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: Synoptic Paper

Monday 27 June 2005 – Afternoon

Time: 2 hours

Examiner's use only

Team Leader's use only

Question Number	Leave Blank
1	
2	
3	
4	
Total	

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 initial(s).
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 Question 1.
The marks for individual questions and the parts of questions are shown in round brackets.
There are four questions in this question 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) Define electric field strength.

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(ii) Explain the meanings of the following phrases as used in the passage:

- directly proportional (paragraph 1),

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- an induced charge (paragraph 3).

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(4)

(b) Give one example of each of the following:

(i) static electricity produced by friction,

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(ii) a use for an electrostatic mill.

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(c) An electrostatic mill measures the strength of the Earth's electric field to be $240\,N\,C^{-1}$.

(i) Calculate the potential difference between the charged ionosphere and the Earth's surface when they are 60 km apart. State any assumption you make.

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(ii) In these conditions the total charge stored in the 'giant capacitor' formed by the ionosphere and the Earth's surface is 1.1 MC. Calculate the capacitance of this 'giant capacitor'.

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(6)

(d) (i) Why is there an electric field around the Earth?

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(ii) Draw a labelled sketch showing the shape and direction of this field.

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(e) (i) Draw a sketch showing the relative positions of the rotating vane plate and the fixed earthed plate when the induced charge on the vane plate is maximum. (An accurate diagram is not required.)

(2)

(ii) Explain why, in order for the peak current in an electrostatic mill to be proportional to the electric field strength being investigated, the vane plate must be rotated at a constant speed.

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(iii) Sketch a curve showing how the current in an electrostatic mill varies with time when the frequency of rotation of the vane plate is 50 Hz. Give values on the time axis.

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(f) Show that the equation $q = \varepsilon_0 EA$ is homogeneous with respect to units.

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(g) The size of the current produced by an electrostatic mill is very small, a few nanoamperes. Explain, with the aid of a circuit diagram, how the peak current from an electrostatic mill is measured (paragraph 3). Give values for any components and ranges for any meters used.

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(4)

Q1

(Total 31 marks)

TOTAL FOR SECTION I: 31 MARKS

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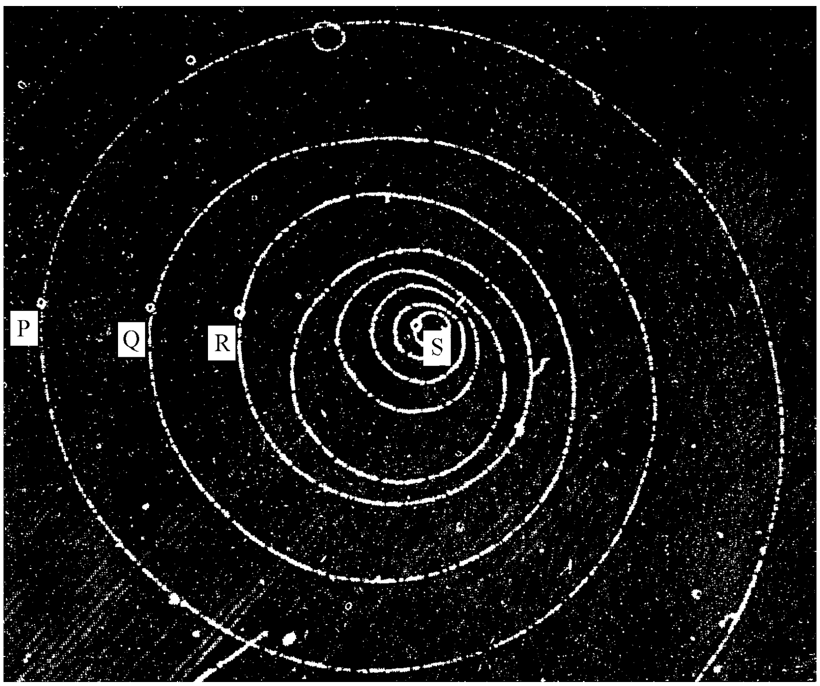
SECTION II

(Answer ALL questions)

2. The photograph shows the path of an electron spiralling inwards anticlockwise in a bubble chamber. **The photograph is full size.**



(a) (i) Explain how the electron produces the white track. You may be awarded a mark for the clarity of your answer.

