Centre No.						Paper Reference							Surname	Initial(s)
Candidate No.						6	7	3	6	/	0	1	Signature	

Paper Reference(s)

6736/01
Edexcel GCE
Physics
Advanced Level
Unit Test PHY6
Thursday 22 June 2006 – Afternoon
Time: 2 hours

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1	
2	
3	
4	
Total	

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Materials required for examination	Items included with question papers
Nil	Insert

Instructions to Candidates

In the boxes above, write your centre number, candidate number, your signature, your surname and initials.
Answer **ALL** questions in the spaces provided in this question paper.
In calculations you should show all the steps in your working, giving your answer at each stage.
Calculators may be used.
Include diagrams in your answers where these are helpful.

Information for Candidates

This question paper is designed to give you the opportunity to make connections between different areas of physics and to use skills and ideas developed throughout the course in new contexts. You should include in your answers relevant information from the whole of your course, where appropriate.
You should have an insert that is the passage for use with Section I.
The marks for individual questions and the parts of questions are shown in round brackets.
There are four questions in this paper. The total mark for this paper is 80.
The list of data, formulae and relationships is printed at the end of this booklet.

Advice to Candidates

You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking account of your use of grammar, punctuation and spelling.

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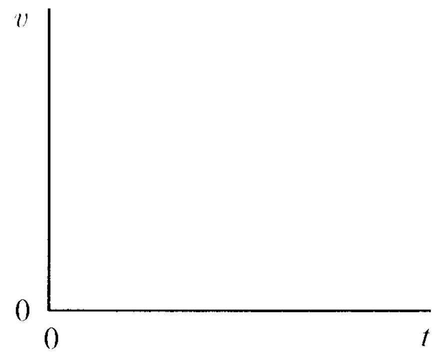
SECTION I

1. Read the passage on the separate insert and then answer the Section I questions.

(a) (i) On the axes below sketch and label a velocity-time graph for a body released from rest and falling in a viscous medium to illustrate what is meant by terminal velocity (paragraph 3).



(ii) Explain the following phrases used in the passage:

a viscous medium (paragraph 3),

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charge is quantised (paragraph 4).

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(5)

Leave blank

(b) (i) Show that the weight of an oil drop of radius 7.9×10^{-5} cm is about 2×10^{-14} N for oil of density 920 kg m^{-3}.

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(ii) What percentage of its weight is the buoyant force of the air on such a drop? Take the density of air to be 1.2 kg m^{-3}.

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Percentage = ...

(iii) Deduce an algebraic expression for r, the radius of a drop, from the statement

'weight minus buoyant force equals the viscous force'.

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(7)

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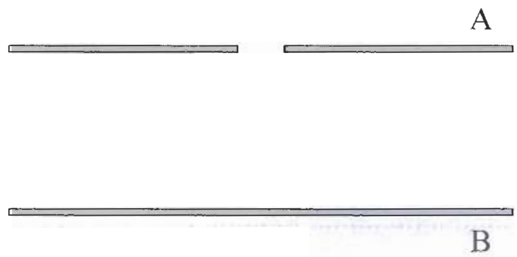
(c) (i) Draw the electric field pattern between the plates A and B.



(ii) The plates are 12 mm apart. Calculate the potential difference between the plates when the electric field strength is $6.5 \times 10^4\ \mathrm{N\ C^{-1}}$.

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Potential difference = ...

(iii) If, for this p.d., the potentiometer connection P is set half-way down the resistor, deduce the e.m.f. of the power supply. State any assumption you make.

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(6)

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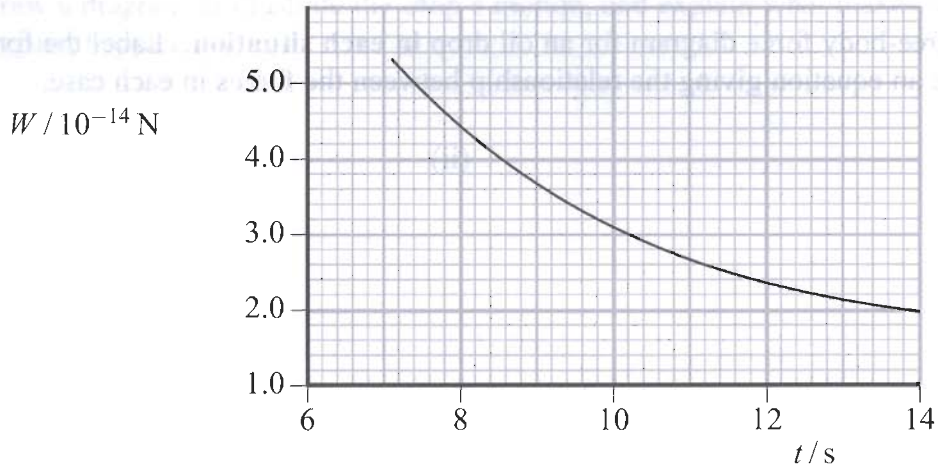
(d) The graph shows the times t taken for drops of different weights W, each moving at its terminal velocity, to fall a fixed distance when there is no electric field.



