OXFORD
INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________
I declare this is my own work.

INTERNATIONAL A-LEVEL
PHYSICS

Unit 5 Physics in practice

Wednesday 21 June 2023   07:00 GMT   Time allowed: 2 hours

Materials
For this paper you must have:
- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	

Do not write outside the box

There are no questions printed on this page

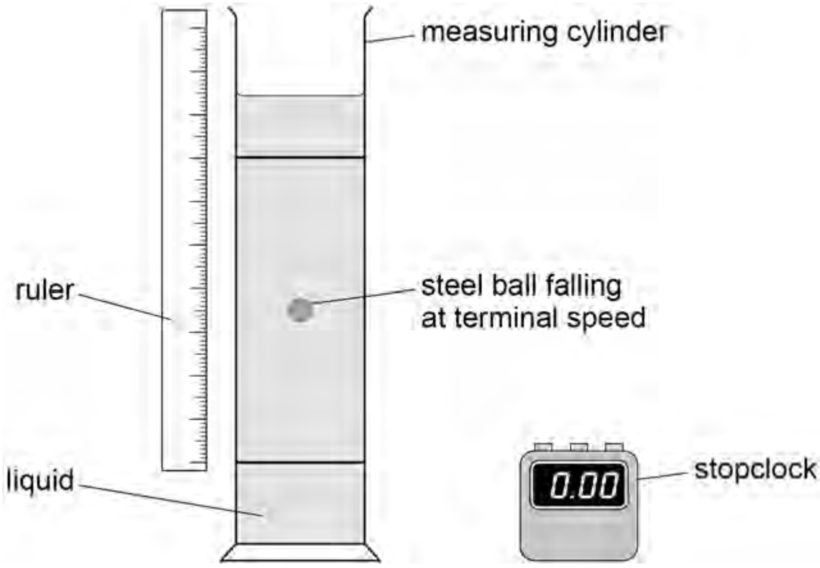
DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Section A

Answer **all** questions in this section.

0 1 A student measures the terminal speed of a steel ball as it falls through a liquid. **Figure 1** shows the apparatus used.

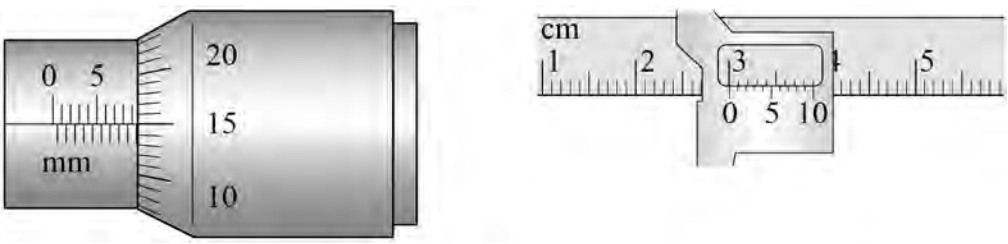
Figure 1



The steel ball travels at terminal speed v between the two lines marked on the measuring cylinder.

Figure 2 shows parts of a micrometer and a vernier caliper that the student can use to measure the diameter of the steel ball.

Figure 2



Question 1 continues on the next page

Turn over ►

Do not write outside the box

0 1 . 1 The steel ball has a diameter of approximately 4 mm.

Explain whether the student should use the micrometer or the vernier caliper to measure the diameter of the steel ball.

[2 marks]

Theory suggests that v is related to the radius r of the steel ball by:

$$v = \frac{2}{9\eta} r^2 g \left(\rho_s - \rho_l \right)$$

where:
$v = 4.74 \times 10^{-2}\ \mathrm{m\ s^{-1}} \pm 4\%$
η = a constant for the liquid
$r = (3.58 \pm 0.01)\ \mathrm{mm}$
g = acceleration due to gravity = $9.81\ \mathrm{m\ s^{-2}}$
ρ_s = density of steel = $(7.90 \times 10^3 \pm 0.03 \times 10^3)\ \mathrm{kg\ m^{-3}}$
ρ_l = density of liquid = $(1.30 \times 10^3 \pm 0.02 \times 10^3)\ \mathrm{kg\ m^{-3}}$

0 1 . 2 Explain why the given value of g implies an uncertainty of 0.1%.

[2 marks]

Do not write outside the box

0 1 . 3 Determine the student's value for η.
State the appropriate unit for η.

[3 marks]

η = ______________________

unit for η = ______________________

0 1 . 4 Determine the percentage uncertainty in the student's value for η.

[3 marks]

percentage uncertainty = ______________________

10

Turn over for the next question

Do not write outside the box

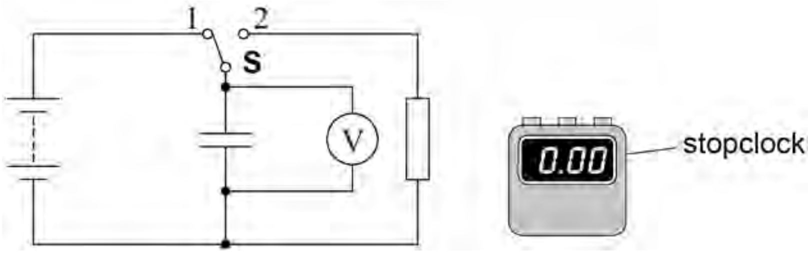
There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

0 2 A student investigates the discharge of a capacitor of capacitance C through a resistor of resistance R.
Figure 3 shows the apparatus used.

Figure 3



The student uses an analogue voltmeter.

