Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Thursday 15 June 2023

Morning (Time: 2 hours 30 minutes) | **Paper reference** **9PH0/03**

Physics

Advanced

PAPER 3: General and Practical Principles in Physics

You must have:
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions marked with an **asterisk** (*****), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

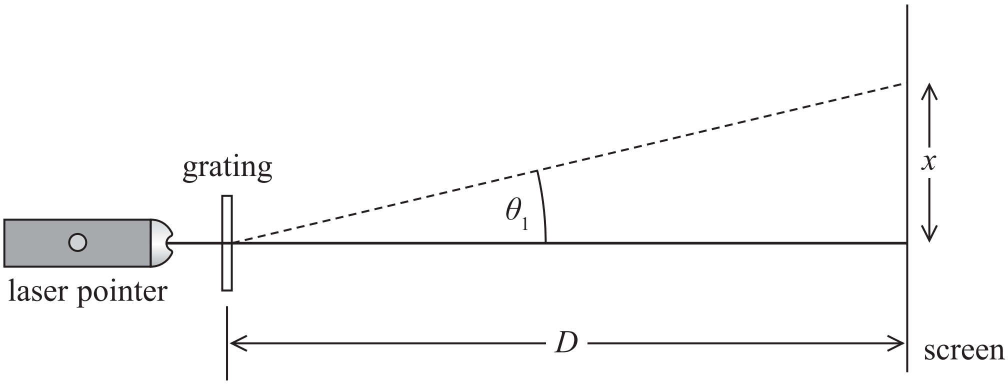
- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- You are advised to show your working in calculations including units where appropriate.

Turn over ▶

Pearson

Answer ALL questions in the spaces provided.

1 A student used a laser pointer to direct monochromatic light normal to the plane of a diffraction grating as shown.



A diffraction pattern was produced on the screen. The distance between the first order maximum and the central maximum of the diffraction pattern was x. The distance between the diffraction grating and the screen was D.

(a) The diffraction grating had 300 lines per mm.
The laser pen was marked with $\lambda = 520\,\text{nm}$.

Determine whether the spacing of the diffraction pattern was consistent with these values.

$x = 43.5\,\text{cm}$
$D = 2.75\,\text{m}$

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(b) The student wrote the following conclusion:

"The value of x was measured with a metre rule. A metre rule has a precision of 0.1 cm, so this value was determined with a high degree of accuracy."

Comment on this conclusion.

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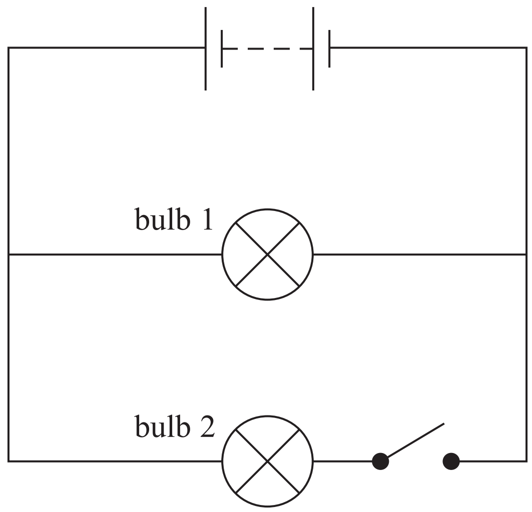
(Total for Question 1 = 7 marks)

2 A battery has an e.m.f. of 12 V and an internal resistance of 0.50 Ω. The battery is connected into a circuit, as shown.



Each bulb has a normal working power of 40 W when a potential difference (p.d.) of 12 V is applied.

(a) Initially the switch is open.

Calculate the terminal p.d. of the battery when bulb 1 is lit. Assume that the resistance of the bulb has its normal working value.

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Terminal p.d. of battery = ...

(b) Explain how the brightness of bulb 1 changes when the switch is closed. No further calculations are necessary.

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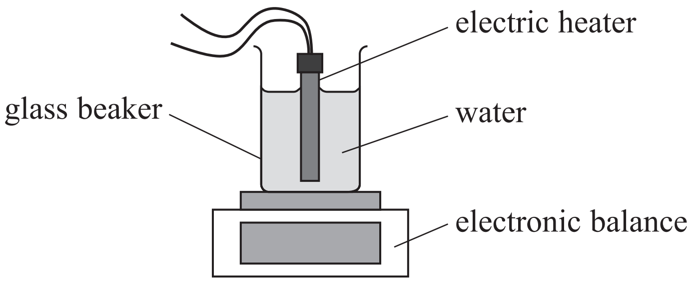
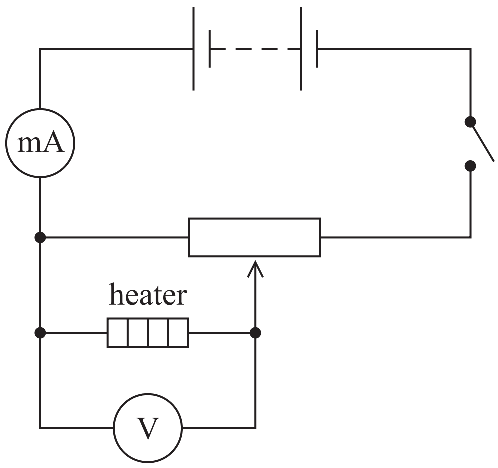
(Total for Question 2 = 7 marks)

3 The specific latent heat of vaporisation of water can be determined using the apparatus shown.



(a) A student planned to vary the current in the heater from 0 A to 5 A. The student connected the following circuit to measure the current in the heater.



Criticise the student's circuit.

