UNIVERSITY OF NOTTINGHAM

FACULTIES OF PURE SCIENCE AND

APPLIED SCIENCE

FIRST YEAR PART 1 EXAMINATION, 1966

PHYSICS (i)

WEDNESDAY *June* 1st 9.45 — 12.45

*Answer* six *questions.*

1. State and define the two kinds of products useful in physics which may be obtained from two vectors **A** and **B** inclined at an angle $\theta$ to one another.

In the theory of atomic structure the two vectors L and **S** and their sum **J** have integral magnitudes. Find all the possible values of **J** and the corresponding angles between **L** and **S** when $L = 3$ and $S = 2$, illustrating your answer with suitable vector diagrams.

Calculate the energy $\lambda$ **L. S** of the system for each value of $J$ where $\lambda$ is a constant and illustrate by means of an energy level diagram.

*[Turn over*



[49311

2. Explain briefly what is meant by damped harmonic motion giving two physical examples. For one chosen example show that the equation of motion is of the form

$$\ddot{x} + \alpha \dot{x} + \beta x = 0$$

where $\alpha$ and $\beta$ are constants.

Given that the solution to this equation is

$$x = E \exp[-\frac{1}{2}(\alpha - m)t] + F \exp[-\frac{1}{2}(\alpha + m)t]$$

where $m^2 = (\alpha^2 - 4\beta)$ and $E$ and $F$ are arbitrary constants. show that

$$x = G \exp(-\frac{1}{2}\alpha t)\sin(\frac{1}{2}m' t + \delta)$$

is a convenient form of the solution in the underdamped case. Explain the significance of each term in the latter expression and describe how $G$ and $\delta$ may be determined in your chosen example.

Define the logarithmic decrement and calculate its value in terms of $\alpha$ and $\beta$.

3. Distinguish between transverse and longitudinal waves giving two different examples of each. What is a stationary wave?

A transverse sine wave of amplitude 10 cm and of wavelength 200 cm is moving from left to right along a long horizontal taut string with a speed of 100 cm sec$^{-1}$. The origin is taken as the left end of the undisturbed string. At the time $t = 0$ the left end of the string has zero displacement and is moving downwards. Deduce:

(*a*) the frequency $\nu$ of the wave,

(*b*) the angular frequency $\omega$ of the wave,

(*c*) the wave number *k*,

(*d*) the equation for the displacement of the string as a function of time and position along the string,

(*e*) the displacement at time *t* of the left end of the string,

(*f*) the displacement at time *t* of a particle 150 cm to the right of the origin, (*g*) the maximum transverse velocity of any particle of the string,

(*h*) the transverse displacement and the transverse velocity of a particle 150 cm to the right of the string at time t = 3.25 sec,

(*i*) the shape of the string for a length of 400 cm from the origin at time 3.25 sec.

4. A particle moves such that its position vector at time *t* is **r.** Explain what is meant by (a) the velocity **v**, (*b*) the speed and (*c*) the angular velocity **ω** of the particle. Derive the relation between **ω** and **v.** If the particle performs uniform circular motion prove that its acceleration **a** is given by

$$\mathbf{a} = \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r})$$

Discuss brieflv how Newton's laws of motion are affected if the position of the particle under examination is referred to two coordinate systems moving relative to one another. You mav assume that the mass remains eonstant in the two svstems. In what situation would Newton's laws be the same in both systems?

5. Define the angular momentum and moment of inertia of a particle of mass *m* whose position vector at a time *t* is **r** relative to an origin *0*.

A set of forces $\mathbf{F}_i$ act on a rigid body at points having position vectors $\mathbf{r}_i$ . Find an expression for the rate of change of the angular momentum of the body about *0* and hence deduce the principle of conservation of angular momentum**.** Under what conditions does the body remain at rest?

A man stands on a horizontal turntable holding a pair of dumb-bells with his arms extended. After being given a certain angular velocity about the vertical axis through the centre of the turntable he pulls the dumb-bells in towards his body. His angular speed is found to increase six-fold. If the mass of each dumb-bell is one sixth the mass of the man and the dumb-bells are initially 1 m and finally 0.3 m from the axis of rotation, estimate the radius of gyration of the man. Neglect friction.

*[Turn over*

6. Attempt FOUR of the following:

(*a*) The phase velocitv *v* of ripples in a water tank is given by $v^2 = 2\pi T / \lambda\rho$, where *T* is the surface tension, $\rho$ is the density of the water and $\lambda$ is the wavelength. Calculate the group velocity of ripples of wavelength 1.00 cm in pure water for which *T* = 75.8 dyne $cm^{-1}$.

(*b*) A $\tau$ meson decays at rest into three $\pi$ mesons. Calculate their velocities in the case when they are emitted syrnmetricallv if the energy released in the disintegration is 1.2 x $10^{-11}$ joule and the mass of a $\pi$ meson is 2.5 x $10^{-28}$ kg.

(c) Describe how the elastic properties of a material are related to the forces between the constituent atoms.

(*d*) Discuss the basic differences in structure between solids, liquids and gases.

(*e*) Explain, with examples what is meant by gvroscopic motion.

(*f*) Prove that the angular momentum of a rigid body about an axis through a point *O* is equal to the sum of the angular momenta of the constituent particles relative to their centre of mass *G* and the angular momentum about *O* of the total mass of the body concentrated at G.

(*g*) Explain how the study of earthquakes gives information on the earth's structure.

7. Calculate the angular separation of the two yellow lines in the sodium spectrum when observed in first order at normal incidence with a diffraction grating of width 1.5 cm having 15000 lines. Derive the formulae you use.

How much of the grating can be obscured by an opaque screen before the two lines are no longer resolved?

Would the lines then be resolved in the second order spectrum?

[Wave1engths of sodium lines are 5890 $\overset{o}{A}$, 5896 $\overset{o}{A}$ ]

[493]

8. Describe how you would measure the wavelength of light from a monochromatic source using the Lloyd’s mirror method. Derive any expressions you would need to use.

Describe briefly what you expect to observe if

(*a*) the mirror is moved a short distance in a direction perpendicular to the plane of its surface.

(*b*) the width of the source slit is increased.

9. Given a sheet of glass of known refractive index and a photoelectric light meter describe how you would investigate whether a beam of light from an unknown source were plane polarised or not. How would you then determine the plane of polarisation?

[493]