With the switch **S** in position 1, she measures the potential difference V_0 across the charged capacitor.
She then moves **S** to position 2 and starts the stopclock at the same time.
She records the potential difference V across the capacitor every $10\ \mathrm{s}$ until the capacitor is almost completely discharged.

The student plots a graph of $\ln(V / \mathrm{V})$ against time t for the capacitor discharge.

0 2 . 1 Show that the gradient of the graph is $-\dfrac{1}{RC}$

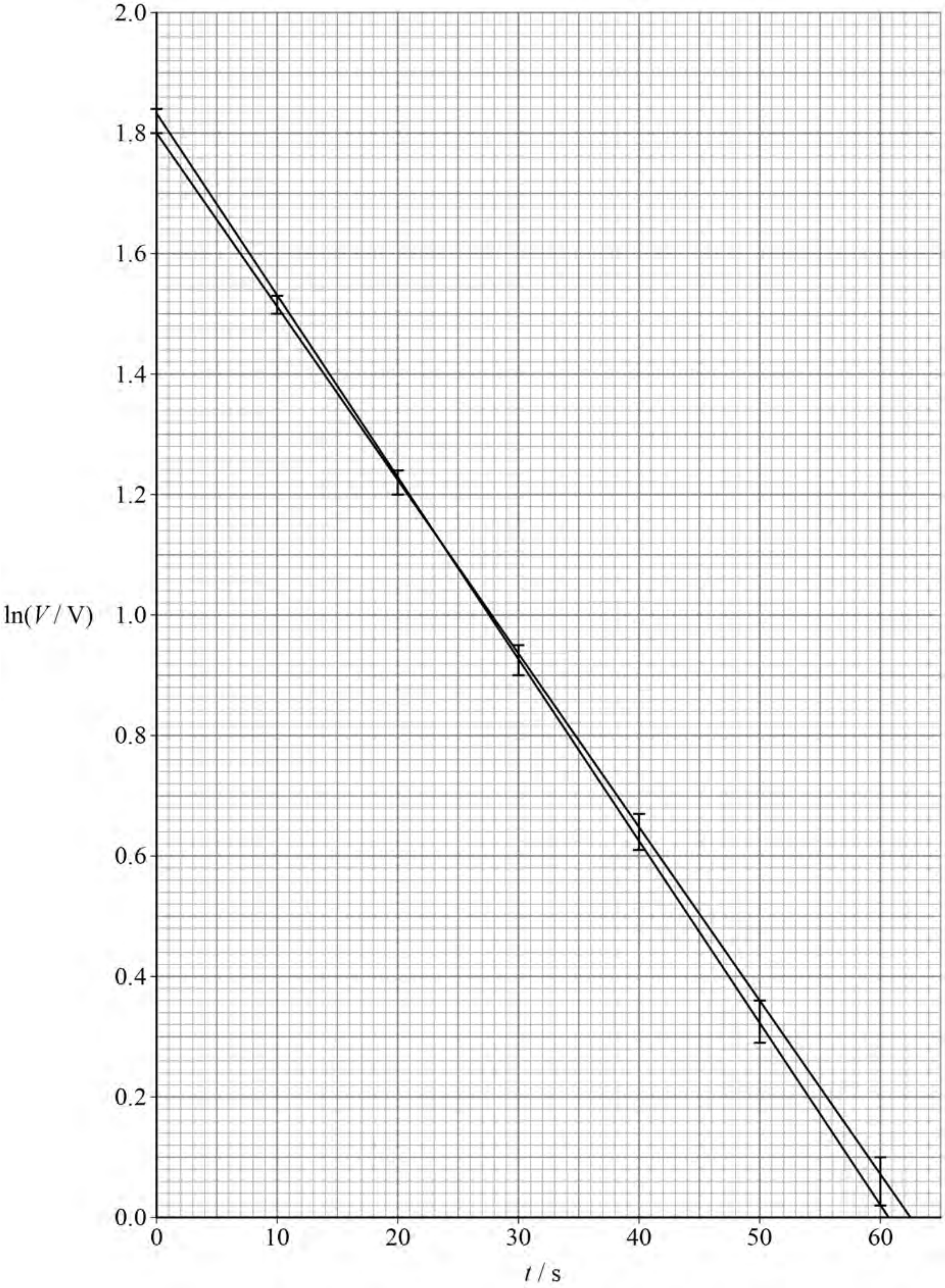
[2 marks]

Question 2 continues on the next page

Turn over ►

Figure 4 shows the student's graph. The lines have the maximum and the minimum gradients consistent with the error bars.

Figure 4



Do not write outside the box

0 2 . 2 Determine, using **Figure 4**, the mean value of the time constant RC.

[3 marks]

RC = ______________________ s

0 2 . 3 State the absolute uncertainty in your value of RC.

[1 mark]

absolute uncertainty = ______________________ s

0 2 . 4 Describe **one** random error that may occur in this experiment.

[1 mark]

____

____

0 2 . 5 Describe **one** systematic error that may occur in this experiment.

[1 mark]

____

____

Question 2 continues on the next page

Do not write outside the box

0 2 . 6 A second student repeats the experiment.
She makes a video of the voltmeter and stopclock and takes measurements of V and t from the video recording.

Explain **two** advantages of the second student's method.