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P 7 1 9 1 7 R A 0 6 3 6

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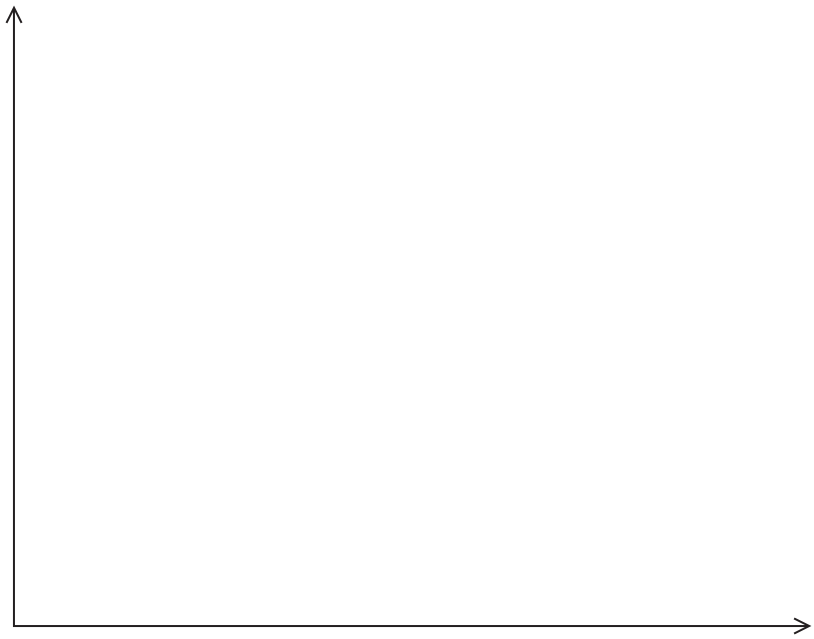
(b) (i) The student corrected the circuit and closed the switch. He waited until the water started boiling. He started a stopwatch and recorded the readings on the balance at regular time intervals.

Sketch a graph, on the axes below, of how the readings on the balance would vary with time.

(3)



(ii) The heater was switched on for 6.0 minutes and the change in mass of water in the beaker was 7.5 g.

Calculate the specific latent heat of vaporisation of water, L.

$V = 12\,\text{V}$
$I = 4.2\,\text{A}$

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L = ...

(iii) The errors in the experiment include uncertainty in the mass reading and uncertainty in reading the stopwatch, as the water boils.

Explain how another significant source of error affects the value of L obtained from the experiment.

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(Total for Question 3 = 10 marks)

*4 Alpha particle scattering experiments led Rutherford to propose the nuclear model of the atom. Alpha particles were directed towards a thin gold foil.

Describe how evidence from these experiments supports the nuclear model of the atom.

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(Total for Question 4 = 6 marks)

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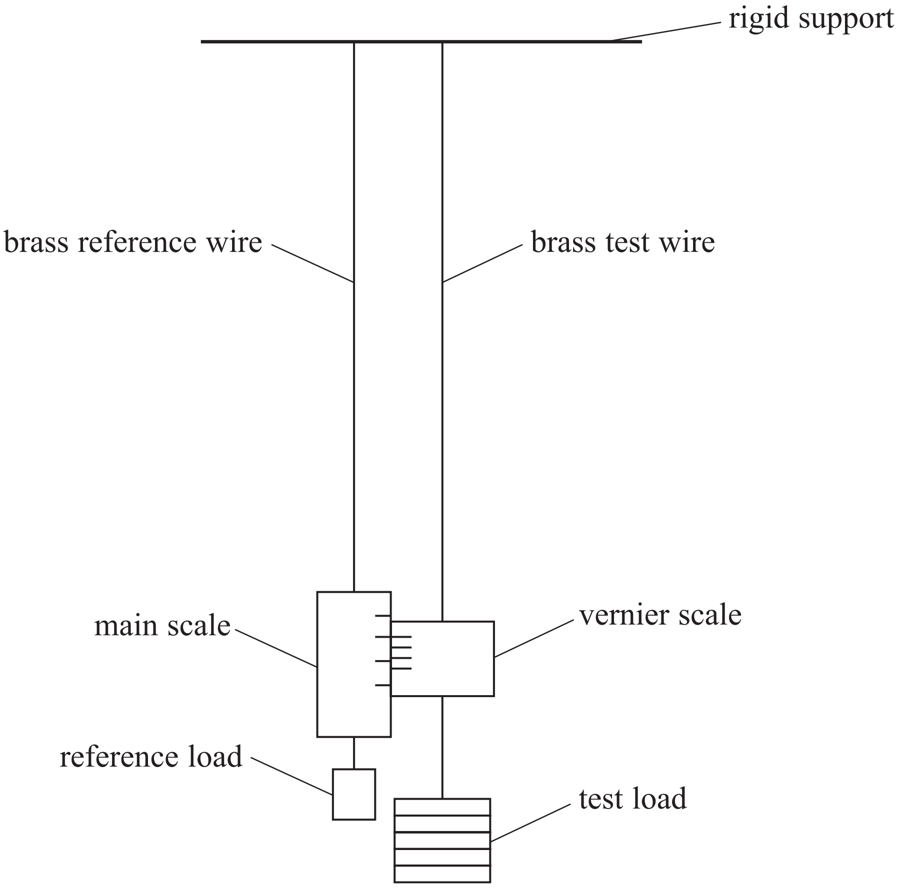
5 A student used the apparatus shown to determine the Young modulus of brass. Loads were added to the test wire and corresponding readings taken from the vernier scale. The test wire and the reference wire were identical.



(a) (i) Give one advantage of using a reference wire as well as a test wire.

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(ii) State why a reference load was applied to the reference wire.

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(b) Explain why the test wire should be both long and thin.

