THE UNIVERSITY OF SYDNEY

FACULTIES OF ARTS, EDUCATION, ENGINEERING AND SCIENCE

SAMPLE EXAM PAPER

PHYSICS 1 (ADVANCED)

November 2000

Time allowed: THREE Hours

MARKS FOR QUESTIONS ARE AS INDICATED
TOTAL: 90 marks

INSTRUCTIONS

- **All questions are to be answered.**
- **Use a separate answer book for each section.**
- **All answers should include explanations in terms of physical principles.**

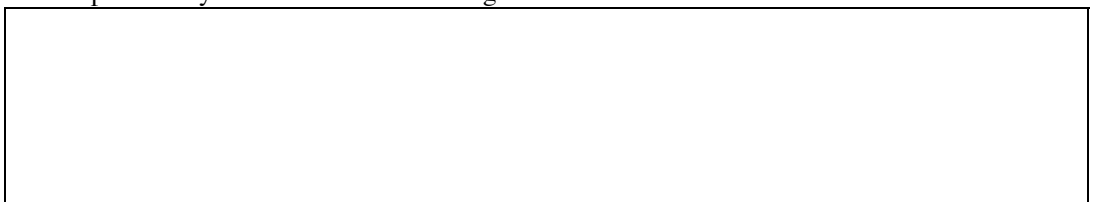
DATA

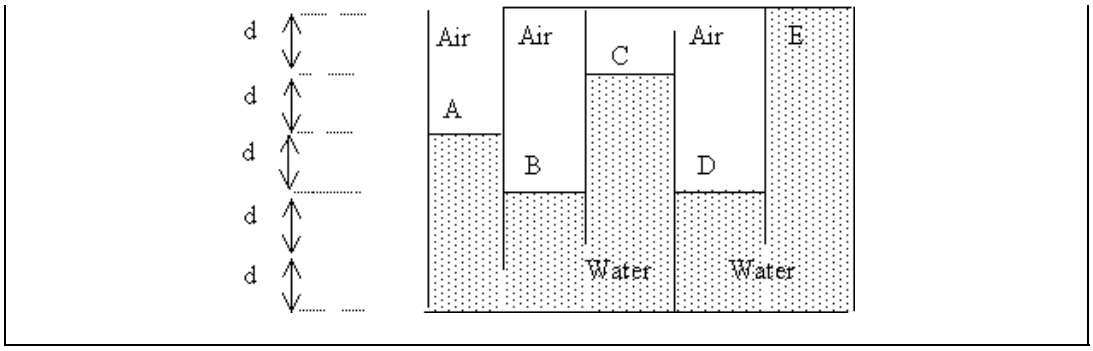
Density of water	r	=	1.00×10^{3} kg.m^{-3}
Gravitational constant	G	=	6.67×10^{-11} N.m^{2}.kg^{-2}
Magnitude of local gravitational field	g	=	9.81 N.kg^{-1}
Avogadro constant	N_A	=	6.023×10^{23} mol^{-1}
Permittivity of free space	e_0	=	8.85×10^{-12} F.m^{-1}
Permeability of free space	μ_0	=	$4p \times 10^{-7}$ T.m.A^{-1}
Elementary charge	e	=	1.602×10^{-19} C
Electron-volt	eV	=	1.602×10^{-19} J
Speed of light in vacuum	c	=	2.998×10^{8} m.s^{-1}
Planck constant	h	=	6.63×10^{-34} J.s = 4.14×10^{-15} eV.s
Rest mass of an electron	m_e	=	9.11×10^{-31} kg = 0.511 MeV.c^{-2}
Rest mass of a neutron	m_n	=	1.675×10^{-27} kg
Rest mass of a proton	m_p	=	1.673×10^{-27} kg
Rest mass of a hydrogen atom	m_H	=	1.674×10^{-27} kg
Boltzmann constant	k	=	1.38×10^{-23} J.K^{-1} = 8.61×10^{-5} eV.K^{-1}
Atomic mass unit		u =	1.66×10^{-27} kg = 931.5 MeV.c^{-2}

SECTION A – Fluids and Fields
Please use a separate book for this section

Question 1

e container whose cross-section is shown below holds water and air as illustrated. The walls, lid, joints and base are water-tight and air-tight. The five horizontal interfaces are labelled as shown. Indicate clearly in your answer book which of the five statements below are true, which are false, and which are unable to be decided, giving justification in each case. Ignore the compressibility of the water and the weight of the air.



