

**THE UNIVERSITY OF SYDNEY**  
**FACULTIES OF ARTS, EDUCATION, ENGINEERING**  
**AND SCIENCE**

**SAMPLE EXAM PAPER**

**PHYS 1902 – PHYSICS 1B (ADVANCED)**

**November 2002**

**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**

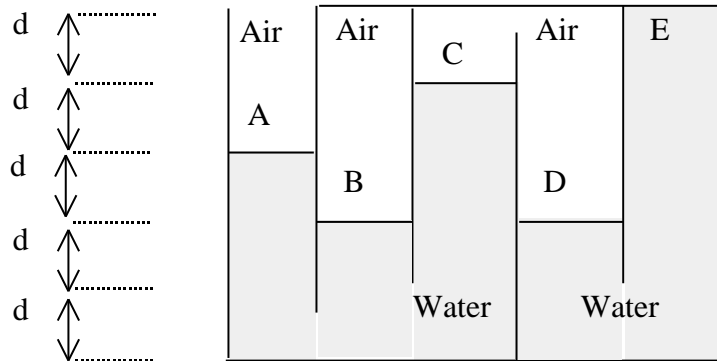
Density of water	=	$1.00 \times 10^3 \text{ kg.m}^{-3}$
Density of air	=	$1.20 \text{ kg.m}^{-3}$
Atmospheric pressure	1 atm =	$1.01 \times 10^5 \text{ Pa}$
Magnitude of local gravitational field	$g$ =	$9.81 \text{ m.s}^{-2}$
Avogadro constant	$N_A$ =	$6.022 \times 10^{23} \text{ mol}^{-1}$
Permittivity of free space	$\epsilon_0$ =	$8.854 \times 10^{-12} \text{ F.m}^{-1}$
Permeability of free space	$\mu_0$ =	$4 \times 10^{-7} \text{ T.m.A}^{-1}$
Elementary charge	$e$ =	$1.602 \times 10^{-19} \text{ C}$
Speed of light in vacuum	$c$ =	$2.998 \times 10^8 \text{ m.s}^{-1}$
Planck constant	$h$ =	$6.626 \times 10^{-34} \text{ J.s}$
Rest mass of an electron	$m_e$ =	$9.110 \times 10^{-31} \text{ kg}$
Rest mass of a neutron	$m_n$ =	$1.675 \times 10^{-27} \text{ kg}$
Rest mass of a proton	$m_p$ =	$1.673 \times 10^{-27} \text{ kg}$
Rest mass of a hydrogen atom	$m_H$ =	$1.674 \times 10^{-27} \text{ kg}$
Boltzmann constant	$k$ =	$1.381 \times 10^{-23} \text{ J.K}^{-1}$
Atomic mass unit	$u$ =	$1.661 \times 10^{-27} \text{ kg}$

## SECTION A – Fluids and Fields

**Please use a separate book for this section**

### Question 1

The 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.

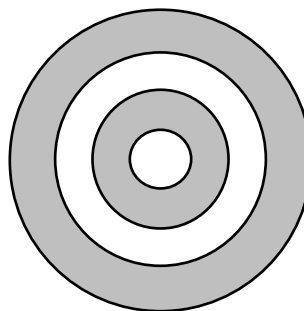


- (a) The pressure at A is the pressure of the atmosphere.
- (b) The pressure at B is less than the pressure at A.
- (c) The pressure at D is equal to the pressure at C.
- (d) The pressure at E is zero.
- (e) The pressure at D is less than the pressure at A.

**(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

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.

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

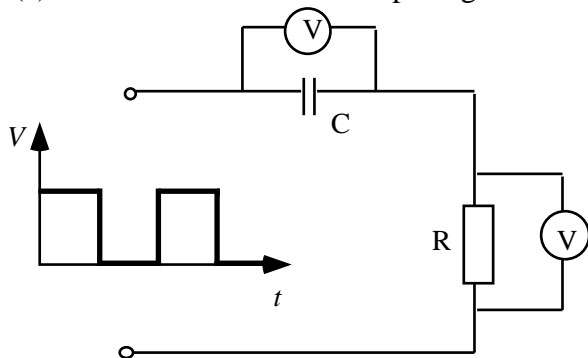


Figure (a)

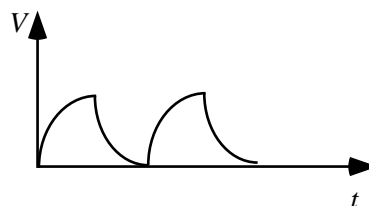


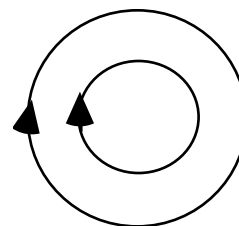
Figure (b)

(5 marks)

### Question 4

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

- a short portion of the inner loop,
- the whole inner loop.