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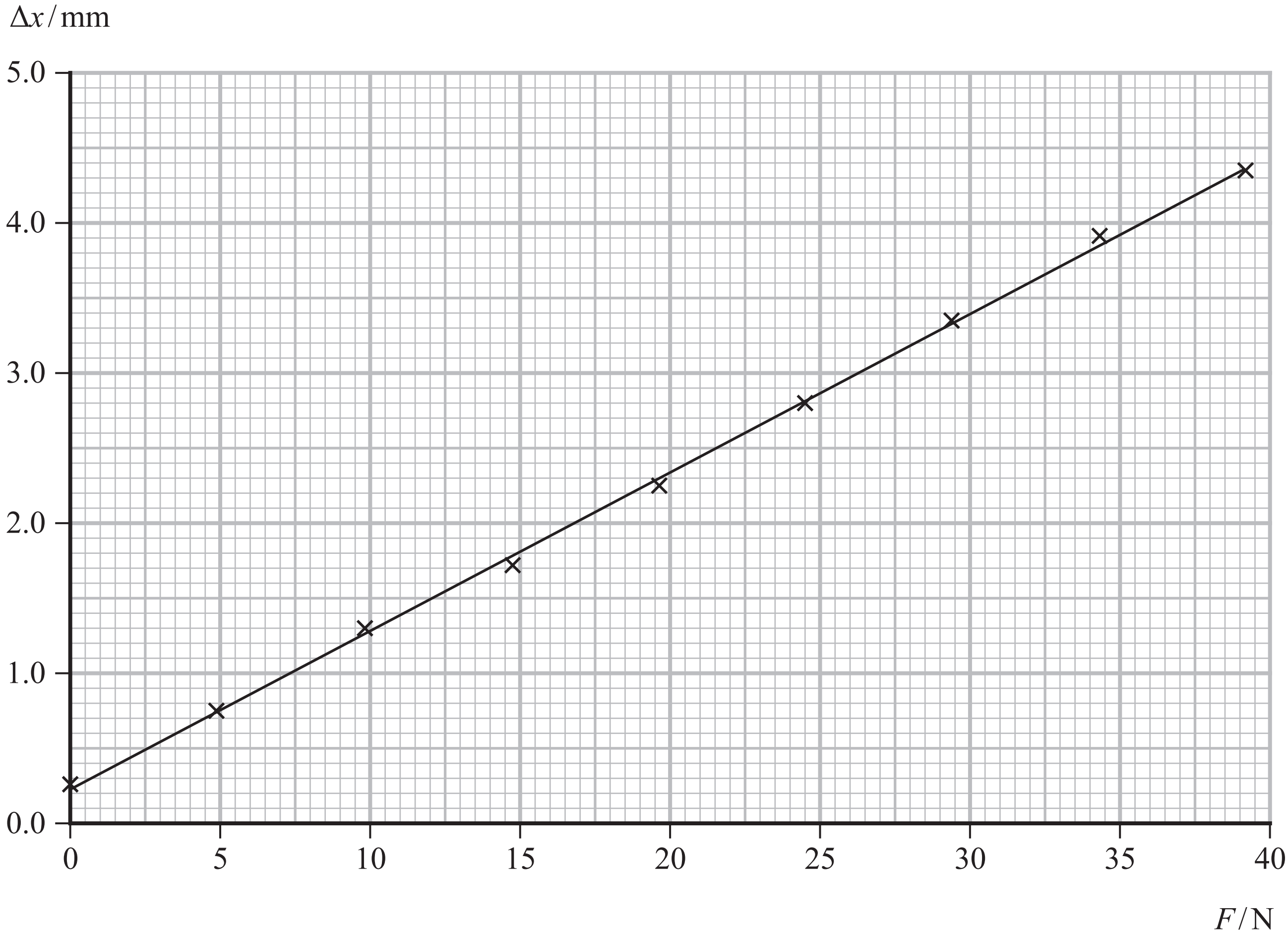
(c) The student varied the load F on the test wire and recorded the corresponding change in length Δx from the vernier scale. The results are shown on the graph.



Determine a value for the Young modulus of brass.

length of wire = 2.75 m
diameter of wire = 5.60×10^{-4} m

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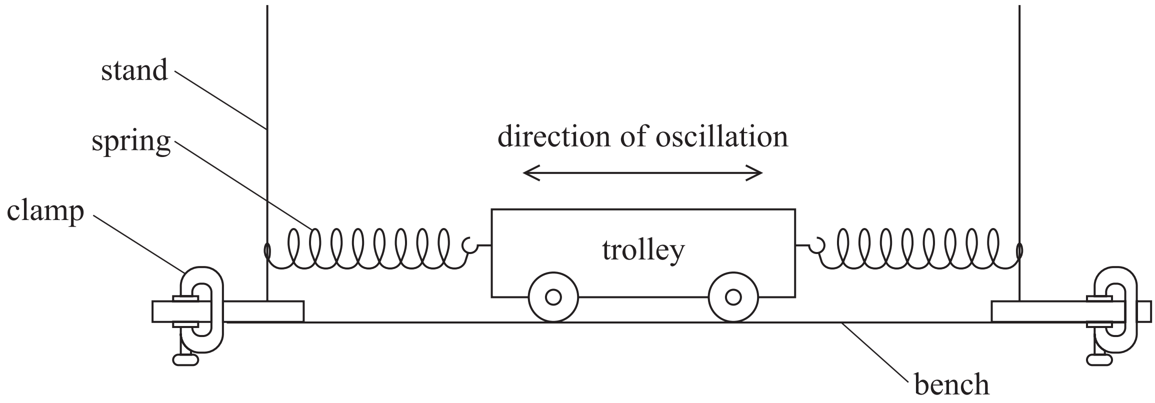
Young modulus of brass = ...