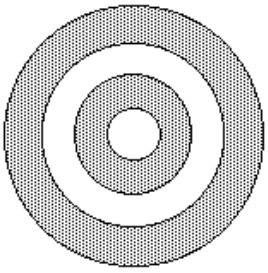


The pressure at A is the pressure of the atmosphere.
The pressure at B is less than the pressure at A.
The pressure at D is equal to the pressure at C.
The pressure at E is zero.
The pressure at D is less than the pressure at A.

(5 marks)

Question 2

The diagram indicates a cross-sectional view of two long, hollow, concentric, metal cylinders; the inner cylinder is positively charged and there is an equal negative charge on the outer conductor.



Copy the diagram. Indicate clearly on the diagram where the electric charge is to be found. Sketch on the diagram the electric field associated with the charge distribution.

(5 marks)

Question 3

A horizontal pipe of radius 10 mm is joined to a horizontal pipe with radius 15 mm with both pipes at the same height. A fluid flows through both pipes from the narrow pipe to the wider pipe with an average velocity of 3 mm s^{-1} in the narrow pipe. Assume that the fluid has zero viscosity.

(a) What is the volume flow rate?

(b) What is the average pressure difference between the two pipes?

The two pipes are now moved so that the wider pipe is a distance h above the narrow pipe.

(c) If the volume flow rate remains the same what happens to the pressure?

[10 marks]

Question 4

A uniform sphere of mass, M, has a radius a. It contains a concentric cavity of radius b.

Find an expression for the gravitational force on a particle, mass m, at distance r from the centre of the sphere, when

(a) $r < b$

(b) $b \leq r \leq a$

(c) $r > a$.

Give a short explanation of the principle underlying your answer in each case.

(d) If m is at a distance $r < b$, and a second sphere, mass M_2 and radius a is placed with its centre at distance $5a$ from the centre of the first sphere, will the gravitational force on m change?

Give reasons for your answer.

(10 marks)

SECTION B - ELECTRICITY & MAGNETISM
(Please use a separate book for this section.)

Question 5

R-C circuits are often used to change the shape of a signal. Figure (a) below shows a network being fed a square-wave signal comprising a series of rectangular dc voltage pulses rising to +ve and falling to 0. Figure (b) shows the corresponding voltage across the capacitor.

(i) Explain why the the graph in Figure (b) has the shape shown .
(ii) What can you say about the value of RC(the time constant of the circuit) in comparison with the width of each pulse?
(iii) Draw a curve of the output signal as seen across the resistor and explain its features.

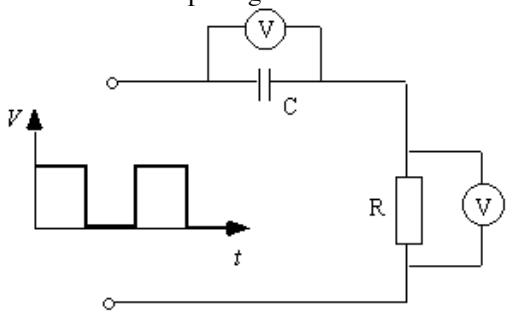


Figure (a)

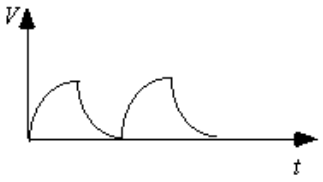
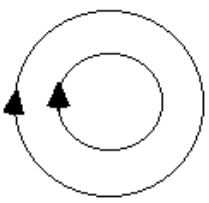


Figure (b)

(5 marks)

Question 6

Two concentric, coplanar, circular loops of wire, with different diameters carry currents in the same sense. Describe qualitatively the magnetic forces exerted by the outer loop on

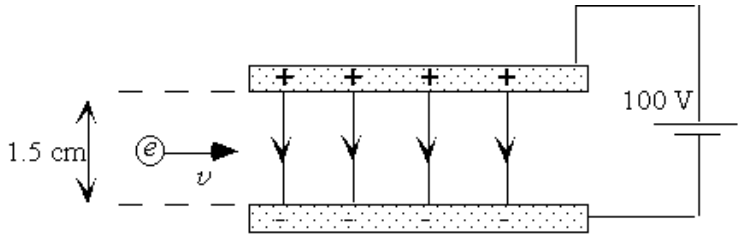


(i) a short portion of the inner loop,

(ii) the whole inner loop.

(5 marks)

Question 7



An electron is accelerated through a potential difference of 1.0 kV and then enters the region between two parallel plates separated by a distance of 1.5 cm. The plates are connected to a 100 V battery.

(a) Draw a diagram showing the path of the electron.

(b) The plates are now immersed in a uniform magnetic field **B** which is perpendicular to the electric field **E** and also perpendicular to the initial path of the electron. If **B** is large enough, the electron can pass straight through the plates in a straight line without being deflected.