By taking suitable readings from the graph, determine whether or not the time t is inversely proportional to the weight W.

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(4)

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(e) The passage describes two situations in which an oil drop is in equilibrium:

(i) held stationary (paragraph 2), and (ii) falling at a terminal velocity (paragraph 3).

Draw a free-body force diagram for an oil drop **in each situation**. Label the forces and write an equation giving the relationship between the forces in each case.

(i) (ii)

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(5)

(f) Millikan briefly introduced a radioactive source into the space between the plates A and B in order to change the magnitude of the charge on a drop.

Suggest why he used a source of beta particles rather than an alpha or a gamma source.

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(2)

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(g) When a very tiny drop is observed with no electric field, it is seen to jiggle about in a random way as it falls.

Draw a diagram to illustrate the drop's motion, and explain what makes the random jiggling happen.

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(5) **Q1**

(Total 34 marks)

TOTAL FOR SECTION I: 34 MARKS

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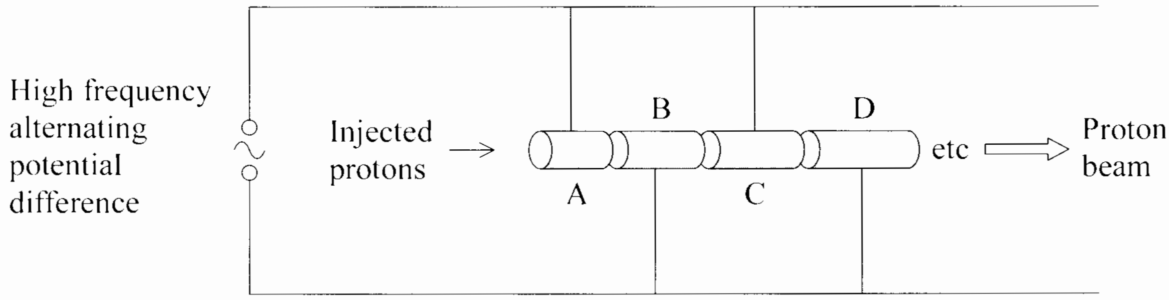
SECTION II

(Answer ALL questions)

2. The diagram shows part of a linear accelerator – a linac. Alternate metal tubes are connected together and to opposite terminals of a high-frequency alternating potential difference of fixed frequency.



(a) Describe how the protons are accelerated as they move along the linac and explain why the tubes get longer towards the right. You may be awarded a mark for the clarity of your answer.

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(5)

(b) A particular linac has 420 metal tubes and the peak voltage of the alternating supply is 800 kV.

(i) Show that the emerging protons have gained a kinetic energy of about 5×10^{11} J and express the mass equivalent of this energy as a fraction of the mass of a stationary proton. Take the mass of a proton m_p as 1.01 u.

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(6)

(ii) The frequency of the alternating supply is 390 MHz. Calculate how long it takes a proton to travel along the linac.

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Time = ...

(2)

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(c) The emerging protons can be made to collide with

(i) a target of fixed protons, e.g. liquid hydrogen, or

(ii) a similar beam of protons travelling in the opposite direction.

State some advantages of either or both experimental arrangement(s).

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(2) **Q2**

(Total 15 marks)

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3. Water molecules oscillate when stimulated by high-frequency electromagnetic waves. A microwave oven heats food that contains water by forcing the water molecules to oscillate at their resonant frequency f_0.

(a) Explain what is meant by resonance and suggest why the microwave frequency is chosen to be about f_0.

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(3)

(b) A microwave oven is used to heat 1.2 kg of meat. The temperature of the meat increases by 75 K in the first 10 minutes.

The power of the microwave source is 800 W.

Calculate the efficiency of the heating process during this time. Take the specific heat capacity of the meat to be 3200 J kg^{-1} K^{-1}.

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Efficiency = ...

Why does the temperature of the meat not continue to rise at this rate for the next 10 minutes?

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(4)

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(c) The frequency of the microwaves used is 2500×10^6 Hz.

(i) Show that the wavelength of the microwaves is 12 cm.