(Total for Question 5 = 10 marks)

6 A student investigated the horizontal oscillations of a trolley between two springs, using the apparatus shown.



The student displaced the trolley from its equilibrium position. She then released the trolley and started a stopwatch. She stopped the stopwatch when the trolley had completed one oscillation.

(a) Describe how the method used by the student could be improved to determine a more accurate value of the time period.

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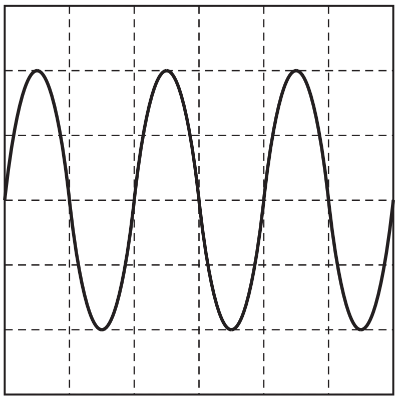
(b) The student displaced the trolley 6.0 cm from the equilibrium position. She recorded the velocity of the oscillating trolley using a sensor connected to a data logger.

The output from the data logger is shown below.



The time-base of the data logger output was set to $250\,\text{ms div}^{-1}$.

Determine the maximum velocity of the trolley.

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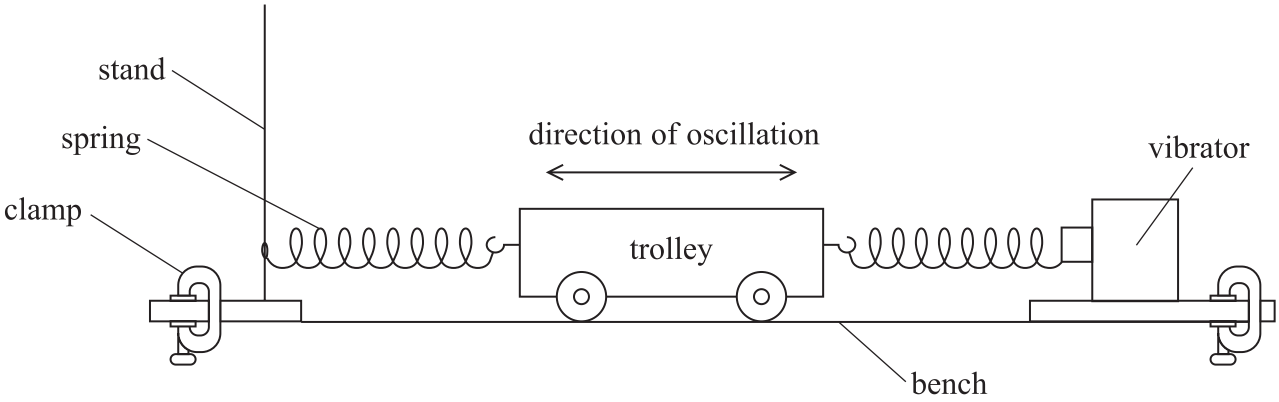
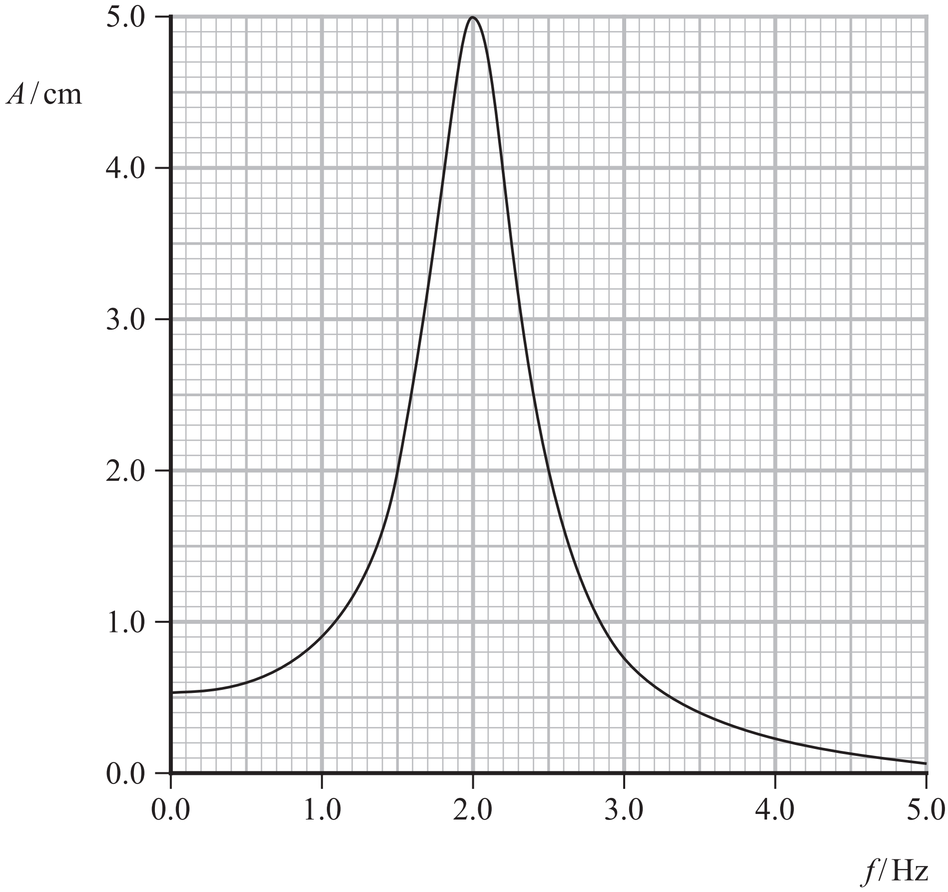
Maximum velocity of trolley = ...

(c) The student modified the apparatus so that the trolley was driven into oscillation by a vibrator, as shown.

A sensor connected to a data logger recorded the amplitude *A* of the oscillations.