[2 marks]

1 ______________________________

____

____

2 ______________________________

____

____

10

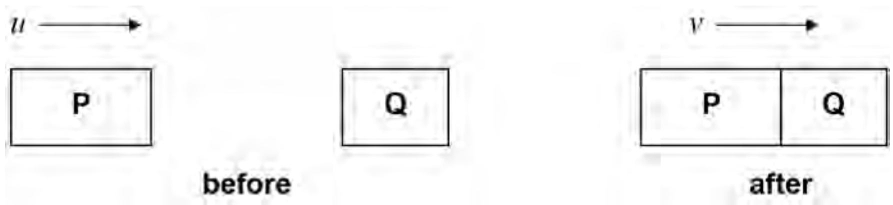
Do not write outside the box

0 3 A student wants to demonstrate the principle of conservation of momentum for objects moving in a horizontal plane.

A freely-moving object **P** collides with a stationary object **Q**.
P and **Q** move together after the collision.

Figure 5 shows the objects before and after the collision.
Before the collision, the velocity of **P** is u and the velocity of **Q** is zero.
After the collision, the velocity of **P** and **Q** is v.

Figure 5



0 3 . 1 Explain why it is necessary to minimise friction during a demonstration of the conservation of momentum.

[1 mark]

____

____

____

Question 3 continues on the next page

Turn over ►

Do not write outside the box

0 3 . 2 Describe how the student can demonstrate that momentum is conserved in the situation shown in **Figure 5**.

Your answer should include:

- a description of the apparatus used and how it minimises friction
- an account of the method
- an explanation of how the measurements are used.

[6 marks]

Do not write outside the box

0 3 . 3 In one experiment, **Q** is initially stationary.
The student determines that u is $(1.43 \pm 0.01)\ \mathrm{m\ s^{-1}}$ and v is $(0.85 \pm 0.01)\ \mathrm{m\ s^{-1}}$.

mass of **P** $= 1.82\ \mathrm{kg}$
mass of **Q** $= 1.19\ \mathrm{kg}$

Assume that the uncertainty in the values of the masses is negligible.

Discuss whether the data in this experiment support the principle of conservation of momentum.

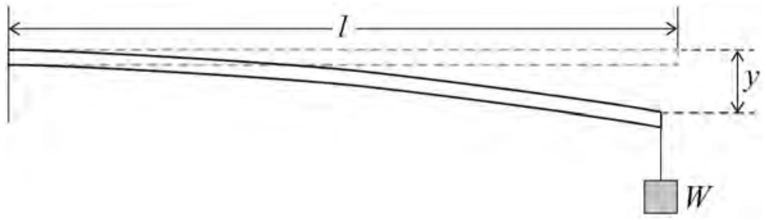
[2 marks]

9

Turn over for the next question

0 4 **Figure 6** shows a beam of length l being deflected by a constant weight W. The vertical deflection of the end of the beam is y.

Figure 6



Theory suggests that y is given by $y = kl^3$ where k is a constant.

A student measures y to the nearest mm for a range of values of l.
Table 1 shows the student's measurements and spaces for derived values.

Table 1

l / m	y / mm	$\sqrt[3]{y}$ / $\text{mm}^{\frac{1}{3}}$
0.200	1	
0.300	6	
0.400	14	
0.500	30	
0.600	50	

0 4 . 1 Complete **Table 1**.

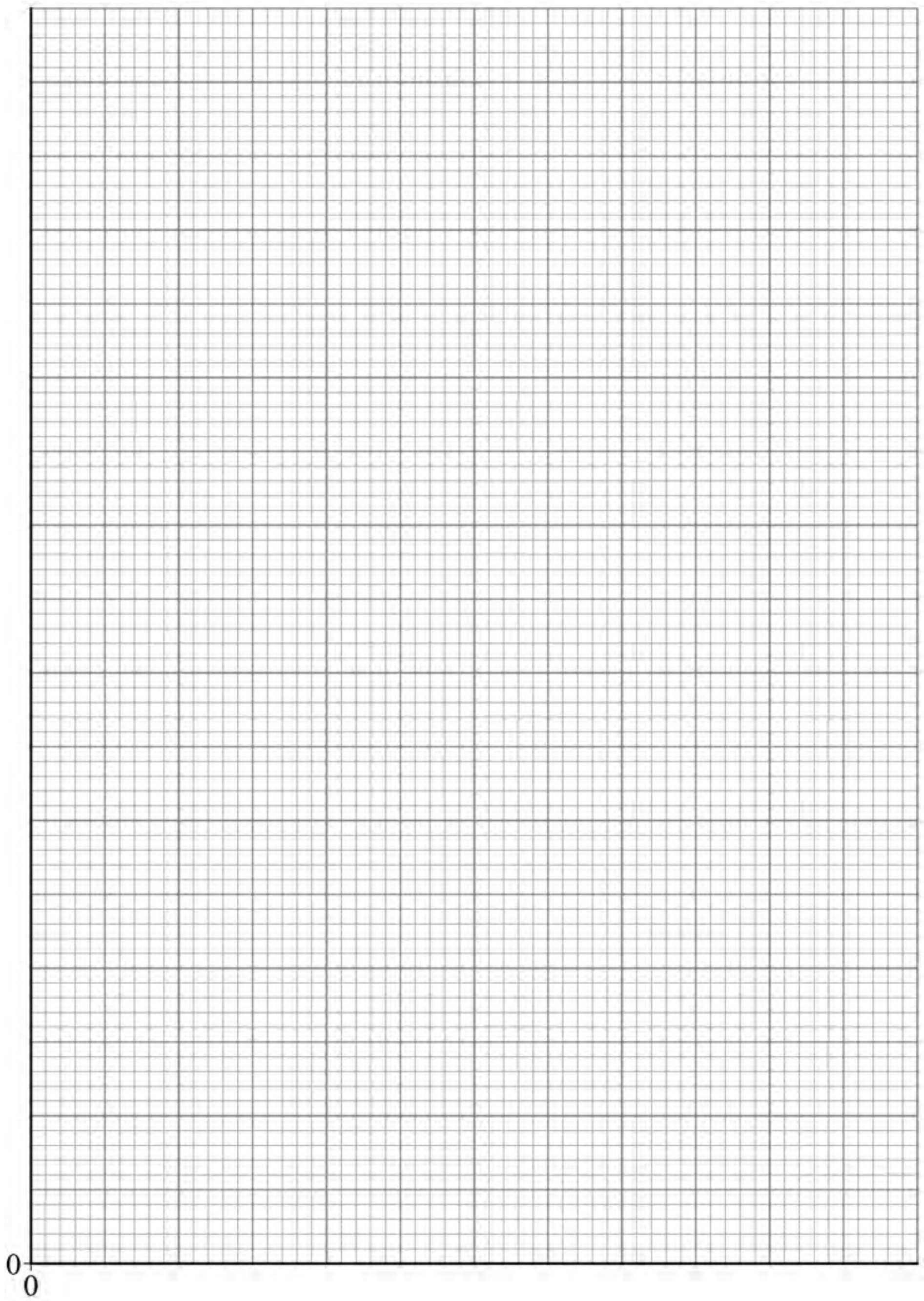
[1 mark]