What is the magnitude of **B**? Should **B** be directed into the page or out of the page?

(10 marks)

Question 8

The long straight wire in Figure 1 carries constant current *I*. A metal bar with length *L* is moving at constant velocity *v* as shown in the figure. Point a is a distance *d* from the wire.

(i) Calculate the emf induced in the bar.

(ii) Which point, a or b, is at higher potential?

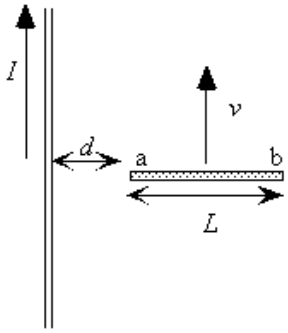


Figure 1

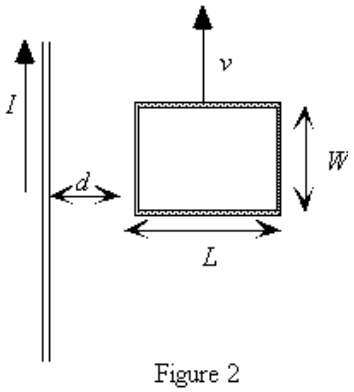


Figure 2

(iii) If the bar is replaced by a rectangular wire loop of resistance R (Figure 2), what is the magnitude of the current induced in the loop?

(10 marks)

SECTION C - QUANTUM PHYSICS

(Please use a separate book for this section.)

Question 9

(a) A golf ball has a mass of 0.045 kg and a speed of 35 $m.s^{-1}$. This speed can be measured to a precision of 1.5%. What limits does the uncertainty principle place on your ability to measure the position of the golf ball?

(b) Comment on your answer to part (a), and explain how it relates to the correspondence principle.

(5 marks)

Question 10

Draw labelled energy level diagrams of a metal above and below its superconducting transition temperature.
Explain how the behaviour of the magnetic field present in the metal when it is cooled below its superconducting transition temperature enables us to distinguish the two types of superconductivity.

(5 marks)

Question 11

An experiment is carried out in which light is shone on a photocell whose plate (cathode) has a work function of 1.5 eV. Two series of measurements are made. For the first the light has a wavelength of 400 nm and an intensity I and for the second the light has a wavelength of 500 nm and an intensity of three times I (ie. $3I$). In each case the photoelectric current is measured as a function of the voltage applied between the cathode and anode of the photocell.

(i) Calculate the stopping potential for each wavelength.

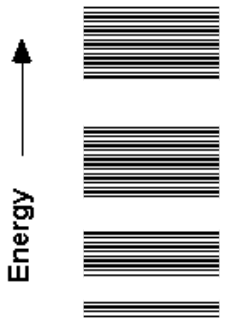
(ii) On a graph of current versus applied voltage draw two curves, each curve representing one of the two series of measurements. The curves must be drawn with the correct relative scales and be clearly marked with the appropriate wavelength.

(iii) In the photoelectric effect, why does the existence of a cut-off frequency speak in favour of the photon theory and against the wave theory?

(iv) Briefly describe how Planck's constant can be determined from observations of the type plotted in the graph of part (ii).

(10 marks)

Question 12



The diagram above is an idealized representation of the energy bands and energy gaps in a hypothetical solid substance. The height of the vertical (energy) axis may be taken to be several eV.

(a) Imagine that this substance is an electrical **conductor**.

Reproduce the diagram in your answer booklet, name any important features and indicate clearly which energy levels are occupied and which are unoccupied.

(b) Now imagine that this substance is an electrical **insulator**.

Draw another version of the diagram in your answer booklet, name any important features and indicate clearly which energy levels are occupied and which are unoccupied

(c) An electrical conductor is a material in which an electrical current will flow when an electric potential difference is applied across it; whereas in an insulator such an electrical current will NOT flow.

Explain, using the diagrams that you have drawn, why electrons will start to flow through this hypothetical substance in part (a) if you apply a potential difference across it; but this will not happen in the hypothetical substance of part (b).

(d) Now imagine the substance is a semiconductor. Furthermore it is an **intrinsic semiconductor** — one which does not rely on the presence of doping atoms for its semiconducting behaviour.

Draw yet another version of the diagram in your answer booklet, making it very clear how it differs from the diagrams you drew in parts (a) and (b).

Again name any important features and indicate clearly which energy levels are occupied and which are unoccupied.

(e) One of the important characteristics of a semiconductor is that its electrical conductivity increases as the temperature increases.

Explain, using the diagram that you drew, why you would expect this behaviour for the hypothetical substance in part (d).

(10 marks)