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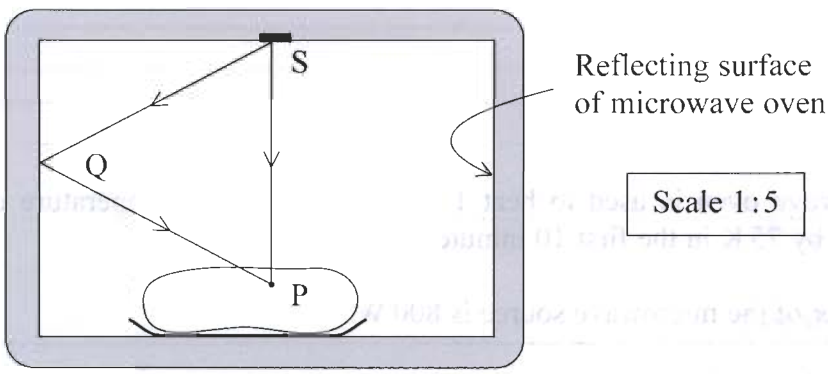
(ii) Microwaves from the source at S reach a point P in the meat both directly and after reflection at Q. The diagram is drawn to one-fifth scale.



Use measurements from the diagram to explain the result of the superposition of these two waves at P.

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(6)

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(iii) Superposition causes a stationary wave pattern in the microwave oven.

Explain why this will lead to uneven heating of the meat and suggest how a more even heating can be achieved.

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(3)

Q3

(Total 16 marks)

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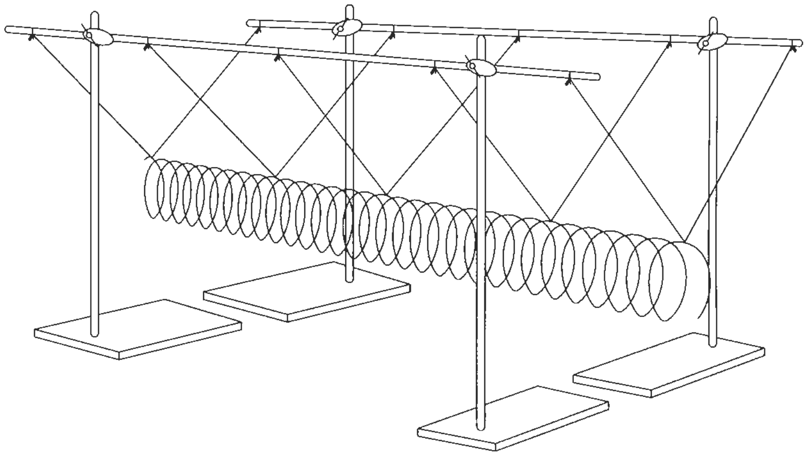
4. In order to study the propagation of longitudinal waves on a spring, a metal 'slinky' was suspended as shown.



(a) Describe how you would measure the speed of a short compression pulse along the slinky. How could you improve the reliability of your result?

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(4)

N 2 2 0 5 5 A 0 1 4 2 4

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(b) The speed c of the pulse is given by

$$c = \sqrt{\frac{kl^2}{m}}$$

where m and l are the total mass and the suspended length of the slinky, and k is the constant in $F = kx$, i.e. the spring constant of the suspended slinky.

(i) Show that the equation is homogeneous with respect to units.

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(ii) The slinky is cut in half and one half is now suspended in a similar manner. The speed of the pulse on a half slinky with mass $m/2$ and length $l/2$ is found to be the same as that on the whole slinky.

What does this tell you about the value of k for the half slinky?

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(4)

(c) The ends of the suspended metal half slinky are now connected to a d.c. power pack and a current of 5.0 A is passed through it.

(i) A Hall probe, suitably placed inside the slinky, registers a steady magnetic field of 0.34 mT.

Calculate the number of turns per unit length of the slinky.

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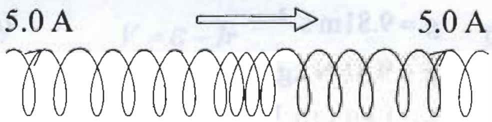
Number of turns per unit length = ...

(3)

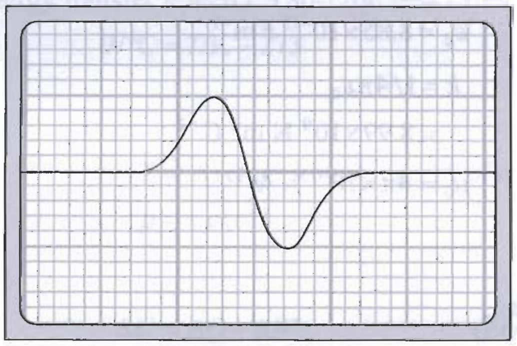
(ii) The Hall probe is then replaced by a short coil, inside the slinky, connected to an oscilloscope. The axis of the coil is parallel to the length of the slinky.