0 4 . 2 Plot, on **Figure 7**, a graph of l against $\sqrt[3]{y}$.

[5 marks]

Do not write outside the box

Figure 7



0 4 . 3 Explain why your graph does not support the theory.

[1 mark]

7

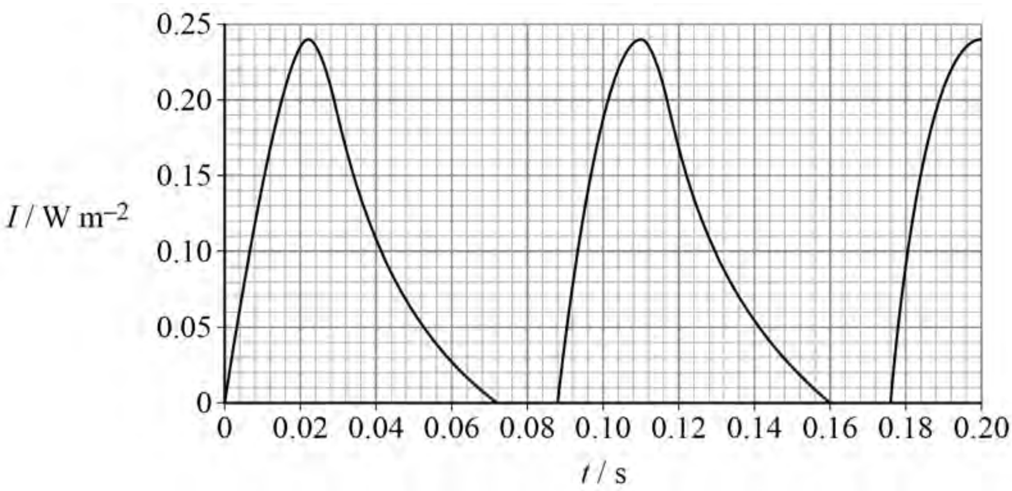
END OF SECTION A

Section B

Answer **all** questions in this section.

0 5 A stroboscope is a light that flashes on and off at a regular frequency. The intensity I of the light is measured 2.8 m from a stroboscope. **Figure 8** shows the variation of I with time t.

Figure 8



0 5 . 1 Calculate the frequency of the stroboscope flashes.

[2 marks]

frequency = ____________________ Hz

0 5 . 2 The stroboscope acts as a point source of light.

Show that the stroboscope emits light energy with a peak power of approximately 24 W.

[2 marks]

The stroboscope uses a filament lamp that has an efficiency of only 5.7% because it has a high operating temperature.

0 5 . 3 The stroboscope is switched on by applying a potential difference of 220 V dc across the filament lamp.

Calculate the resistance of the filament lamp when it is emitting light at its peak power.

[2 marks]

resistance = ____________________ Ω

0 5 . 4 During one pulse:

- the 220 V potential difference is applied across the filament lamp for 22 ms
- the filament lamp emits light for 72 ms.

Explain how this accounts for the shape of the pulses in **Figure 8**.

[2 marks]

____

____

____

____

____

____

Question 5 continues on the next page

0 5 . 5 A different stroboscope applies a sinusoidal ac voltage to an array of identical light emitting diodes (LEDs). LEDs only emit light when they are conducting.
Figure 9 shows the I–V characteristic for one of these LEDs.

