UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualification:-

Physics 1B72: Waves and Modern Physics

COURSE CODE	:	**PHYS1B72**
UNIT VALUE	:	**0.50**
DATE	:	**20-MAY-03**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

03-C1065-3-40

TURN OVER

Answer ALL questions from Section A and THREE questions from Section B.

The numbers in the square brackets in the right-hand margin indicate the provisional allocation of maximum marks per sub-section of a question.

elementary charge, $e = 1.60 \times 10^{-19}$ C
mass of electron, $m = 9.11 \times 10^{-31}$ kg
mass of neutron, $m_N = 1.67 \times 10^{-27}$ kg
permittivity of free space, $\varepsilon_0 = 8.854 \times 10^{-12}$ F m^{-1}
Planck's constant, $h = 6.63 \times 10^{-34}$ J s
velocity of light in vacuum, $c = 3.0 \times 10^8$ ms^{-1}

SECTION A

1. A radio station broadcasts at a frequency of 100 MHz with a total radiated power of 15000 watts. Calculate:
(a) the wavelength of this radiation [1]
(b) the energy (in eV) in each of the photons that compose this radiation [2]
(c) the number of photons emitted per second [2]
(d) the number of photons emitted per cycle of oscillation [1]

2. A mass oscillates on a spring in simple harmonic motion, moving up and down over a total range of 40 mm. The period of motion is T = 2 s. A clock is started at t = 0 s, when the mass is at its minimum height.
Calculate the height and velocity of the mass at t = 10.5 s. [7]

3. If the smallest detectable sound intensity is I_0, define the sound level, in decibels, of a sound with intensity I. [2]

Given that $I_0 = 10^{-12}$ W m^{-2}, calculate the sound level, in decibels, of a sound whose intensity is $I = 8.3 \times 10^{-4}$ W m^{-2} [1]

A source emits sound with equal intensity in all directions. If the sound level measured at a distance of 5 m from the source is 83 dB, what is the power output of the source? [3]

4. Two travelling waves that move in opposite directions along the x-axis interfere to form a standing wave of the form

$$6 \sin(kx) \cos(\omega t)$$

(a) write down the forms of the two travelling waves [3]

(b) if $k = 3\pi \ m^{-1}$ and $\omega = 22\pi \ s^{-1}$, calculate the frequencies (in Hz), the wavelengths (in m) and the velocities of the travelling waves. [4]

[You may note that $\sin(A+B) = \sin A \cos B + \sin B \cos A$,
and $\sin(A-B) = \sin A \cos B - \sin B \cos A$]

5. In a Young's slits experiment, monochromatic light with wavelength λ illuminates two narrow slits separated by a distance d. Fringes are observed on a screen at a distance D from the slits. Show that the separation between neighbouring bright fringes is $\lambda D/d$. [5]

Light of frequency 5.494×10^{14} Hz is incident on two such slits separated by 0.15 mm. Calculate the separation of the fringes observed on a screen 90 cm from the slits. [2]

6. Write down Heisenberg's Uncertainty Principle, and explain briefly how this limits the accuracy of a simultaneous measurement of the position and momentum of a particle. [3]

An electron with a kinetic energy of approximately 3 keV has an uncertainty in its momentum of 2%. What is the minimum uncertainty in its position? [4]

SECTION B

7. Give a physical example of (a) longitudinal, and (b) transverse wave motion. Describe a physical property of transverse waves that may be used to distinguish them from longitudinal waves. [5]

Derive the wave equation for longitudinal waves travelling in a long thin rod, and show that the velocity of these waves is $\sqrt{(Y/\rho)}$, where Y is the Young's modulus and ρ the density of the material of the rod. [11]

The velocity of longitudinal waves travelling in a thin metal rod of diameter 8 mm, length 600 mm and mass 82 g is 5.04 km s^{-1}.
Calculate the Young's modulus of the metal. [4]

8. Outline the evidence for the wave-like properties of electrons. [5]

State the de Broglie equation for the wavelength of a moving particle in terms of its momentum . [2]

Calculate the kinetic energy (in joules) of an electron that has been accelerated through an electrostatic potential of 10 kV. [1]

What is the value of the momentum of the electron, and its units? [2]

Use the de Broglie equation to calculate the wavelength of the electron. [2]

What would be the kinetic energy (in eV) of a *neutron* having this wavelength? [3]

A beam of such electrons (i.e. having been accelerated through 10 kV) undergoes Bragg reflection from a set of parallel planes in a crystal that are 10^{-10} m apart. Calculate the angle between the incident and scattered beams. [5]

9. Describe, using diagrams where appropriate, typical results of an experiment to demonstrate the photoelectric effect. [6]

Explain how the photon model enables the results to be understood. [6]

Ultraviolet light of wavelength 320 nm and intensity 5 Wm^{-2} is directed perpendicular to a potassium metal surface of size 6 mm x 12 mm.

(a) Calculate the maximum kinetic energy (in eV) of the photoelectrons, given that the work function of potassium is 2.2 eV. [4]

(b) calculate the number of photoelectrons emitted per second, if 5% of the incident photons produce photoelectrons. [4]

10. Use Bohr's model to deduce the energy levels of the hydrogen atom:

$$E_n = -\frac{m e^4}{8 \varepsilon_o^2 h^2 n^2}$$ [13]

Draw a diagram of the energy levels, indicating how the transitions corresponding to the Lyman and Balmer series arise. [3]

Calculate the wavelengths of the longest and shortest wavelength lines in the Balmer series. [4]

[You may use the numerical result $E_n = - \{13.6/n^2\}$ eV]

11. State the two postulates of Einstein's theory of special relativity. [4]

Two Cartesian frames of reference, S and S', are coincident at time $t = 0$. The frame S' moves with velocity v, along the x-axis, with respect to S.
In S' the time interval measured between two events which take place at the same location is $\Delta t'$ and in S, the time interval measured is Δt. Derive from first principles the relation

$$\Delta t = \frac{\Delta t'}{\sqrt{[1 - (v/c)^2]}}$$ [10]

According to a clock in the spaceship, how many years will it take a spaceship travelling at 0.999 c to cross a galaxy with a diameter, as measured in the galaxy's rest frame, of 2.5 $\times 10^{19}$ m? [6]