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 2004

Time allowed: THREE Hours

Candidates should answer no more than SIX 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}	$\mathrm{F\,m^{-1}}$
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$	$\mathrm{H\,m^{-1}}$
Speed of light in free space	c	=	2.998×10^{8}	$\mathrm{m\,s^{-1}}$
Gravitational constant	G	=	6.673×10^{-11}	$\mathrm{N\,m^2\,kg^{-2}}$
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}	$\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	σ	=	5.670×10^{-8}	$\mathrm{W\,m^{-2}\,K^{-4}}$
Gas constant	R	=	8.314	$\mathrm{J\,mol^{-1}\,K^{-1}}$
Avogadro constant	N_A	=	6.022×10^{23}	$\mathrm{mol^{-1}}$
Molar volume of ideal gas at STP		=	2.241×10^{-2}	$\mathrm{m^3}$
One standard atmosphere	P_0	=	1.013×10^{5}	$\mathrm{N\,m^{-2}}$
Acceleration of gravity	g	=	9.810	$\mathrm{m\ s^{-2}}$

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SECTION A – Answer SIX parts of this section

1.1) Assume that the brakes in your car create a constant deceleration, regardless of how fast you are going. Derive an expression relating the time and distance needed to stop with your driving speed. If you double your driving speed, how does this affect the time required to come to a stop and the distance needed to stop?

[7 marks]

1.2) When two people push in the same direction on an object of mass 2 kg they cause an acceleration of 8 m s^{-2}. When they push in opposite directions, the acceleration of the object is 3 m s^{-2}. Determine the magnitude of the force exerted by each of the two people.

[7 marks]

1.3) The density of ice is 920 kg m^{-3} and that of sea water is 1030 kg m^{-3}. What fraction of the total volume of an iceberg is exposed?

[7 marks]

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

[7 marks]

1.5) Write down the equation of state of an ideal gas and define the quantities involved. An ideal gas is confined to a sealed container with an adjustable volume. The temperature is constant. By what factor will the volume change if the pressure triples?

[7 marks]

1.6) $^{198}_{79}$Au, one of the many isotopes used in cancer treatment, has a half-life of 2.70 days. Determine the number of $^{198}_{79}$Au nuclei required to give an activity of 8.35×10^{10} Bq.

[7 marks]

1.7) Explain the difference between transverse waves and longitudinal waves. Give one example of each type of wave motion.

[7 marks]

1.8) The intensity level of an orchestra is 85 dB. A single violin achieves a level of 70 dB. By what factor is the intensity of the sound of the full orchestra larger than that of the violin's sound?

[7 marks]

SECTION B – Answer TWO questions

2)

a) Explain the principle of conservation of mechanical energy.

i) A sled slides without friction down a small, ice-covered hill. If the sled starts from rest at the top of the hill and its speed at the bottom is 8.50 m s^{-1}, what is the height of the hill?

ii) On a second run, the sled of part i) starts with a speed of 1.50 m s^{-1} at the top. What is the speed of the sled at the bottom of the hill after the second run?

[12 marks]

b) Define linear momentum and explain the principle of its conservation.

As a result of an explosion, an object initially at rest breaks into two pieces. One piece has three times the mass of the other. Determine the ratio of the kinetic energies of the two pieces.

[9 marks]

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

During a snowball fight two balls with masses of 0.4 and 0.6 kg are thrown in such a manner that they meet head on and combine to form a single mass. Immediately before the collision each snowball has a speed of 15 m s^{-1}. What is the speed of the single mass immediately after the collision and in which direction does it move?

[9 marks]

3)

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

If the density of blood is 1.05×10^3 kg m^{-3} and the distance between the heart and feet of a person is 1.20 m, find the difference in blood pressure between the feet and the heart.

[8 marks]

b) State the continuity equation for an incompressible fluid.

The approximate inside diameter of the aorta is 0.50 cm; that of a capillary is 10 μm. The approximate average blood flow speed is 1.0 m s^{-1} in the aorta and 1.0 cm s^{-1} in the capillaries. If all the blood in the aorta eventually flows through the capillaries, estimate the number of capillaries in the circulatory system.

[13 marks]

c) The Poiseuille equation

$$\frac{\Delta V}{\Delta t} = \frac{(P_1 - P_2)\pi r^4}{8\eta L}$$

gives the flow rate for a viscous fluid through a tube with circular cross-section.

i) Define the symbols in this equation.

ii) If cholesterol builds up in major arteries so that their diameter is reduced by 10%, by what percentage will the blood flow be reduced? (Assume that all the other properties of the arteries remain unchanged).

[9 marks]

4)

a) Define heat capacity and specific heat.

Lead pellets, each of mass 1.00 g, are heated to 200 °C. How many pellets must be added to 500 g of water that is initially at 20.0 °C to make the equilibrium temperature 25.0 °C? Neglect any energy transfer to or from the container. [Specific heat of water = 4186 J kg^{-1} $°C^{-1}$; specific heat of lead = 128 J kg^{-1} $°C^{-1}$]

[10 marks]

b) Describe the process of thermal expansion and define the coefficient of linear expansion.

A pair of spectacle frames is made of epoxy plastic [coefficient of linear thermal expansion = 130 × 10^{-6} $°C^{-1}$]. At room temperature (20.0 °C) the frames have circular lens holes of radius 2.20 cm. What is the minimum temperature to which the frames must be heated in order to insert lenses of radius 2.21 cm?

[8 marks]

c) What is it meant by latent heat?

A heat transfer of 9.5 × 10^5 J is required to convert a block of ice at -12 °C to water at 12 °C. What was the mass of the block of ice? [Specific heat of ice = 2090 J kg^{-1} $°C^{-1}$; specific heat of water = 4186 J kg^{-1} $°C^{-1}$; latent heat of fusion = 33.5 × 10^4 J kg^{-1}]

[12 marks]

5)

a) How do the numbers of protons and neutrons in the parent and daughter nuclei compare in each of the following processes:

i) α decay

ii) β^- decay

iii) β^+ decay

iv) γ decay

[8 marks]

b) Define the half-life of a radioactive substance. Show that the half-life $T_{1/2}$ is related to the decay constant λ by

$$T_{1/2} = \frac{ln(2)}{\lambda}$$

[7 marks]

c) In one of the rocks brought back from the Moon, it is found that 80.5% of the potassium-40 contained initially in the rock has decayed to argon-40.

i) If the half-life for this decay is 1.20×10^9 years, how old is the rock?

ii) How much longer will it take until only 10.0% of the original potassium-40 remains in the rock?

[15 marks]