The graph shows how *A* varied as the student increased the frequency *f* of the oscillations.



(i) Explain the shape of the graph.

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(ii) Determine the effective spring constant k of the oscillating trolley system.

mass of trolley = 0.87 kg

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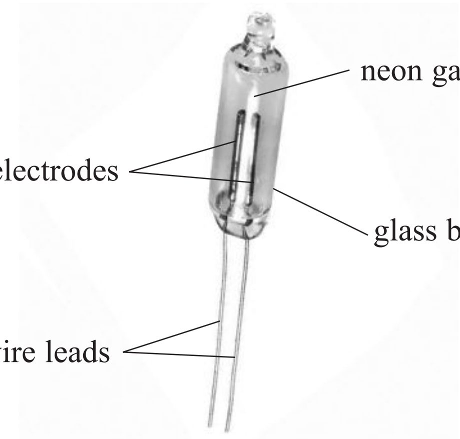
k = ...

(Total for Question 6 = 15 marks)

7 The neon lamp shown is a glass bulb filled with neon gas at low pressure.



(Source: https://media.digikey.com/Photos/Visual%20Communications%20Company%20VCC/A1A.JPG)

*(a) When in use, the neon gas between the electrodes emits electromagnetic radiation.

Explain why this happens when there is an electric current between the electrodes.

(6)

(b) When light from the neon lamp is incident upon a metal surface, electrons with a maximum speed of $2.68 \times 10^5 \, m\, s^{-1}$ are emitted from the surface.

The table shows the work functions of some metals.

Metal	Caesium	Potassium	Sodium
Work function / 10^{-19} J	3.36	3.68	3.84

Deduce which metal the light is incident upon.

frequency of light from the neon lamp = 5.56×10^{14} Hz

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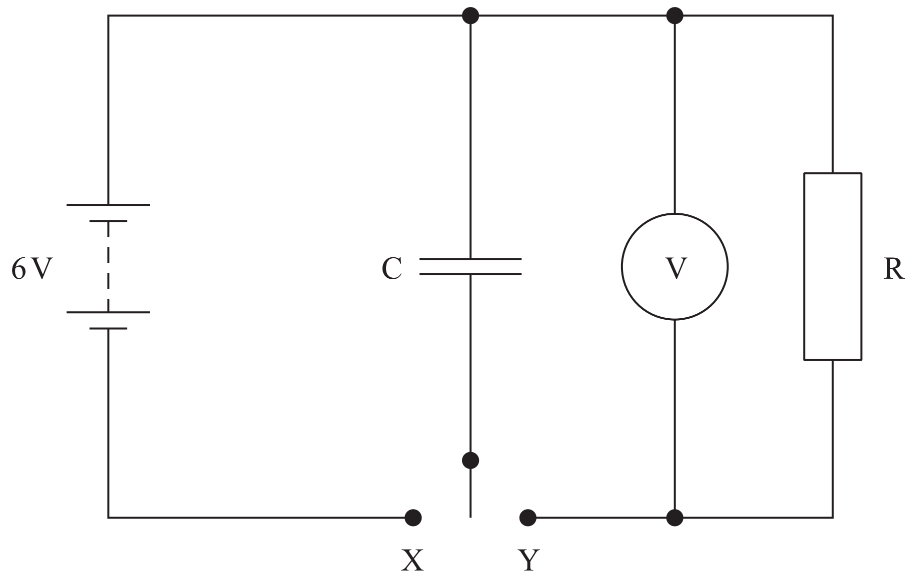
(Total for Question 7 = 10 marks)

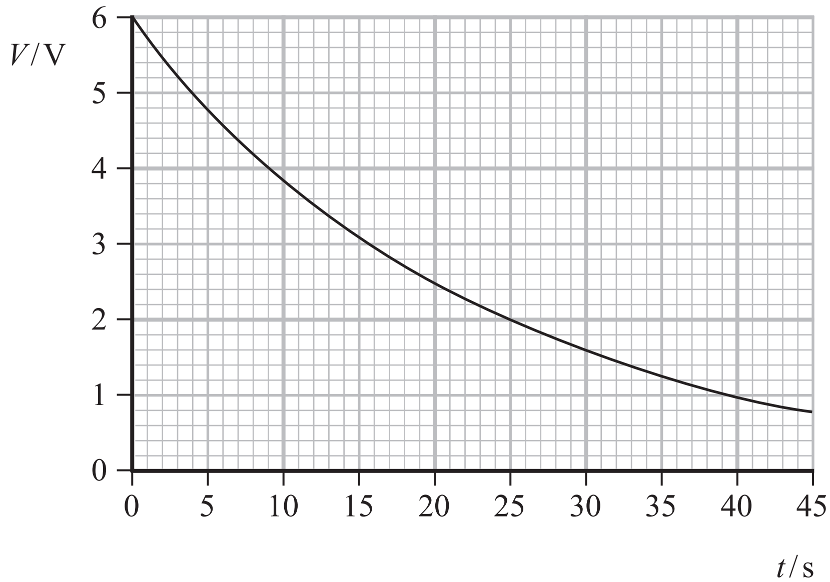
8 A student investigated the discharge of a capacitor C through a resistor R using the circuit shown.



The student used the switch to connect C to X to charge the capacitor. She then connected C to Y to discharge the capacitor through R.

As the capacitor discharged, she recorded values of the potential difference V across C and corresponding values of time t. She used a stopwatch to measure t.

The student used her results to plot the following graph.



(a) The capacitor was marked $220\,\mu F \pm 20\%$.

Deduce whether the student's data give a value of capacitance within the stated range.

$R = 82\,k\Omega$

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(b) The student suggested that her results would have been more accurate if she had used a data logger to record the data.

Assess the student's suggestion.

