# 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**

**CP/1020 Basic Physics II**

**Summer 2001**

**Time allowed: THREE Hours**

**Candidates must answer SIX parts of SECTION A,**
**and TWO questions from SECTION B.**

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

**Separate answer books must be used for each Section of the paper.**

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

**TURN OVER WHEN INSTRUCTED**

Acceleration due to gravity = $9.8\,\mathrm{m\,s^{-2}}$

## SECTION A - Answer **SIX** parts of this section

1.1) Distinguish between *fundamental units* and *derived units* in the SI, giving examples to illustrate your answer.

[7 marks]

1.2) Define the *decibel*, used in measuring the loudness of a sound. The sound intensity corresponding to the threshold of hearing is usually taken as $10^{-12}\,\mathrm{W\,m^{-2}}$. What is the sound level in decibels in the vicinity of a pneumatic drill, where the sound intensity is $0.2\,\mathrm{W\,m^{-2}}$?

[7 marks]

1.3) Describe the motion of atoms in a monatomic gas in a container, and hence explain why the gas exerts a pressure on the container walls.

[7 marks]

1.4) Explain briefly why ionising radiation can be effective in the treatment of a tumour. Describe one way in which damage to healthy tissue in the region of an irradiated tumour can be limited.

[7 marks]

1.5) Define (a) a *perfectly elastic collision* and (b) a *totally inelastic collision*. During shunting operations in a rail yard, a moving truck of mass 5 tonnes is in collision with a stationary truck of mass 6 tonnes. After the collision, the trucks move off together with a velocity of $10\,\mathrm{km\,hr^{-1}}$. What was the velocity of the moving truck before the collision?

[7 marks]

1.6) Define the *thermal conductivity* of a substance. The solid wooden exterior door of a house is 2.1 m high, 1 m wide and 4 cm thick. If the temperature inside the house is maintained at 21°C and the outside temperature is −2°C, how much heat flows through the door in 1 hr? (Thermal conductivity of wood = $0.09\,\mathrm{W\,m^{-1}\,K^{-1}}$.)

[7 marks]

1.7) What is the *mechanical advantage* of a machine? A pulley system consists of two pulley blocks, each with two pulley wheels, appropriately threaded with cord. The upper block is attached to a rigid support, while the other block, vertically below the upper one, is attached to a package of x-ray films of mass 30 kg. Draw a diagram of the system suitably arranged to lift the package. Show that the tension in the cord is 73.5 N and determine the mechanical advantage of the system.

[7 marks]

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1.8) What is meant by the *conservation of mechanical energy*? A patient in a hospital ward accidentally drops a book from a height of 1.5 m above the floor. If the book falls without rotating, has no initial vertical velocity and encounters no obstacles during its descent, what is its vertical velocity immediately before it strikes the floor?

[7 marks]

## SECTION B - Answer TWO questions

2) Describe the phenomenon of *natural radioactivity*. Include decay schemes associated with the emission of α-particles, β-particles and γ-radiation in your answer.

[10 marks]

For a radioactive decay process, show that the number, $N$, of radioactive atoms remaining after a time, $t$, is given by $N = N_0 \exp(-kt)$, where $N_0$ is the number of atoms at $t = 0$ and $k$ is the decay constant. State any assumptions made in your derivation.

[10 marks]

What is meant by the half-life ($T_{½}$) of a radioactive substance? Show that $T_{½} = \frac{\ln 2}{k}$.

[5 marks]

The activity of a sample of the radioactive isotope $^{131}$I, used in the treatment of diseased thyroid tissue, is found to fall by 20% in 2.6 days. What is the half-life of $^{131}$I?

[5 marks]

3) Describe the structure and mode of operation of a transducer that can be used for the generation and detection of ultrasound.

[10 marks]

Give a qualitative description of the Doppler effect in acoustics, and show, without detailed analysis, how it may be used to determine the velocity of a sound source. Describe briefly how this effect may be used to obtain information about blood flow in human blood vessels.

[10 marks]

Define the *acoustic impedance* of a material. Determine the acoustic impedances of tissue and air. Why is *impedance matching* important in relation to ultrasonic examination of tissues within the human body? How is it achieved in practice? (Velocity of ultrasound in human tissue = 1580 m s$^{-1}$; velocity of ultrasound in air = 331 m s$^{-1}$; density of human tissue = 1040 kg m$^{-3}$; density of air = 1.29 kg m$^{-3}$.)

[10 marks]

**SEE NEXT PAGE**

4) What is meant by the *viscosity* of a fluid? Define the *coefficient of viscosity*.

[8 marks]

What is a Newtonian fluid? The flow of liquid through a horizontal cylindrical tube is described by the relation

$$V = \frac{\pi P a^4}{8\eta l}.$$

Explain the significance of each symbol in this equation.

[7 marks]

Draw a labelled diagram of an Ostwald viscometer, and explain how it is used to determine the coefficient of viscosity of a Newtonian liquid.

[8 marks]

A syringe is used to inject 10 $cm^3$ of liquid medication into a patient. The needle of the syringe has a length of 5 cm and an internal diameter of 0.3 mm, and the time taken to empty the syringe is 20 s. Determine the pressure difference between the ends of the needle during the injection. (Assume the needle is horizontal throughout the injection, which takes place at a steady rate, and that the liquid is Newtonian. The coefficient of viscosity of the medication = $1.1 \times 10^{-3}$ Pa s.)

[7 marks]

5) Describe the construction and operation of the following thermometers:

(a) a mercury-in-glass thermometer designed to be used as a clinical thermometer;
(b) a thermocouple.

What are the advantages and disadvantages of these thermometers when used in a clinical environment?

[15 marks]

What is meant by the *specific heat capacity* of a substance? 1 kg of water, initially at a temperature of 20°C, is heated to 100°C in an electric kettle. If the kettle is thermally insulated so that no heat is lost, how much energy is needed to heat the water?

All the water is poured into a ceramic hot water bottle of mass 2 kg, initially at a temperature of 20°C. If no heat is lost from the system, what is the final temperature of the hot water bottle? (Specific heat capacity of water = 4190 J $kg^{-1}$ $K^{-1}$; Specific heat capacity of ceramic = 900 J $kg^{-1}$ $K^{-1}$.)

[15 marks]

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