the resistance of R_V is now 120 Ω. **2**

27. (continued) *Marks*

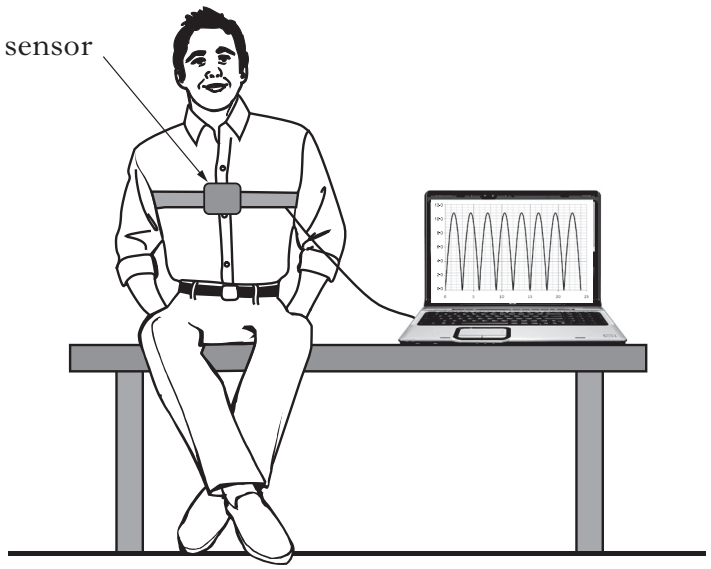
(*b*) The Wheatstone bridge is now connected to an op-amp circuit as shown.



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

(ii) Calculate the gain of the op-amp. **1**

(iii) The 50 mm length of fabric remains connected in the circuit. This sensor is attached to a patient to monitor his chest movements. The fabric stretches as he breathes in.

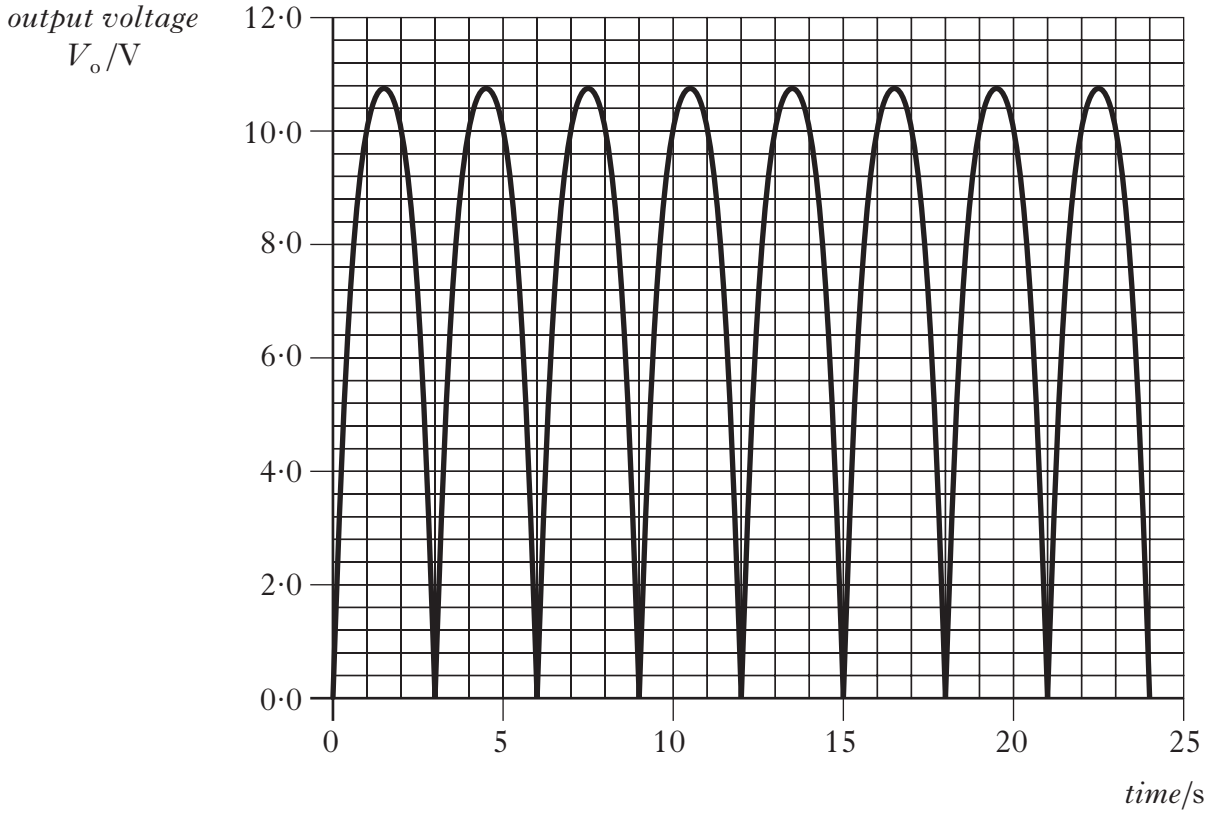


The potential at Y is 2·25 V. R_V remains at 120 Ω.