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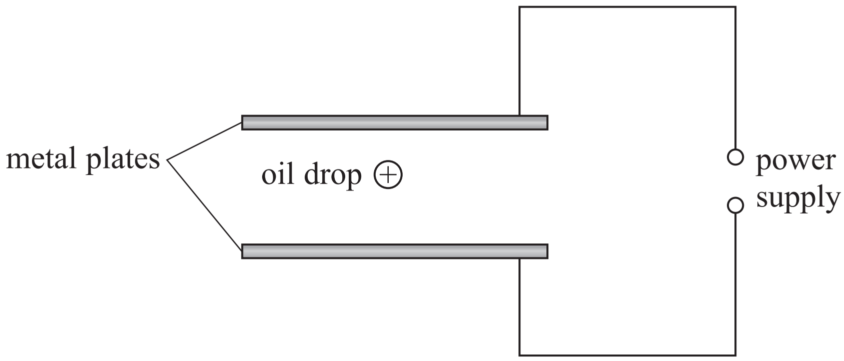
(Total for Question 8 = 8 marks)

9 A student investigated the behaviour of small, positively charged oil drops in an electric field.

He introduced an oil drop between two horizontal metal plates. A potential difference V was applied to bring the oil drop to rest as shown.



(a) (i) Add to the diagram to show the polarity of the power supply when the oil drop is at rest.

(1)

(ii) The oil drop was at rest when $V = 4870\,\text{V}$.

The student expected the charge on the oil drop to be a whole number multiple of the charge on an electron.

Deduce whether this is confirmed by the experimental data.

distance between top plate and bottom plate = 1.55 cm
density of oil = $920\,\text{kg}\,\text{m}^{-3}$
radius of the oil drop = $1.78 \times 10^{-6}\,\text{m}$

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(b) The student determined the terminal velocity of the oil drop in order to obtain a value for the weight of the oil drop.

He disconnected the power supply and the oil drop fell downwards. He viewed the oil drop through a microscope.

(i) Explain why the student should wait a short while before starting to take measurements.

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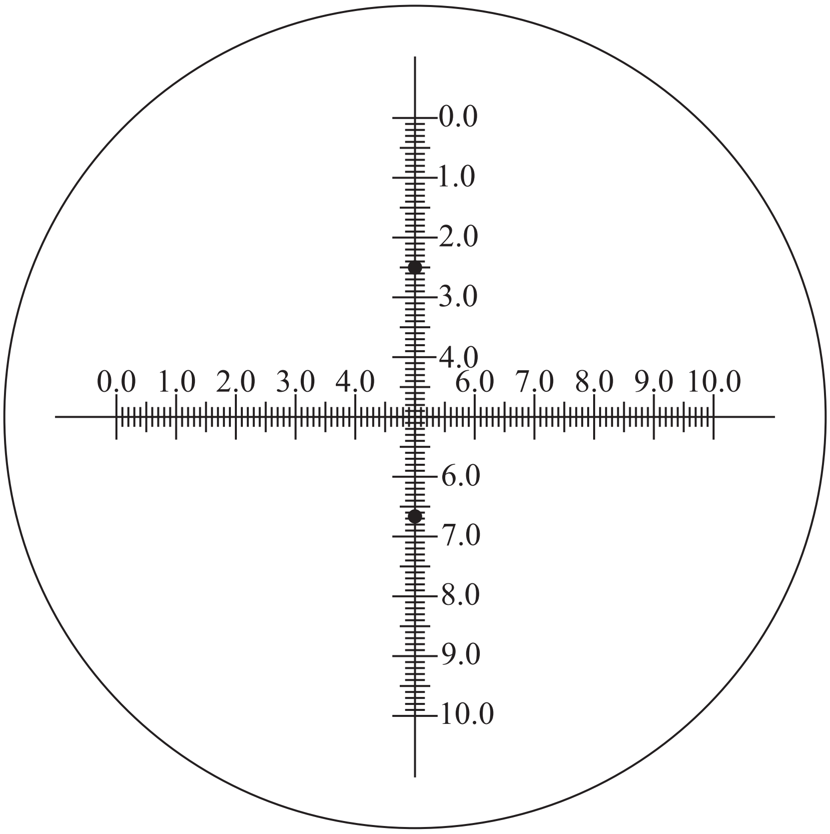
(ii) The view through the microscope is shown below. The scale is in millimetres.



The position of the oil drop at the start and end of a 120 s time interval is indicated by the black dots.

Determine the terminal velocity of the oil drop.