A short compression pulse is sent along the slinky as shown.



Compression pulse

This causes the following trace to appear on the oscilloscope screen as the pulse passes the small coil.



Oscilloscope screen

Explain the shape of the trace as the pulse travels past the coil.

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(4) Q4

(Total 15 marks)

TOTAL FOR SECTION II: 46 MARKS

TOTAL FOR PAPER: 80 MARKS

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N 2 2 0 5 5 A 0 1 7 2 4

List of data, formulae and relationships

Data

Speed of light in vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$	
Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to the Earth)
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to the Earth)
Elementary (proton) charge	$e = 1.60 \times 10^{-19}\ \text{C}$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Unified atomic mass unit	$\text{u} = 1.66 \times 10^{-27}\ \text{kg}$	
Molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$	
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Coulomb law constant	$k = 1/4\pi\varepsilon_0$ $= 8.99 \times 10^{9}\ \text{N m}^{2}\ \text{C}^{-2}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \text{N A}^{-2}$	

Rectilinear motion

For uniformly accelerated motion:

$$v = u + at$$

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

$$v^2 = u^2 + 2ax$$

Forces and moments

Moment of F about O = F × (Perpendicular distance from F to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

Dynamics

Force $\qquad F = m\dfrac{\Delta v}{\Delta t} = \dfrac{\Delta p}{\Delta t}$

Impulse $\qquad F\Delta t = \Delta p$

Mechanical energy

Power $\qquad P = Fv$

Radioactive decay and the nuclear atom

Activity $\qquad A = \lambda N \qquad$ (Decay constant λ)

Half-life $\qquad \lambda t_{\frac{1}{2}} = 0.69$

N 2 2 0 5 5 A 0 1 8 2 4

Electrical current and potential difference

Electric current $I = nAQv$

Electric power $P = I^2R$

Electrical circuits

Terminal potential difference $V = \mathcal{E} - Ir$ (E.m.f. $\mathcal{E}$; Internal resistance r)

Circuit e.m.f. $\Sigma\mathcal{E} = \Sigma IR$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Heating matter

Change of state: energy transfer $= l\Delta m$ (Specific latent heat or specific enthalpy change l)

Heating and cooling: energy transfer $= mc\Delta T$ (Specific heat capacity c; Temperature change ΔT)

Celsius temperature $\theta/°\mathrm{C} = T/\mathrm{K} - 273$

Kinetic theory of matter

Temperature and energy $T \propto$ Average kinetic energy of molecules

Kinetic theory $p = \frac{1}{3}\rho\langle c^2\rangle$

Conservation of energy

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Energy transferred thermally ΔQ; Work done on body ΔW)

Efficiency of energy transfer $= \frac{\text{Useful output}}{\text{Input}}$

Heat engine maximum efficiency $= \frac{T_1 - T_2}{T_1}$

Circular motion and oscillations

Angular speed $\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r}$ (Radius of circular path r)

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

Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$ (Frequency f)

Simple harmonic motion:

displacement $x = x_0 \cos 2\pi ft$

maximum speed $= 2\pi f x_0$

acceleration $a = -(2\pi f)^2 x$

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

For a mass on a spring $T = 2\pi\sqrt{\frac{m}{k}}$ (Spring constant k)

Waves

Intensity	$I = \frac{P}{4\pi r^2}$	(Distance from point source r; Power of source P)

Superposition of waves

Two slit interference	$\lambda = \frac{xs}{D}$	(Wavelength λ; Slit separation s; Fringe width x; Slits to screen distance D)

Quantum phenomena

Photon model	$E = hf$	(Planck constant h)
Maximum energy of photoelectrons	$= hf - \varphi$	(Work function φ)
Energy levels	$hf = E_1 - E_2$	
de Broglie wavelength	$\lambda = \frac{h}{p}$	

Observing the Universe

Doppler shift	$\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$	
Hubble law	$v = Hd$	(Hubble constant H)

Gravitational fields

Gravitational field strength	$g = F / m$	
for radial field	$g = Gm / r^2$, numerically	(Gravitational constant G)

Electric fields

Electric field strength	$E = F / Q$	
for radial field	$E = kQ / r^2$	(Coulomb law constant k)
for uniform field	$E = V / d$	
For an electron in a vacuum tube	$e\Delta V = \Delta(\frac{1}{2}m_e v^2)$	

