THE UNIVERSITY OF SYDNEY

FACULTIES OF ARTS, EDUCATION, ENGINEERING AND SCIENCE

PHYSICS 1003 : PHYSICS I - TECHNOLOGICAL

NOVEMBER 1998

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

Magnitude of local gravitational field	g	=	9.81 N.kg^{-1}.
Avogadro constant	N_A	=	6.023×10^{23} mol^{-1}.
Universal gas constant	R	=	8.314 J.mol^{-1}.K^{-1}.
Permittivity of free space	ε_0	=	8.85×10^{-12} F.m^{-1}.
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ T.m.A^{-1}
Elementary charge	e	=	1.6022×10^{-19} C.
Electronvolt	eV	=	1.602×10^{-19} J.
Speed of light in vacuum	c	=	2.9979×10^{8} m.s^{-1}.
Planck constant	h	=	$6.626\,07 \times 10^{-34}$ J.s. = 4.136×10^{-15} eV.s
Rest mass of an electron	m_e	=	$9.109\,39 \times 10^{-31}$ kg = 0.511 MeV.c^{-2}
Rest mass of a neutron	m_n	=	$1.674\,93 \times 10^{-27}$ kg
Rest mass of a proton	m_p	=	$1.672\,62 \times 10^{-27}$ kg
Rest mass of a hydrogen atom	m_H	=	$1.673\,53 \times 10^{-27}$ kg
Rydberg constant	R	=	0.01097 nm^{-1}
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 = 931.502 MeV.c^{-2}
Heat of fusion of water	L_f	=	333 kJ.kg^{-1}
Heat of vaporisation of water	L_V	=	2.26×10^{6} J..kg^{-1}

SECTION A
(Please use a separate book for this section.)

Question 1

A mercury thermometer is laid out in direct sunlight.

(a) Does it measure the temperature of the sun, the air, the mercury or something else?

(b) Justify your answer using principles of physics.

(c) Meteorological measurements of temperature are taken in the shade. Why is this so?

(5 marks)

Question 2

You are going on a picnic on a warm summer's day and you pack your insulated picnic box (esky) with plenty of ice at 0°C and warm lemonade which you have just picked up from the shop. You are intrigued by the notion of entropy having just heard about it in lectures and discuss it with your friends. What are your answers to the following:

After you put the room temperature lemonade into the esky with the ice

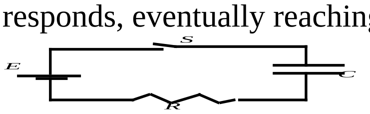
(i) does the entropy of the lemonade increase, decrease or stay the same?
(ii) does the entropy of the ice increase, decrease or stay the same?
(iii) does the entropy of the system (lemonade + ice) increase, decrease or stay the same?

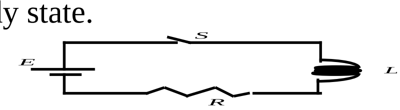
Give a justification of all your answers.

(5 marks)

Question 3

Two different circuits are shown below. S is a switch, E is an emf device generating a potential difference V, R is a resistor, C is a capacitor which is initially uncharged, and L is an inductor. The switch S is closed at time $t = 0$ and each circuit then responds, eventually reaching a steady state.





(i) Draw two graphs to indicate how the current changes with time. The time axis of your graph should start at $t = 0$ and extend over an interval of time many times greater than the time constant of the circuit.

(ii) On each of your graphs, indicate clearly values of initial and final current. Where possible express these values in terms of V, R, C and L.

(5 marks)

Question 4

A magnet dropped through a hollow copper pipe is observed to fall very slowly. By considering what happens as the magnet moves past a fixed point P on the pipe, carefully explain this observation.

Your explanation should include a diagram and be given in terms of physical principles but without using equations. Your answer should be less than half a page long, not including the diagram.

For convenience, assume the magnet falls without spinning, with its north pole downwards.

(5 marks)

Question 5

(a) In the wave theory of light, intensity is associated with the squares of the amplitude of the electric and magnetic fields. In the particle theory of light, what determines the intensity?

(b) Electrons are ejected from a surface when light of a certain frequency is incident upon the surface. Does the maximum kinetic energy of ejected electrons increase, decrease or stay the same if

((i) the frequency of the incident light is doubled?
(ii) the intensity of the incident light is doubled?
(iii) the exposure time is doubled?