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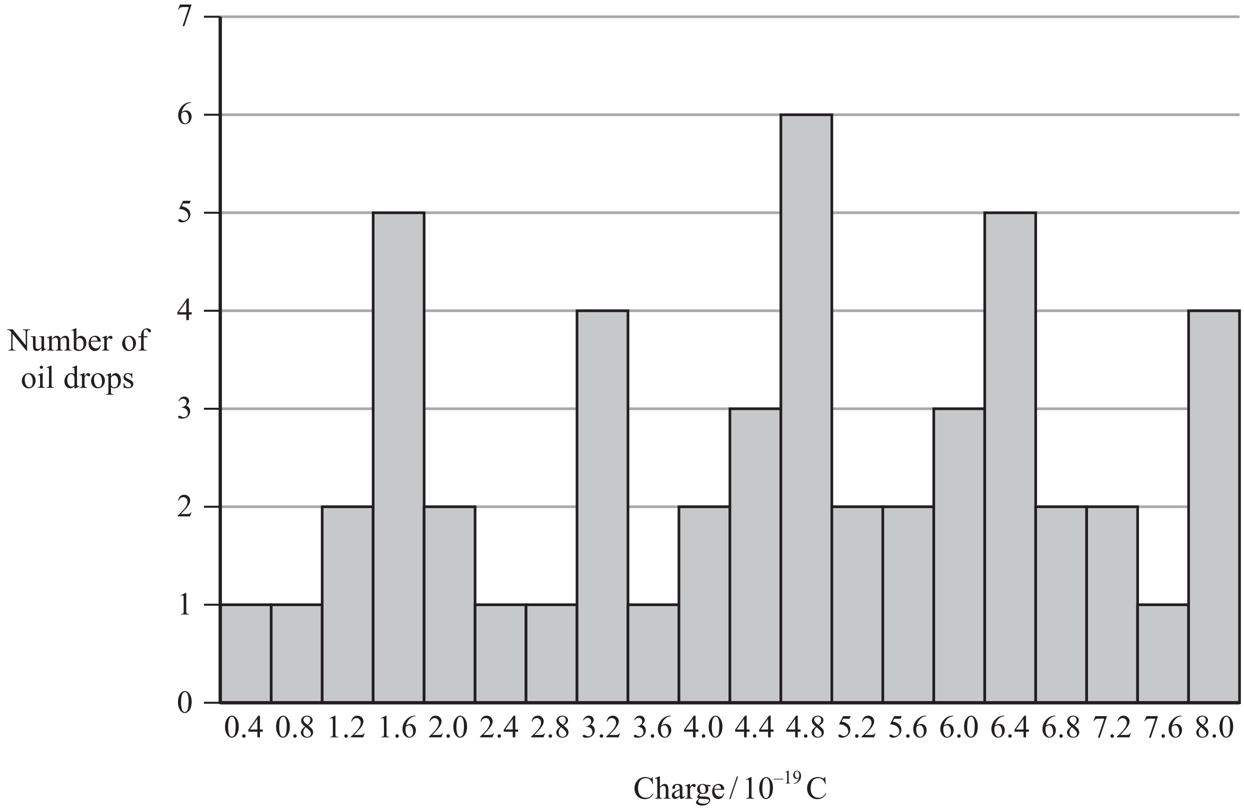
Terminal velocity = ...

(c) The student repeated the measurements on fifty oil drops. For each drop the student calculated the charge on the oil drop.

His results are shown in the bar chart.



The student predicted that the charge on each oil drop would be a whole number multiple of the charge on an electron.

Comment on the extent to which the bar chart supports the student's prediction.

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(Total for Question 9 = 15 marks)

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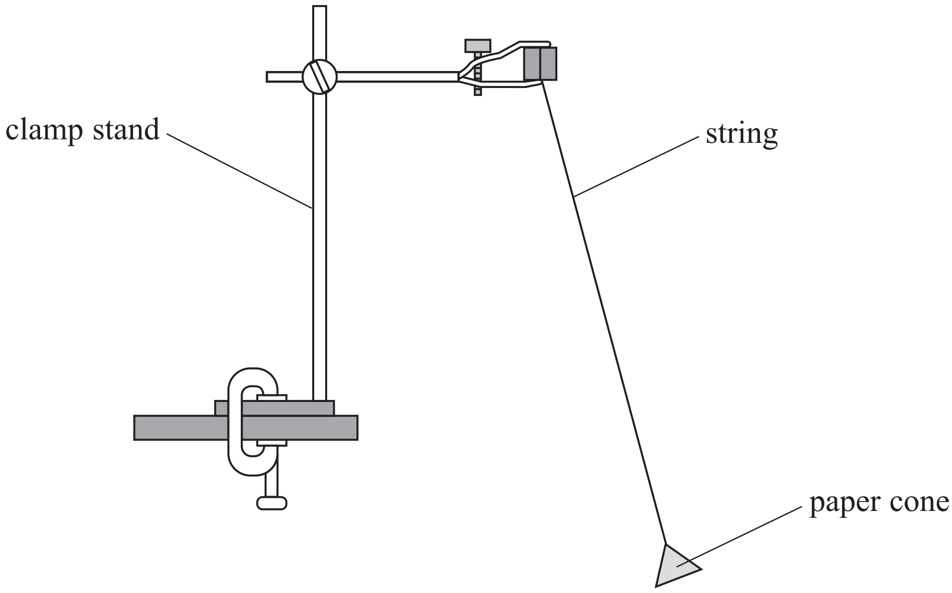
10 A student made a simple pendulum by connecting a paper cone to a piece of string. She attached the pendulum to a clamp as shown.



(a) (i) The student displaced the pendulum through a small angle so that it oscillated. She determined the time period T as 2.50 s.

Calculate the length of the pendulum.

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Length of pendulum = ...

(ii) Explain why the amplitude of oscillation of the pendulum did not stay constant.

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(b) The student recorded how the amplitude of oscillation varied over time.

(i) It is suggested that the relationship between amplitude A and time t is

$$A = A_0 e^{-\frac{kt}{T}}$$

where A_0 is the initial amplitude of the oscillation and k is a constant.

Explain why a graph of $\ln A$ against t would give a straight line.

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(ii) The table shows the student's data.

***t* / s**	***A* / cm**	
2.5	17.6	
5.0	14.3	
7.5	11.6	
10.0	9.4	
12.5	7.6	

Plot a graph of $\ln A$ against t on the grid opposite. Use the additional column to show your processed data.

(5)

(iii) Determine values for A_0 and k.

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A_0 = ...

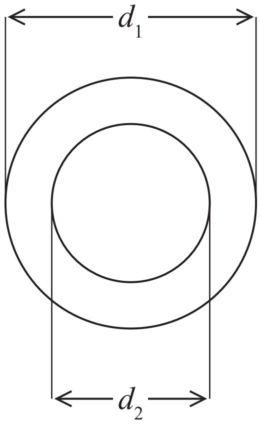
k = ...

