King's College London

UNIVERSITY OF LONDON

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

B.Sc. EXAMINATION

CP1020 Basic Physics II

Summer 2006

Time allowed: THREE Hours

Candidates should answer ALL parts of SECTION A, and no more than TWO questions from SECTION B. No credit will be given for answering further questions.

The approximate mark for each part of a question is indicated in square brackets.

You must not use your own calculator for this paper. Where necessary, a College calculator will have been supplied.

TURN OVER WHEN INSTRUCTED

Physical Constants

Permittivity of free space	ε_0	=	8.854×10^{-12}	F m^{-1}
Permeability of free space	μ_0	=	$4\,\pi \times 10^{-7}$	H m^{-1}
Speed of light in free space	c	=	2.998×10^{8}	m s^{-1}
Gravitational constant	G	=	6.673×10^{-11}	N m^{2} kg^{-2}
Elementary charge	e	=	1.602×10^{-19}	C
Electron rest mass	m_{e}	=	9.109×10^{-31}	kg
Unified atomic mass unit	m_{u}	=	1.661×10^{-27}	kg
Proton rest mass	m_{p}	=	1.673×10^{-27}	kg
Neutron rest mass	m_{n}	=	1.675×10^{-27}	kg
Planck constant	h	=	6.626×10^{-34}	J s
Boltzmann constant	k_{B}	=	1.381×10^{-23}	J K^{-1}
Stefan-Boltzmann constant	σ	=	5.670×10^{-8}	W m^{-2} K^{-4}
Gas constant	R	=	8.314	J mol^{-1} K^{-1}
Avogadro constant	N_{A}	=	6.022×10^{23}	mol^{-1}
Molar volume of ideal gas at STP		=	2.241×10^{-2}	m^{3}
One standard atmosphere	P_0	=	1.013×10^{5}	N m^{-2}
Acceleration of gravity	g	=	9.81	m s^{-2}
Absolute zero of temperature	T_0	=	0 K =	−273.15 °C
Density of water	ρ_w	=	1000	kg m^{-3}

SECTION A – Answer ALL parts of this section

1.1) A child sitting on a sledge slides down a frictionless slope. If the child and the sledge start from rest at the top of the slope and have a speed of 9 m s^{-1} at the bottom, what is the height of the slope?

[5 marks]

1.2) State Newton's second law of motion. To lift a patient, four nurses each grip one of the corners of the sheet on which the patient is lying and lift upward. If each nurse exerts an upward force of 220 N and the patient has an upward acceleration of 0.703 m s^{-2}, what are the mass and the weight of the patient?

[7 marks]

1.3) State the continuity equation for the flow of an incompressible fluid between regions of different cross-sectional area. Water flows through a hose of diameter 2.5 cm with a speed of 3 m s^{-1}. A nozzle with a cross-sectional area of 0.5 cm^2 is then attached to the hose. With what speed does the water exit the nozzle?

[6 marks]

1.4) A car's fuel tank is filled to the brim with 45 L of petrol at 15 °C. Immediately afterwards, the vehicle is parked in the sun. If the temperature of the petrol increases to 35 °C, how much petrol overflows from the tank? Neglect the expansion of the tank. The coefficient of volume thermal expansion for petrol is 9.6×10^{-4} (°C)$^{-1}$.

[7 marks]

1.5) Define the half-life of a radioactive substance. A radioactive sample is placed in a closed container. Two days later three quarters of the sample have decayed. What is the half-life of this sample?

[7 marks]

1.6) A point source emits sound waves with a power of 100 W. Find the intensity and the intensity level, in decibels, at a distance of 10 m from the source. At what distance would you experience the sound at 120 dB, the threshold of pain? The intensity at the threshold of hearing is $I_0 = 10^{-12}$ W m^{-2}.

[8 marks]

SECTION B – Answer TWO questions

2a) Write down the equations for position and velocity, as a function of time, for motion with constant acceleration in one dimension.

A car is stopped at a traffic light. When the light turns green, the car starts from rest with an acceleration of 2.8 m s^{-2}. At the same time, a truck travelling with a constant speed of 50 km h^{-1} passes the car. When and where will the car catch up with the truck?