Figure 9

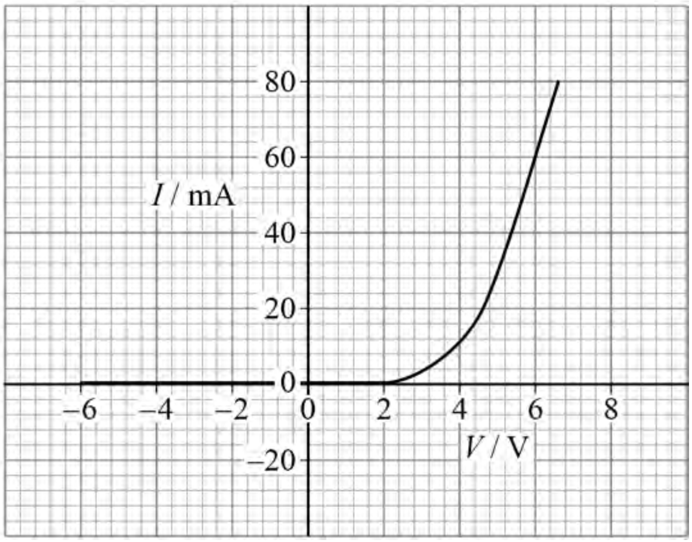
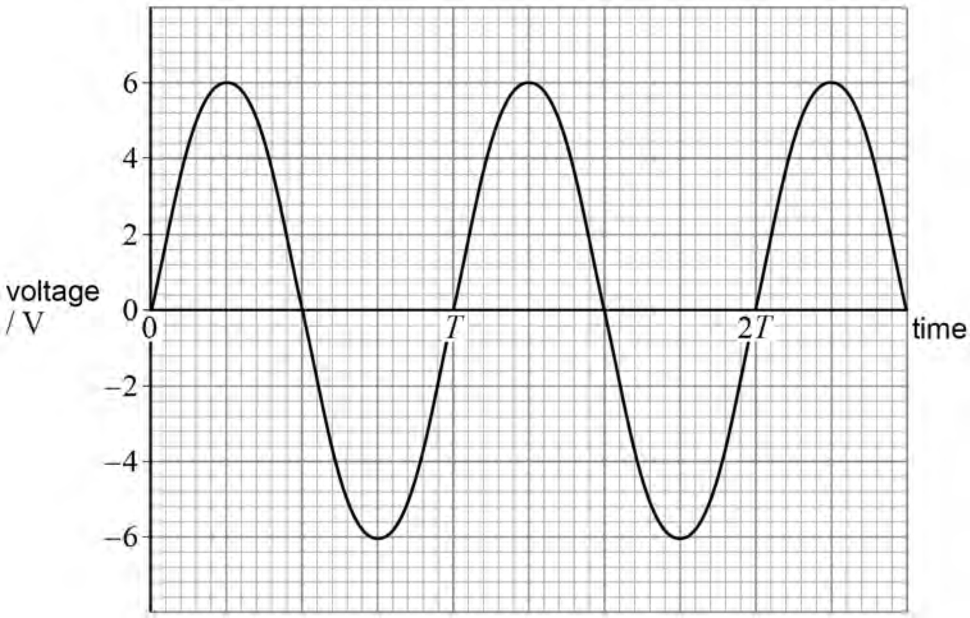


Figure 10 shows the variation with time of the sinusoidal voltage applied across the LED.
The periodic time of the applied voltage is T.

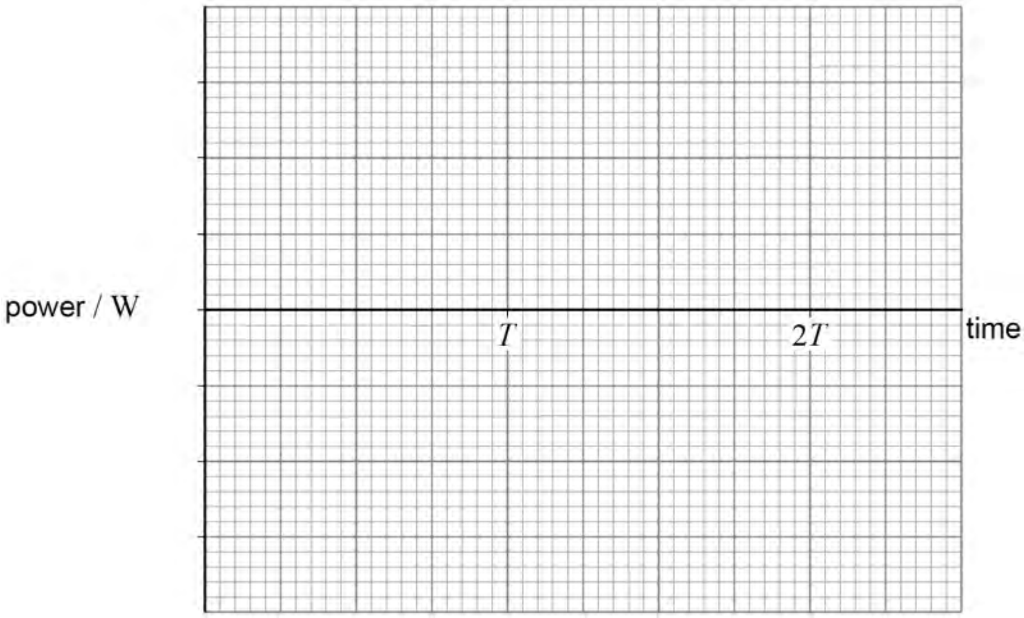
Figure 10



Sketch on **Figure 11** a graph to show the corresponding variation of output power with time for the LED.
Indicate the value of the peak power.
Assume that the LED is perfectly efficient.

[3 marks]

Figure 11



0 5 . 6 A stroboscope that uses LEDs is more efficient than a stroboscope that uses a filament lamp.

Suggest **one** other reason why LEDs are preferred for a stroboscope producing high-frequency flashes.