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N 1 7 1 0 0 A 0 6 2 0

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(ii) Explain the origin of the centripetal force that is making the electron spiral in this manner.

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Why does the radius of the circle in which it is moving gradually decrease?

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(b) Theory shows that the momentum p of the electron at any point on its path is given by $p = Ber$, where B is the magnetic flux density perpendicular to its motion, r is the radius of its path at that point and e has its usual meaning.

(i) The magnetic flux density in the bubble chamber is 1.2 T. By making suitable measurements on the photograph, determine approximate values for the momentum of the electron at P, Q and R. If you are using a transparent ruler, it may help to place a piece of white paper underneath it. (Take the centre of the spiral to be at S.)

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(ii) The speed v of the electron at all three places P, Q and R on its spiral is $3.0 \times 10^8 \text{ m s}^{-1}$ to two significant figures.
Deduce the effective mass of the electron at each point and comment on your results.

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Q2

(Total 15 marks)

N 1 7 1 0 0 A 0 8 2 0

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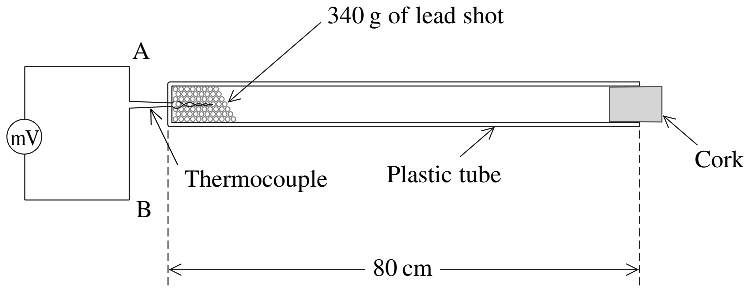
3. Some tiny spheres of lead (lead shot) of total mass 340 g are trapped in a long plastic tube. At one end there is an electrical thermometer called a thermocouple. This thermocouple registers changes in temperature as small voltages on a sensitive voltmeter.



(a) The plastic tube is held vertically and then inverted 60 times. All the lead shot is allowed to fall to the bottom of the tube after each inversion.

(i) Explain carefully why the temperature of the lead shot is found to rise.

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(ii) The specific heat capacity of lead is $130\,\mathrm{J\,kg^{-1}\,K^{-1}}$. Estimate the rise in temperature ΔT of the lead shot.

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(iii) Would you expect the measured value of ΔT to be greater or smaller than your estimated value? Explain your answer.

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(iv) The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. Discuss the outcome of a similar experiment using a few cm^3 of water in place of the lead shot.

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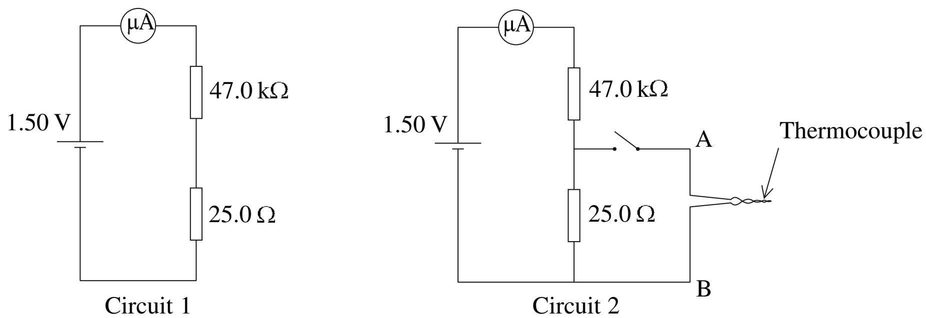
(b) The thermocouple generates only a fraction of a millivolt in experiments of this kind. In order to check this voltage a potential divider is used.