[12 marks]

b) Which quantities are conserved in elastic and inelastic collisions?

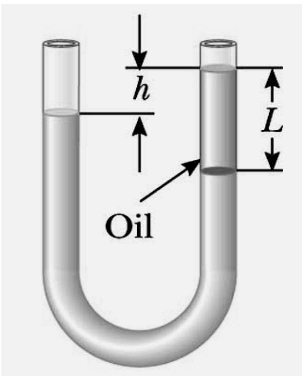
Two objects moving with a speed v travel in opposite directions along a straight line. The objects stick together when they collide and move with a speed of $v/4$ after the collision. What is the ratio of the masses of the two objects? What is the ratio of the final kinetic energy of the system to the total initial kinetic energy?

[10 marks]

c) Describe, with the use of an appropriate equation, how the pressure in a fluid depends on depth.

A U-tube open at both ends is partially filled with water. Oil is then poured into the right arm and forms a column L = 6 cm high. Determine the difference h in the heights of the two liquid surfaces. The density of oil is 750 kg m^{-3}.

[8 marks]



3a) Define heat capacity, specific heat and latent heat.

i) A lake contains 4×10^{11} m^3 of water. How much energy is required to raise the temperature of that volume of water from 11 °C to 12 °C? How many years would it take to supply this amount of energy by using the 10^9 W exhaust energy of an electric power plant?

ii) A 0.1 kg cube of ice at 0 °C is dropped into 1.0 kg of water that was originally at 80 °C. What is the final temperature of the water after the ice melts?

The specific heat of water is 4186 J kg^{-1} $(°C)^{-1}$ and the latent heat of fusion of water is 33.5×10^4 J kg^{-1}.

[12 marks]

b) Write down the equation of state of an ideal gas and define the quantities involved.

An air bubble has a volume of 1.5 cm^3 when it is released by a submarine 100 m below the surface of a lake. What is the volume of the bubble when it reaches the surface?
The atmospheric pressure at the surface is 1.013×10^5 Pa. Assume that air behaves as an ideal gas, that the pressure inside the bubble is equal to the pressure of the water and that the temperature and the number of air molecules in the bubble remain constant during ascent.

[8 marks]

c) Name and briefly describe the three main mechanisms of heat exchange.

Measurements on two stars indicate that star X has a surface temperature of 5727 °C and star Y has a surface temperature of 11727 °C. If both stars have the same radius and the same emissivity, what is the ratio of radiated power of star Y to the radiated power of star X?

[10 marks]

4a) Consider a nucleus that can undergo either α decay or β^- decay.

i) Describe these two decay processes in terms of the emitted particles and characteristics of the parent and daughter nuclei (i.e. atomic number, neutron number and mass number).

ii) In each case, state whether the radius of the resulting daughter nucleus is greater than, less than or the same as that of the parent nucleus.

[6 marks]

b) i) Show that the half life $T_{1/2}$ of a radioactive substance is related to the decay constant λ by $T_{1/2}=\ln(2)/\lambda$.

ii) Define the activity of a radioactive substance.

[7 marks]

c) i) The half-life of iodine-131 is 8.04 days. Find the number of iodine-131 nuclei necessary to produce a sample with an activity of 1.85×10^4 Bq.

ii) A building has become accidentally contaminated with radium-228. If the building initially contained 10^{-3} kg of this radioactive substance and the safe level is less than 0.5 Bq, determine for how long the building will be unsafe. The mass of a radium-228 atom is 3.79×10^{-25} kg and the half-life of radium-228 is 5.7 years.

[11 marks]

d) A 200-rad dose of radiation is administered to a patient in an effort to combat a cancerous growth, which has a mass of 0.25 kg and specific heat equal to that of water. Assuming that all the energy deposited is absorbed by the growth, calculate its temperature rise. (1 rad = 0.01 J kg^{-1})
The specific heat of water is 4186 J kg^{-1} (°C)$^{-1}$.

[6 marks]