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 2003

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.

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

TURN OVER WHEN INSTRUCTED

Gravitational acceleration	$g = 9.81$ m s^{-2}
Area of a circle	$A = \pi r^2$
Volume of a cylinder	$V = \pi r^2 h$
Units of pressure	1 Torr = 133 Pa

SECTION A – Answer SIX parts of this section

1.1) Explain the role of impedance matching in an ultrasound investigation

[7 marks]

1.2) Explain why some liquids can rise against the force of gravity in a small capillary.

[7 marks]

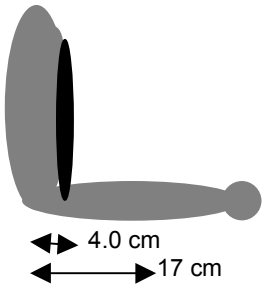
1.3) Explain the molecular origin of pressure in a gas.

[7 marks]

1.4) The activity A of a radioactive sample at time $t = 0$ is 9.0 MBq. At $t = 3$ minutes the activity is 2.0 MBq. What is the radioactive decay constant?

[7 marks]

1.5) How much force is needed to hold your forearm at right angles to your upper arm using your biceps (shown in black in the figure)? Assume that the elbow serves as a fulcrum and is 4.0 cm away from the place where the biceps is attached. The forearm has a mass of 1.5 kg. The centre of gravity of the forearm is 17 cm away from the elbow.



[7 marks]

1.6) The heat lost through a window is given by $\Delta Q = kA\dfrac{\Delta T}{L}t$. Explain the meaning of the symbols used. Calculate the amount of heat that is lost in 1 hour through a window that is 2.0 cm thick with an area of 9.0 m^2 if the inside temperature is 23º C and the outside temperature is 8ºC. The thermal conductivity of the glass is 1.0 W m^{-1} K^{-1}.

[7 marks]

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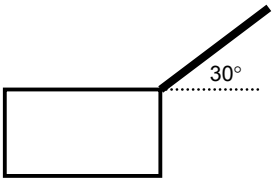
1.7) The figure shows a suitcase being pulled along the ground using a rope which is inclined at 30.0° to the horizontal. Calculate the work done when the suitcase is pulled for a distance of 100 m with a force of 50.0 N.



[7 marks]

1.8) The intensity of sound is measured with respect to the lowest intensity one can hear, $I_0 = 1.0 \times 10^{-12}$ W m^{-2}. What is the intensity level in decibels of a child crying with an intensity of 8.0×10^{-6} W m^{-2}?

[7 marks]

SECTION B – Answer TWO questions

2)

a) i) What are the properties of an ultrasound wave in medical imaging?

[5 marks]

ii) Describe briefly the technique of echo-sounding.

[5 marks]

iii) State briefly the differences between an amplitude scan, a brightness scan and a Doppler scan in terms of what is measured and for what the scan is used.

[6 marks]

b) An ultrasound amplitude scan is used for an eye examination and an echo signal is received after 10.5 μs. The average velocity of ultrasound in the eye is 1510 m s^{-1}. At what distance is the structure that gave rise to the echo?

[7 marks]

c) An ultrasound Doppler scan is used for an examination of a heart valve. The outgoing ultrasound beam has a frequency of 2.20 MHz. It travels at a speed of 1.5 km s^{-1} through soft tissue. It is reflected perpendicularly from the moving heart valve. A Doppler shift of 400 Hz is detected in the reflected beam. At what speed is the heart valve moving?

[You may find the following expression useful: $\Delta f = 2 \frac{u}{v} f \cos\theta$]

[7 marks]

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3)

a) i) What is viscosity? Give an example of a fluid which has a high viscosity.

[3 marks]

ii) By what factor does the velocity of blood flow increase in a small length of aorta whose radius is reduced by ½ due to the build-up of plaque?

[6 marks]

iii) The blood pressure in the wide part of the aorta in (ii) is 120 Torr, and the velocity of the blood flow is 30 cm s^{-1}. What is the blood pressure in the part narrowed by plaque?

[7 marks]

b) A patient receives blood from a bag through a tube into the vein. How high should the bag be hung so that the pressure at the vein is at least 12 Torr?

[7 marks]

c) Blood takes about 1.0 s to pass through a 1.0 mm long capillary. The radius of the capillary is 3.5 μm, and the pressure difference over 1 mm is 2.60 kPa. What is the viscosity, η, of the blood?

[You may find the following expression useful: $\frac{\Delta V}{\Delta t} = \frac{\pi}{8}\frac{r^4}{\eta}\frac{P_1 - P_2}{L}$]

The density of blood at 37 ºC is 1030 kg m^{-3}

[7 marks]

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4)

a) Copy and complete the following table:

	α - decay	β^- - decay	γ -decay
Particle	?	e^-	γ
Decay scheme	$^{208}_{84}Po \rightarrow {}^{?}_{?}Pb + ?$	$^{199}_{78}Pt \rightarrow {}^{?}_{?}Au + e^- + \bar{\nu}$	$^{99*}_{43}Tc \rightarrow {}^{?}_{?}Tc + \gamma$
Ionising ability	?	strong	?

[6 marks]

b) Explain briefly how positron emission tomography (PET) in the brain works.
[4 marks]

c) Define the physical half-life, the biological half-life and the effective half-life for a radioactive substance. Explain how the effective half-live is calculated.
[6 marks]

d) (i) A radioactive substance has a decay constant of 0.139 day^{-1}. Initially, there are 1.00×10^6 radioactive nuclei. How many radioactive nuclei are there after 14 days, assuming that this is governed by the physical half-life?
[7 marks]

(ii) Calculate the physical half-life of the substance.
[7 marks]

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5)

a) (i) Briefly state Newton's three laws of motion.

[3 marks]

(ii) Explain briefly the meaning of the equations $F = ma$ and $F = \frac{\Delta p}{\Delta t}$

[3 marks]

b) (i) A tennis ball of mass 0.0625 kg is moving with 14.5 m s^{-1}. What is its momentum?

[3 marks]

(ii) The tennis ball hits the net in the tennis court and comes to rest in 21.5 ms. What force is put on the tennis ball?

[4 marks]

c) A tennis ball with a mass of 0.0625 kg is moving with 14.5 m s^{-1} when it collides in mid-air head-on with a rubber ball of mass 0.0475 kg moving in the opposite direction at 11.0 m s^{-1}. If the tennis ball rebounds with 7.52 m s^{-1} , find the final velocity of the rubber ball. You may assume that the collisions are perfectly elastic, and that friction may be neglected.

[8 marks]

d) A player holds a tennis ball of mass 0.0625 kg a height of 1.20 m and then lets go of the ball so that the ball falls to the ground.

(i) What is the potential energy of the tennis ball when held?

[3 marks]

(ii) What is the kinetic energy of the tennis ball just before it hits the floor?

[3 marks]

(iii) What is the velocity of the tennis ball just before it hits the floor?

[3 marks]