(i) Calculate, to 3 significant figures, the potential difference across the 25.0 Ω resistor in circuit 1. State any assumption you make.

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(4)

(ii) At the end of the lead shot experiment, when the thermocouple is connected by closing the switch in circuit 2, there is no change in the reading of the microammeter.
Suggest what voltage is being generated by the thermocouple.

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(iii) A thermocouple consists of two different metal wires twisted together to form a probe. What advantage does a thermocouple have over a mercury-in-glass thermometer in experiments of this kind, other than its mechanical robustness?

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Q3

(Total 17 marks)

Leave blank

4. (a) (i) What information about a star can be deduced from its spectrum?

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(ii) In the spectrum of a nearby star, an absorption line is found at 420 nm, which is 20 nm nearer the blue end of the spectrum than its 'laboratory' position.
What is the velocity of the star relative to Earth?

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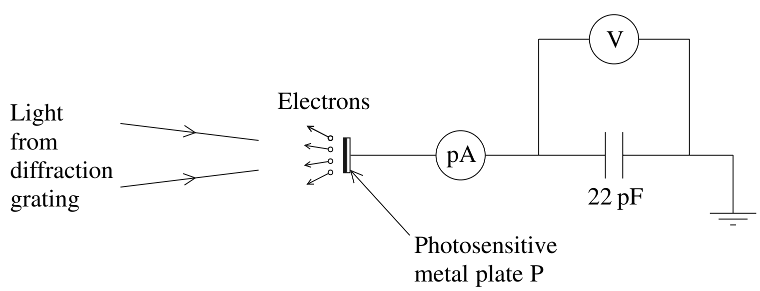
(b) The diagram shows, in principle, how the light from a star can be analysed. A diffraction grating is used to produce a spectrum of the light and each colour is in turn focused onto a metal plate P. Electrons are emitted from P when the energy of the light photons exceeds the work function of the metal.



The picoammeter registers a current that falls gradually to zero when a certain wavelength of light is focused on P. At the same time the reading on the voltmeter rises from zero to a maximum of 0.58 V.

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(i) Explain the origin of this current and state its direction.

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(2)

(ii) Why does the voltmeter reading reach a maximum value?

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(2)

(iii) By calculating the final charge on the capacitor, determine how many electrons are removed from P as the current falls to zero.

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(4)

(c) The analysis of light relies here on the photoelectric effect with a photosensitive material – the metal plate. Draw a labelled diagram of the apparatus you would use to measure the work function of a metal in the laboratory. Assume that you have available a monochromatic light source of known frequency.

(4)

Q4

(Total 17 marks)

TOTAL FOR SECTION II: 49 MARKS

TOTAL FOR PAPER: 80 MARKS

END

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 = $F \times$ (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 $F = m\dfrac{\Delta v}{\Delta t} = \dfrac{\Delta p}{\Delta t}$

Impulse $F\Delta t = \Delta p$

Mechanical energy

Power $P = Fv$

Radioactive decay and the nuclear atom

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

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

Electrical current and potential difference

Electric current	$I = nAQv$	
Electric power	$P = I^2 R$	

Electrical circuits

Terminal potential difference	$V = \varepsilon - Ir$	(E.m.f. ε; Internal resistance r)
Circuit e.m.f.	$\Sigma\varepsilon = \Sigma IR$	
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	$I = \dfrac{P}{4\pi r^2}$	(Distance from point source r; Power of source P)

Superposition of waves

Two slit interference	$\lambda = \dfrac{xs}{D}$	(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	$\lambda = \dfrac{h}{p}$	

Observing the Universe

Doppler shift	$\dfrac{\Delta f}{f} = \dfrac{\Delta\lambda}{\lambda} \approx \dfrac{v}{c}$	
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	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$	
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	$\varepsilon = -\dfrac{N\Delta\Phi}{\Delta t}$	(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

$$\sin(90^\circ - \theta) = \cos\theta$$

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

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

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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