[1 mark]

____

____

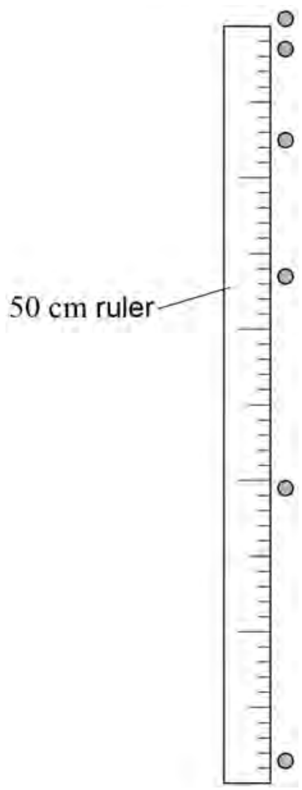
____

Question 5 continues on the next page

Do not write outside the box

0 5 . 7 The frequency of the stroboscope is adjusted to a new value.
It is used to illuminate a ball that is released from rest at the top of a vertical $50\ \mathrm{cm}$ ruler.
A camera records the position of the ball each time it is illuminated by a flash of the stroboscope.
Figure 12 shows the initial position of the ball, together with its positions during the next five flashes.

Figure 12



Air resistance is negligible.

Deduce the frequency of the stroboscope.

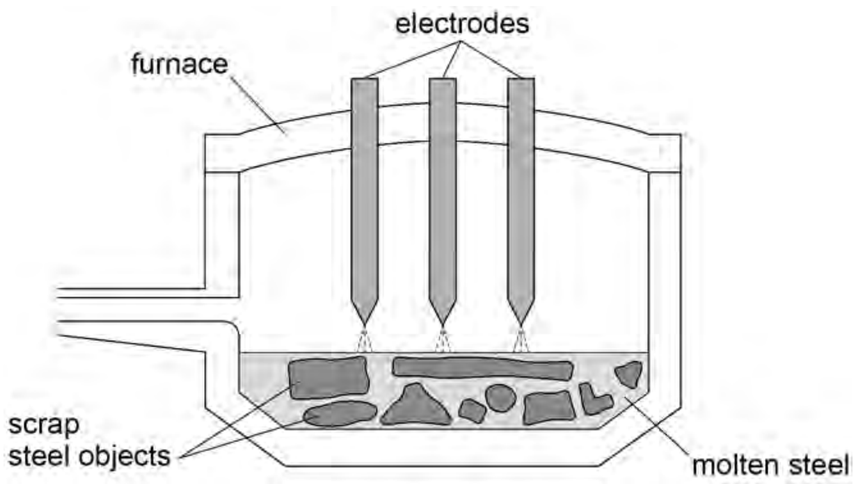
[4 marks]

frequency = ____________________ Hz

16

0 6 **Figure 13** shows an electric arc furnace that is melting scrap steel objects so that the steel can be recycled.

Figure 13



A mass of 9.3×10^4 kg of scrap steel at 20 °C is put into the furnace.
54 MW of power is supplied to the furnace by an ideal transformer.
Three electrodes are connected in parallel across the secondary coil of the transformer.
The potential difference between these electrodes and the scrap steel produces a large current that heats the steel.
The steel melts and its temperature is raised to 1800 °C.

0 6 . 1 Calculate, in minutes, the time taken to melt the steel and raise its temperature to 1800 °C.
Heat transfer to the furnace and surroundings is negligible.

melting temperature of steel = 1460 °C
specific heat capacity of solid steel = 0.510 kJ kg^{-1} K^{-1}
specific heat capacity of liquid steel = 0.980 kJ kg^{-1} K^{-1}
specific latent heat of steel = 240 kJ kg^{-1}

[4 marks]

time = ______________________ minutes

Question 6 continues on the next page

0 6 . 2 The transformer has a primary rms voltage of 66 kV.

Calculate the rms current in one of the electrodes.

$N_s = 36$
$N_p = 2430$

[3 marks]

rms current = ______________________ A

0 6 . 3 Air usually contains a small number of charge carriers.

Describe how the large current is produced in the air.

[2 marks]

____

____

____

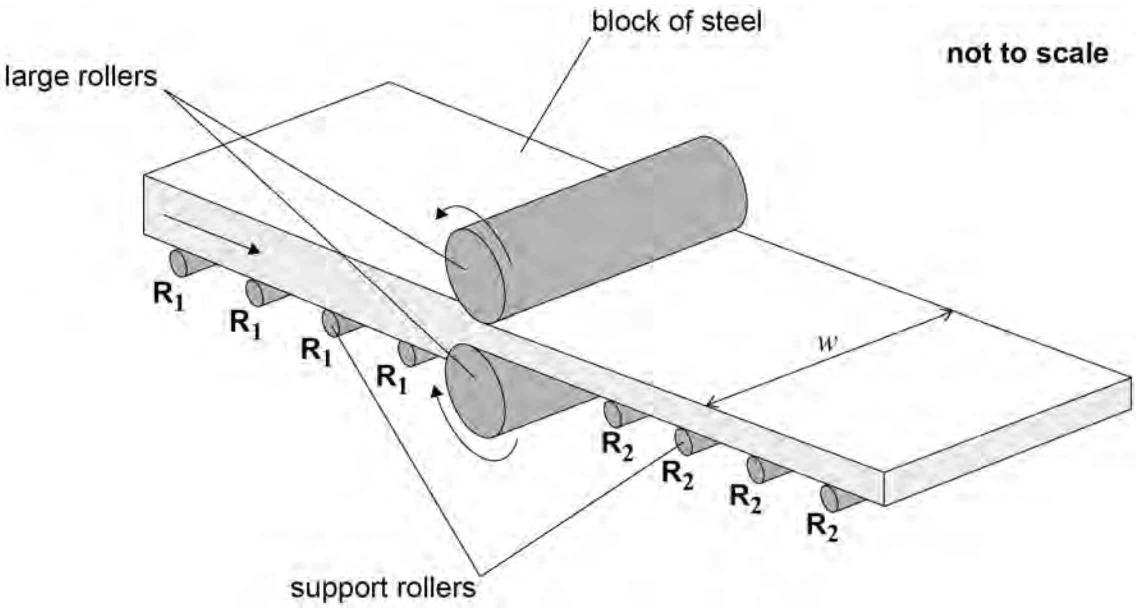
____

____

____

Steel from the furnace is cooled and made into a rectangular block.
The block is reduced in thickness by passing it through a rolling mill.
Figure 14 shows the block as it passes through the rolling mill.
The block approaches the large rollers on a set of smaller support rollers labelled $\mathbf{R_1}$.
The block passes between the large rollers where its thickness is reduced.
It leaves the large rollers on another set of support rollers labelled $\mathbf{R_2}$.