(5 marks)

### Question 5

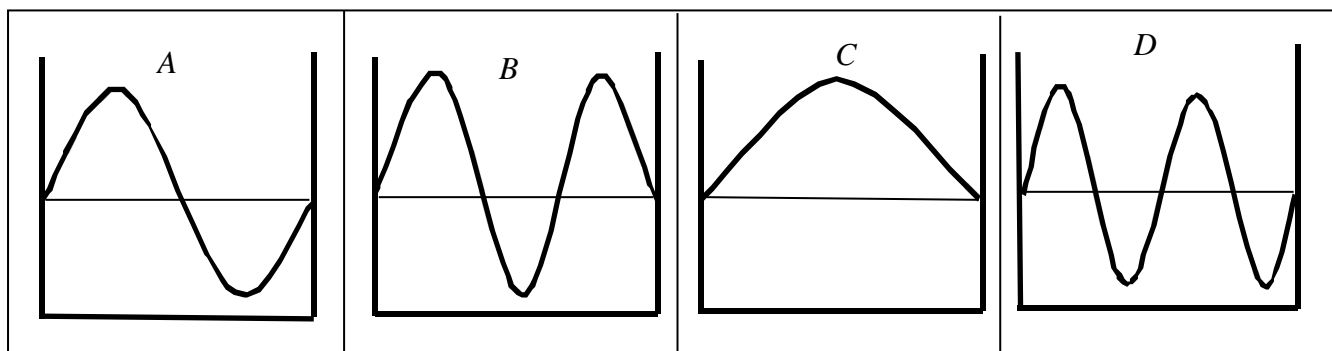
- A golf ball has a mass of 0.045 kg and a speed of  $35 \text{ m.s}^{-1}$ . This speed can be measured to a precision of 1.5%. What limits does the uncertainty principle place on your ability to measure the position of the golf ball?
- Comment on your answer to part (a), and explain how it relates to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

(5 marks)

**Question 6**

Shown below are four (spatial) wave functions of an electron in an infinite potential well.

(a) Rank them in order of increasing energy of the electron. Justify your answer.



The electron is now replaced with a proton.

(b) Is the proton's zero point energy higher or lower than the electron's?

(c) Sketch, to the same scale, the ground state wave functions of the proton and the electron.

**(5 marks)**

**SECTION B**  
**(Please use a separate book)**

**Question 7**

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  $3 \text{ mm s}^{-1}$  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 8**

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)  $r < b$

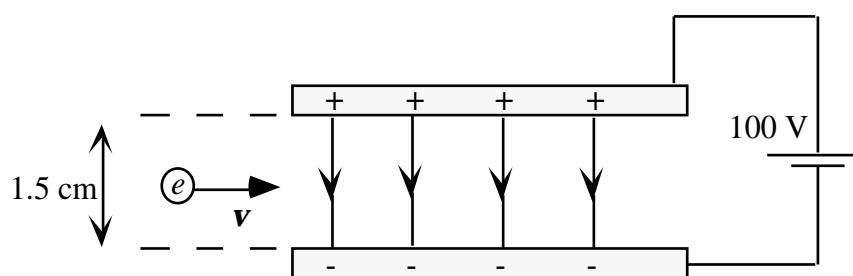
(b)  $b < r < a$

(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)**

**Question 9**

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.

- Draw a diagram showing the path of the electron.
- The plates are now immersed in a uniform magnetic field  $\mathbf{B}$  which is perpendicular to the electric field  $\mathbf{E}$  and also perpendicular to the initial path of the electron. If  $\mathbf{B}$  is large enough, the electron can pass straight through the plates in a straight line without being deflected. What is the magnitude of  $\mathbf{B}$ ? Should  $\mathbf{B}$  be directed into the page or out of the page?

**(10 marks)****Question 10**

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.

- Calculate the emf induced in the bar.
- Which point, a or b, is at higher potential?

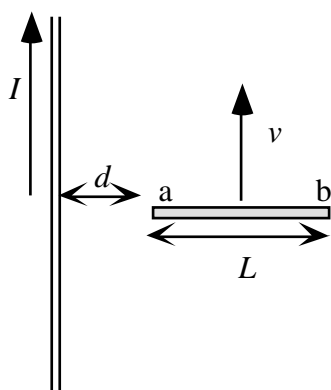


Figure 1

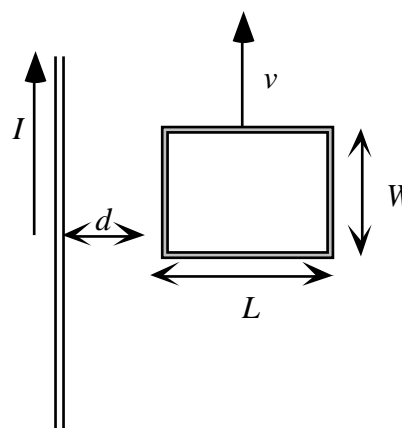


Figure 2

- 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)**

**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.

- (a) Calculate the stopping potential for each wavelength.
- (b) 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.
- (c) 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?
- (d) 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**

*This question requires you to draw a technical diagram. You are requested to draw this very carefully so that it will show exactly what you want it to show. A carelessly drawn diagram or one that is difficult to interpret will not be marked.*

- (a) Draw a neat diagram showing the essential features of the apparatus for a Compton scattering experiment. Clearly indicate the direction of the incident X-ray beam, the direction of the scattered X-rays, and clearly identify the scattering angle  $\theta$ , on your diagram.

The incident X-rays in this experiment have a wavelength of 71.1 pm (corresponding to an energy of  $2.80 \times 10^{-15}$  J). The scattering angle is  $65^\circ$ .

- (b) What is the wavelength of the scattered X-rays?
- (c) What is the frequency of the scattered X-rays?
- (d) What is the kinetic energy of the recoiling electron in Joules?
- (e) Briefly explain why do these observations *not* support the wave theory of light.

**(10 marks)**