The output from the op-amp is connected to a computer.

The voltage V_o produced as the patient breathes in and out for 24 seconds is shown.

27. (*b*) (iii) (continued) *Marks*



(A) Calculate the maximum potential difference between X and Y during this time. **2**

(B) Calculate the maximum length of the fabric during this time. **3**

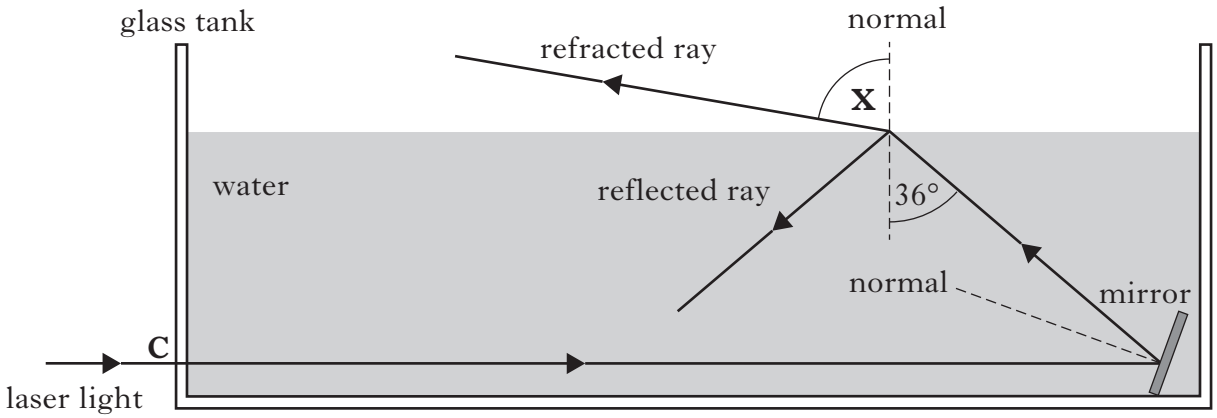
(9)

[Turn over

Marks

28. A technician investigates the path of laser light as it passes through a glass tank filled with water. The light enters the glass tank along the normal at **C** then reflects off a mirror submerged in the water.

not to scale

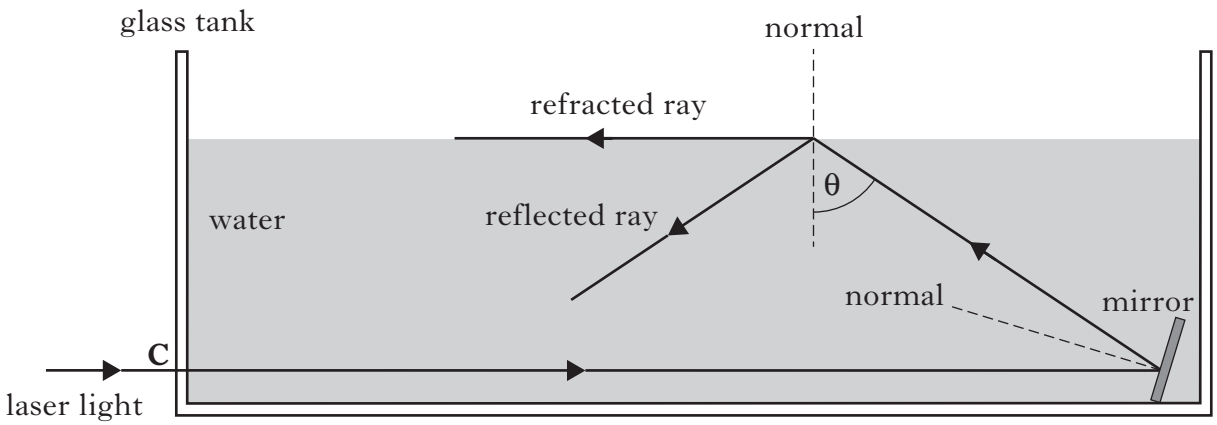


The refractive index of water for this laser light is 1·33.