Figure 14



The thickness of the block is reduced from 22.0 cm to 17.8 cm. The width w of the block does not change.
The block is initially 4.20 m long and takes 3.5 s to pass between the large rollers.
The support rollers $\mathbf{R_1}$ and $\mathbf{R_2}$ have diameters of 12.5 cm.
The block does not slip on the rollers.

0 6 . 4 Calculate the angular velocity of the support rollers $\mathbf{R_2}$.

[3 marks]

angular velocity = ______________________ rad s^{-1}

12

Turn over ►

Do not write outside the box

0 7 **Figure 15** shows an electric guitar.

Figure 15

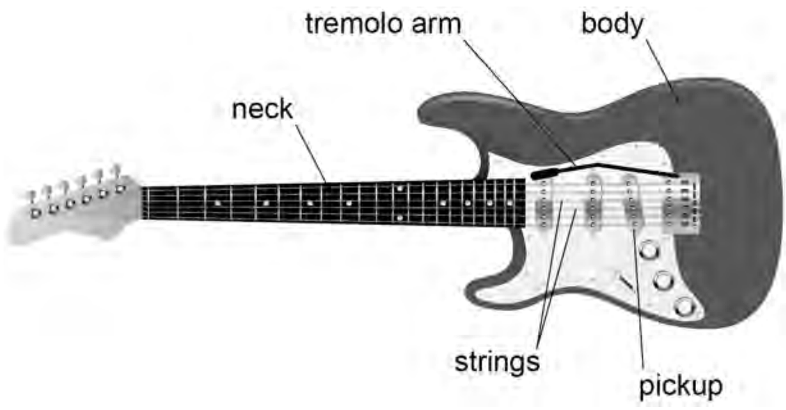
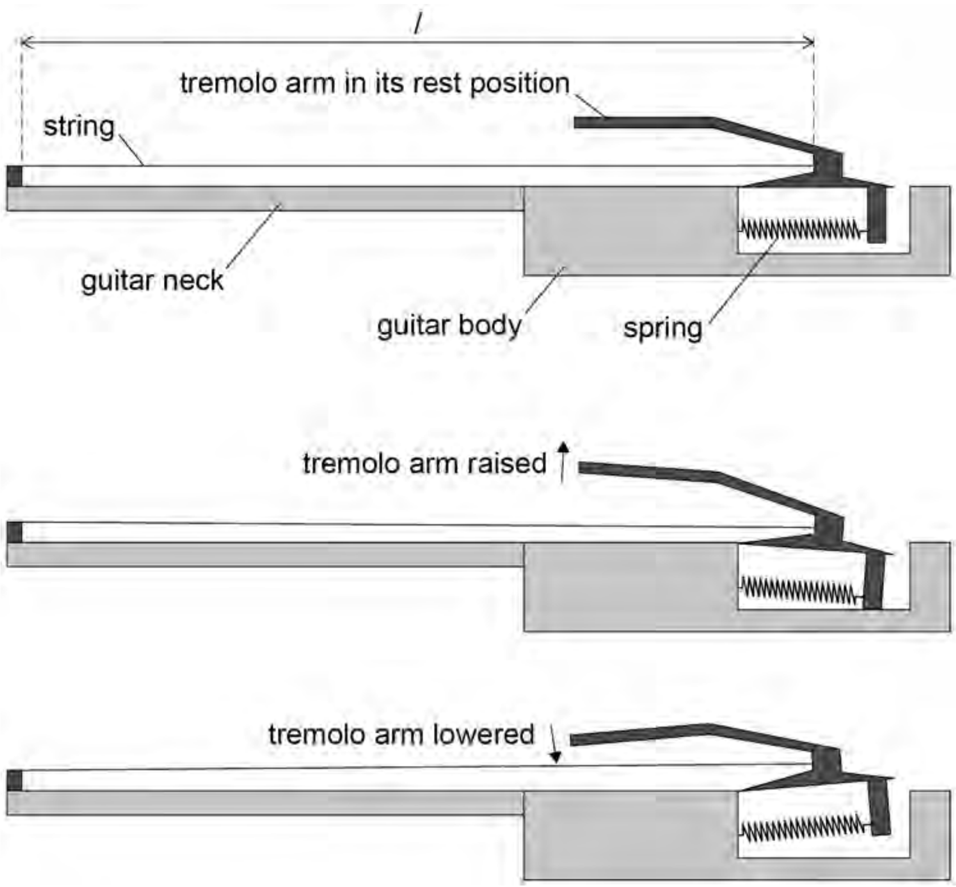


Figure 16 shows the effect on one of the guitar strings of raising and lowering the tremolo arm. The movement of the tremolo arm changes the frequency of the first harmonic of the string.

Figure 16



Changing the position of the tremolo arm changes the tension and length of the string. Assume that the mass per unit length and the diameter of the string do not change.