Capacitance

Energy stored	$W = \frac{1}{2}CV^2$	
Capacitors in parallel	$C = C_1 + C_2 + C_3$	
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	
Time constant for capacitor discharge	$= RC$	

Magnetic fields

Force on a wire	$F = BIl$	
Magnetic flux density (Magnetic field strength)		
in a long solenoid	$B = \mu_0 nI$	(Permeability of free space μ_0)
near a long wire	$B = \mu_0 I / 2\pi r$	
Magnetic flux	$\Phi = BA$	
E.m.f. induced in a coil	$\mathcal{E} = -\dfrac{N\Delta\Phi}{\Delta t}$	(Number of turns N)

Accelerators

Mass-energy	$\Delta E = c^2 \Delta m$
Force on a moving charge	$F = BQv$

Analogies in physics

Capacitor discharge	$Q = Q_0 e^{-t/RC}$
	$\dfrac{t_{\frac{1}{2}}}{RC} = \ln 2$
Radioactive decay	$N = N_0 e^{-\lambda t}$
	$\lambda t_{\frac{1}{2}} = \ln 2$

Experimental physics

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

Mathematics

$$\sin(90° - \theta) = \cos\theta$$

$$\ln(x^n) = n \ln x$$

$$\ln(e^{kx}) = kx$$

Equation of a straight line	$y = mx + c$	
Surface area	cylinder $= 2\pi rh + 2\pi r^2$	
	sphere $= 4\pi r^2$	
Volume	cylinder $= \pi r^2 h$	
	sphere $= \frac{4}{3}\pi r^3$	
For small angles:	$\sin\theta \approx \tan\theta \approx \theta$	(in radians)
	$\cos\theta \approx 1$	

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Paper Reference(s)

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Edexcel GCE

Physics

Advanced Level

Unit Test PHY6: Synoptic Paper

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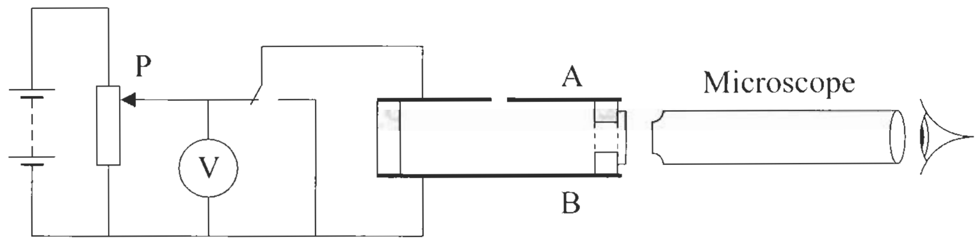
PASSAGE FOR SECTION I

The Millikan oil-drop experiment

One of the classical experiments of all time was the measurement of the charge of an individual electron by R A Millikan. In the apparatus shown below A and B are two horizontal metal plates. Oil is sprayed in fine drops above the upper plate, and a few of the drops fall through a small hole in this plate. The drops, which are illuminated by a light beam, appear like tiny bright stars when viewed through the microscope, falling slowly under the combined influence of their weight, the buoyant force of the air, and the viscous force opposing their motion.



The action of spraying the oil causes the drops to become electrically charged. If now the plates are charged, the region between the plates becomes a uniform electric field, and by adjusting the potentiometer a drop can be held stationary between the plates. It can be shown that when the field has been adjusted to this value

$$qE = \frac{4}{3}\pi r^3 g(\rho - \rho')$$

i.e. the upward electric force is equal to weight minus the buoyant force. In this equation q is the charge on the drop, E the electric field strength, g the acceleration due to gravity, r the radius of the drop, ρ the density of the oil and ρ' the density of the air.

The radii of the drops are a few times 10^{-5} cm: much too small to be measured directly. Millikan devised an ingenious method for determining these radii. When the field is switched off, the drop falls slowly and its rate of fall may be measured by timing it as it passes reference cross hairs in the microscope. A body falling in a viscous medium accelerates until a terminal velocity is reached when the net downward force (weight minus buoyant force) equals the viscous force. The viscous force on the drop is equal to $6\pi r\eta v$, where η is called the viscosity of air and v is the terminal velocity of the drop.

During the years 1909–1913, Millikan measured the charges of thousands of different drops. Every drop was found to have a charge equal to some small integral multiple of a basic charge e, i.e. charge is quantised. The best measurements to date give the magnitude of the electronic charge e to be 1.6022×10^{-19} coulomb.

[The passage is adapted from Sears and Zemansky: *College Physics*, 3rd edition, Addison-Wesley 1960.]