(*a*) Calculate angle **X**. **2**

(*b*) The mirror is now adjusted until the light follows the paths shown.

not to scale



(i) State why the value of θ is equal to the critical angle for this laser light in water. **1**

(ii) Calculate angle θ. **2**

(*c*) The water is now replaced with a liquid which has a greater refractive index. The mirror is kept at the same angle as in part (*b*) and the incident ray again enters the tank along the normal at **C.**

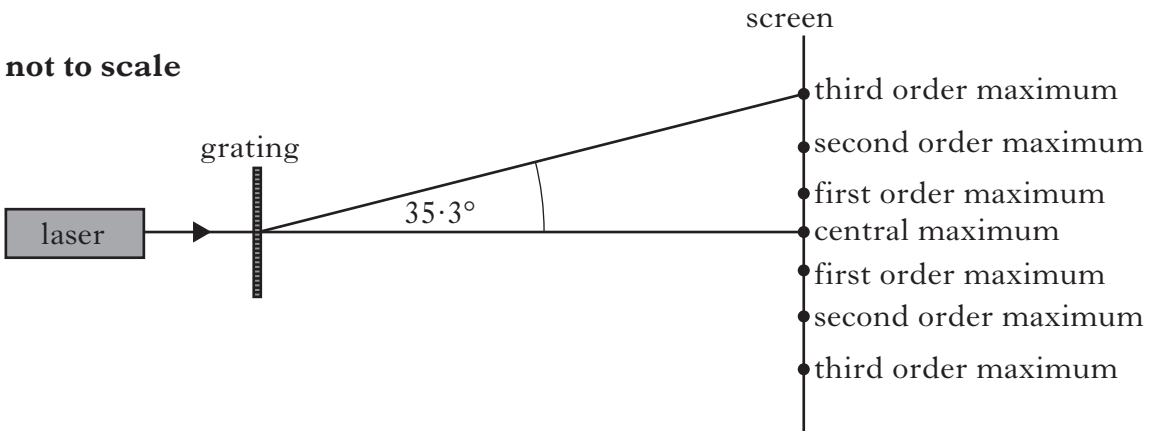
Draw a sketch which shows the path of the light ray after it has reflected off the mirror.

Your sketch should only show what happens at the surface of the liquid. **1**

(6)

Marks

29. A manufacturer claims that a grating consists of $3{\cdot}00 \times 10^5$ lines per metre and is accurate to $\pm$ 2·0%. A technician decides to test this claim. She directs laser light of wavelength 633 nm onto the grating.



She measures the angle between the central maximum and the third order maximum to be 35·3°.

(*a*) Calculate the value she obtains for the slit separation for this grating. **2**

(*b*) What value does she determine for the number of lines per metre for this grating? **1**

(*c*) Does the technician's value for the number of lines per metre agree with the manufacturer's claim of $3{\cdot}00 \times 10^5$ lines per metre $\pm$ 2·0%?

You must justify your answer by calculation. **2**

(5)

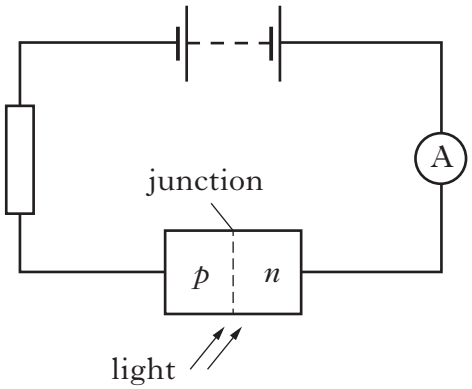
[Turn over

Marks

30. (*a*) An n-type semiconductor is formed by adding impurity atoms to a sample of pure semiconductor material.

State the effect that the addition of the impurity atoms has on the resistance of the material. **1**

(*b*) A p-n junction is used as a photodiode as shown.



(i) In which mode is the photodiode operating? **1**

(ii) The irradiance of the light on the junction of the photodiode is now increased.

Explain what happens to the current in the circuit. **2**

(*c*) The photodiode is placed at a distance of 1·2 m from a small lamp. The reading on the ammeter is 3·0 μA.

The photodiode is now moved to a distance of 0·80 m from the same lamp. Calculate the new reading on the ammeter. **2**

(6)

Marks

31. A medical physicist is investigating the effects of radiation on tissue samples.

One sample of tissue receives an absorbed dose of 500 μGy of radiation from a source.

The radiation weighting factors of different types of radiation are shown.

Type of radiation	*Radiation weighting factor* (w_R)
gamma	1
thermal neutrons	3
fast neutrons	10
alpha	20

(*a*) The tissue sample has a mass of 0·040 kg. Calculate the total energy absorbed by the tissue. **2**

(*b*) The average equivalent dose rate for this tissue sample is 5·00 mSv h^{-1}.
The tissue is exposed to radiation for 2 hours.

Which type of radiation is the medical physicist using?

Justify your answer by calculation. **3**

(5)

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