When the tremolo arm is in its rest position, the frequency of the first harmonic is 330 Hz, l is 0.647 m and the tension in the string is 56.4 N.

The tremolo arm is now raised, increasing l by 0.13 mm.

The increase in tension and in length cause the frequency of the harmonic to change.

0 7 . 1 Calculate the change in frequency of the first harmonic.

cross-sectional area of string = $4.52 \times 10^{-8} \text{ m}^2$
Young modulus of material of string = $1.92 \times 10^{11} \text{ Pa}$
mass per unit length of string = $3.09 \times 10^{-4} \text{ kg m}^{-1}$

[5 marks]

change in frequency = ____________________ Hz

0 7 . 2 Lowering the tremolo arm below its rest position

- decreases the length of the string
- decreases the tension in the string.

Deduce the overall effect on the frequency of the first harmonic of lowering the tremolo arm.

[2 marks]

____

____

____

____

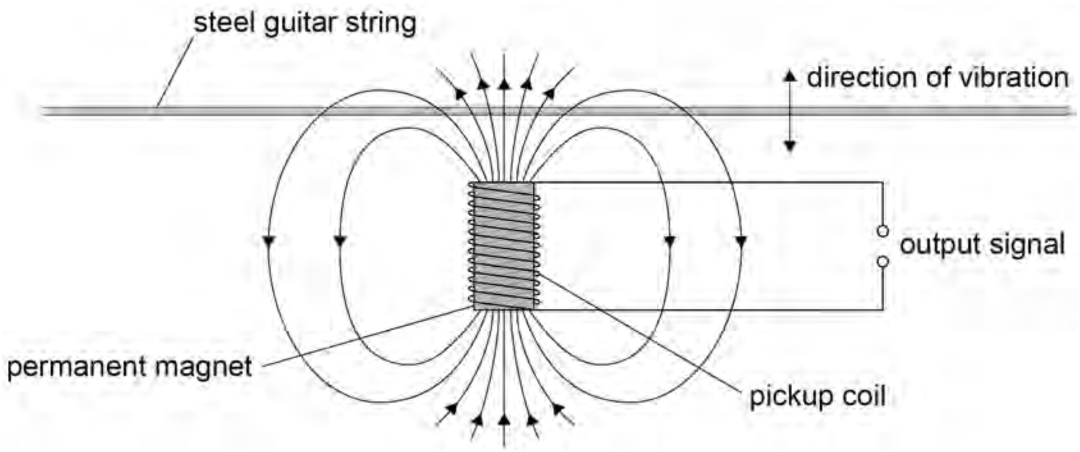
____

____

Do not write outside the box

The string of an electric guitar is made from steel that is a magnetic material.
The guitar uses a pickup to detect the vibrations of the string.
Figure 17 shows a simplified guitar pickup that produces an alternating electrical signal when the string vibrates.

Figure 17



The magnetic flux from the permanent magnet links the steel string and the coil around the magnet. The magnetic field shown in **Figure 17** is changed by the movement of the string.
When the string vibrates, an alternating emf is induced in the coil.
This emf is the output signal that is then amplified.

0 7 . 3 Explain why an emf is induced in the coil when the string moves.

[1 mark]

0 7 . 4 At one instant, the string is moving upwards.

State and explain, using Lenz's law, the effect that this movement has on the magnetic field strength between the magnet and the string.

[2 marks]

Do not write outside the box

0 7 . 5 The pickup coil has 7200 turns.
There is a peak current of 18.0 μA in the coil when the string vibrates.
Table 2 gives data for the wire used to make the coil.

Table 2

Resistivity of material of wire	$1.68 \times 10^{-8}\ \Omega\ m$
Length of wire	815 m
Cross-sectional area of wire	$6.56 \times 10^{-9}\ m^2$

Calculate the maximum rate of change of magnetic flux in the coil.

[3 marks]

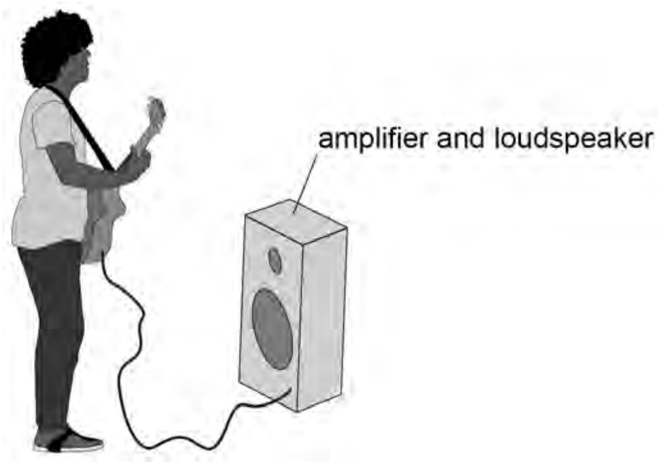
maximum rate of change of magnetic flux = ____________________ $Wb\ s^{-1}$

Question 7 continues on the next page

Do not write outside the box

0 7 . 6 **Figure 18** shows a student using an electric guitar connected to an amplifier and loudspeaker.

Figure 18



Initially the amplifier is turned off. The student stands next to the loudspeaker and plucks a string, so that it vibrates. The string stops vibrating after a short time.

The amplifier is now turned on. When the student plucks the string again he hears the sound from the loudspeaker. This time, the string continues to vibrate and the amplitude of vibrations increases.

Explain why the amplitude of vibrations of the string increases when the amplifier is turned on.

[3 marks]

16

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	Additional page, if required. Write the question numbers in the left-hand margin.

Do not write outside the box

Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

Copyright information