(5 marks)

Question 6

(a) Draw a careful, labelled energy level diagram of a hydrogen atom.

(b) A hydrogen atom is in its second excited state (ie $n = 3$). It emits light with the shortest possible wavelength. Draw on your diagram an arrow to represent this transition.

(c) In what frequency range does the emitted light fall (eg microwave, visible, radio, ultraviolet, x ray, γ ray)?

(5 marks)

SECTION B
(Please use a separate book for this section.)

Question 7

A pot with a steel bottom 0.01 m thick rests on a hot stove. The area of the bottom is 0.1 m^2. The water inside the pot is at 100°C, and 0.05 kg is evaporated every 3 minutes.

(a) Describe briefly two of the thermal processes that are taking place.

(b) Find the temperature of the lower surface of the pot, which is in contact with the stove. (Assume that no heat is lost to the room.)

$\boxed{\kappa_{steel} = 14 \text{W m}^{-1} \text{K}^{-1}, \quad L_V = 2256 \text{kJ kg}^{-1}}$

(10 marks)

Question 8

Twelve (12) litres of 0_2 (diatomic gas, $\boxed{\gamma = 7/5}$) is expanded to a volume of 24 L. The initial pressure is one (1) atmosphere (ie. 101.3 kPa).

(a) Draw on one *p-V* diagram the two curves that would represent this expansion if the process was

(i) adiabatic
(ii) isothermal

Identify on your graph which curve is which.

(b) For both processes identify whether ΔE, Q and W are positive, negative or zero. Give reasons for your answers.

(c) If the temperature was initially 20°C, calculate the final temperature for both cases.

(d) Calculate the final pressure for both cases.

(10 marks)

Question 9

The electric eel has cells, called electroplaques, each of which generate an emf of 0.15 V with an internal resistance of 0.25 Ω.

(a) If each row of electroplaques contains 5000 cells connected in series, what is the total emf and resistance of each row?

(b) If there are 140 such rows connected in parallel, what is the net emf and resistance of all the electroplaques?

(c) A circuit is created by the water presenting a resistance to the real emf source created by the eel's electroplaques. If the current through the water is 1 A, what is the resistance of the water?

(d) How much power is dissipated in each individual electroplaque?

(10 marks)

Question 10

A solenoid of length 20 cm and diameter 4 cm is constructed with 400 turns of wire. The resistance of the wire can be neglected. A current i is supplied to the solenoid in such a way that i increases from zero to 0.5 A at a uniform rate over 2 seconds. The current then stays constant at 0.5 A. Calculate:

(a) the inductance of the solenoid,

(b) the maximum magnetic field in the solenoid,

(c) the potential difference across the solenoid during the time when the current is increasing,

(d) the potential difference across the solenoid during the time when the current remains constant,

(e) the emf induced in a single circular loop of wire during the time when the current is increasing. Assume the loop has diameter 10 cm and is placed around the solenoid in such a way that the axis of the loop coincides with the axis of the solenoid.

(10 marks)

Question 11

(a) Write down the Heisenberg uncertainty relation for position and momentum. State briefly its physical significance. Do not write more than about 5 lines.

(b) The x, y and z components of the velocity of an electron are measured to be:

$v_x = (4.00 \pm 0.18) \times 10^5$ m / s, $v_y = (0.34 \pm 0.12) \times 10^5$ m / s,

$v_z = (1.41 \pm 0.08) \times 10^5$ m / s.

Find the uncertainties in the *x*, *y* and *z* components of the momentum, *p*.

(c) The measurements described above are consistent with the electron being localised in some volume. What is the smallest volume possible?

(10 marks)

Question 12

(a) Draw a careful labelled diagram of the idealised representation of the energy band structure of

(i) an electrical insulator
(ii) a metal
(iii) an intrinsic semiconductor
(iv) an n-type doped semiconductor

In each case show clearly which energy levels are full, empty, or partly filled and label or describe any other important features.

(b) The electrical conductivity of undoped silicon can be increased by irradiating it with photons. This has the effect of exciting valence electrons into the conduction band. Given that the energy band gap of silicon is 1.14 eV,

(i) calculate the lowest energy of a photon that can excite a valence electron to the conduction band.

(ii) What is the wavelength of this photon?

(10 marks)

- - - - - - - - This is the end of your questions. - - - - - - - -