(Total for Question 10 = 16 marks)

11 The photograph shows some metal washers. A student carried out an experiment to determine the density of the metal the washers are made from.

(Source: © NJH Photography/Shutterstock)

Each washer has a diameter d_1 of about 4.5 cm. The internal diameter d_2 of each washer is about 2.5 cm. Each washer has a thickness t of about 4 mm.



(a) The student used a half metre rule to make measurements of a washer.

Comment on the student's choice of measuring instrument.

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(b) The student measured t for each of the five washers and then calculated a mean value.

Explain how the student could modify her method to obtain a more accurate mean value for t.

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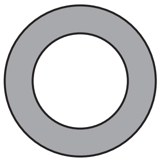
(c) The student obtained the following mean values.

$d_1 = 4.52\,\text{cm} \pm 0.02\,\text{cm}$

$d_2 = 2.53\,\text{cm} \pm 0.02\,\text{cm}$

She calculated the area A of a washer indicated by the shaded section below.



She used the formula $A = \frac{\pi}{4}(d_1 + d_2)(d_1 - d_2)$

(i) Show that the percentage uncertainty in her value for the area of a washer is about 3%.

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(ii) The student obtained the following values of t for each of the five washers.

t / mm	4.3	4.2	4.1	3.9	4.0

The table shows the density of iron and steel.

Metal	Iron	Steel
Density / g cm^{-3}	6.9	7.9

Deduce whether the washers are made from iron or steel.

mean mass of a washer = 32.0 g

The uncertainty in the mass is negligible.

(6)

(Total for Question 11 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

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List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb law constant	$k = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Mechanics

Kinematic equations of motion

$$s = \frac{(u+v)t}{2}$$

$$v = u + at$$

$$s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

$$\text{moment of force} = Fx$$

Momentum

$$p = mv$$

Work, energy and power

$$\Delta W = F\Delta s$$

$$E_k = \tfrac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Electric circuits

Potential difference

$$V = \frac{W}{Q}$$

Resistance

$$R = \frac{V}{I}$$

Electrical power and energy

$$P = VI$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

$$W = VIt$$

Resistivity

$$R = \frac{\rho l}{A}$$

Current

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = nqvA$$

Materials

Density

$$\rho = \frac{m}{V}$$

Stokes' law

$$F = 6\pi\eta rv$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{\Delta x}{x}$$

$$E = \frac{\sigma}{\varepsilon}$$

Elastic strain energy

$$\Delta E_{el} = \tfrac{1}{2}F\Delta x$$

Waves and particle nature of light

Wave speed

$$v = f\lambda$$

Speed of a transverse wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

Intensity of radiation

$$I = \frac{P}{A}$$

Power of a lens

$$P = \frac{1}{f}$$

$$P = P_1 + P_2 + P_3 + \ldots$$

Thin lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Magnification for a lens

$$m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$$

Diffraction grating

$$n\lambda = d \sin \theta$$

Refractive index

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$n = \frac{c}{v}$$

Critical angle

$$\sin C = \frac{1}{n}$$

Photon model

$$E = hf$$

Einstein's photoelectric equation

$$hf = \phi + \tfrac{1}{2}mv^2_{max}$$

de Broglie wavelength

$$\lambda = \frac{h}{p}$$

Further mechanics

Impulse

$$F\Delta t = \Delta p$$

Kinetic energy of a non-relativistic particle

$$E_k = \frac{p^2}{2m}$$

Motion in a circle

$$v = \omega r$$

$$T = \frac{2\pi}{\omega}$$

$$F = ma = \frac{mv^2}{r}$$

$$a = \frac{v^2}{r}$$

$$a = r\omega^2$$

$$F = mr\omega^2$$

Fields

Coulomb's law

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

Electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Capacitance

$$C = \frac{Q}{V}$$

Energy stored in a capacitor

$$W = \tfrac{1}{2}QV$$

$$W = \tfrac{1}{2}CV^2$$

$$W = \tfrac{1}{2}\frac{Q^2}{C}$$

Capacitor discharge

$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field

$$F = BIl \sin \theta$$

$$F = Bqv \sin \theta$$

Faraday's and Lenz's laws

$$\mathscr{E} = \frac{-d(N\phi)}{dt}$$

Root-mean-square values

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Nuclear and particle physics

In a magnetic field

$$r = \frac{p}{BQ}$$

Thermodynamics

Heating

$$\Delta E = mc\Delta\theta$$

$$\Delta E = L\Delta m$$

Molecular kinetic theory

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Ideal gas equation

$$pV = NkT$$

Stefan-Boltzmann law

$$L = \sigma AT^4$$

$$L = 4\pi r^2\sigma T^4$$

Wien's law

$$\lambda_{max}T = 2.898 \times 10^{-3}\ \text{m K}$$

Space

Intensity

$$I = \frac{L}{4\pi d^2}$$

Redshift of electromagnetic radiation

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Cosmological expansion

$$v = H_0 d$$

Nuclear radiation

Mass-energy

$$\Delta E = c^2\Delta m$$

Radioactive decay

$$A = \lambda N$$

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = \frac{\ln 2}{t_{½}}$$

$$N = N_0\, e^{-\lambda t}$$

$$A = A_0\, e^{-\lambda t}$$

Gravitational fields

Gravitational force

$$F = \frac{Gm_1m_2}{r^2}$$

Gravitational field strength

$$g = \frac{Gm}{r^2}$$

Gravitational potential

$$V_{grav} = \frac{-Gm}{r}$$

Oscillations

Simple harmonic motion

$$F = -kx$$

$$a = -\omega^2 x$$

$$x = A\cos\omega t$$

$$v = -A\omega\sin\omega t$$

$$a = -A\omega^2\cos\omega t$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$\omega = 2\pi f$$

Simple harmonic oscillator

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$