NATURAL SCIENCES TRIPOS PART II

Wednesday 22 May 1985 1.30 to 4.30

PHYSICS AND THEORETICAL PHYSICS (1)

Sections A, B and C carry approximately equal marks, although the individual questions may carry different marks.

Answer as many questions as you can. It is not expected that any candidate will be able to answer all of the questions.

The answers to Sections A, B and C should be tied up in separate bundles. Even if no question is answered in a Section, a cover-sheet for that Section must be completed.

This paper contains four *sides.*

This paper is accompanied by a sheet giving the values of constants.

SECTION A

1 Explain why most solids expand on heating, but a rubber band under constant tension contracts on heating.

2 It is easy to blow out a candle at a distance of 0.5 m, but very difficult to suck it out. Why is this?

3 How can it be demonstrated that a laser beam may transport angular momentum?

4 A solid cylinder of length L and density ρ impacts a rigid surface end-on at a velocity v. If the stress wave velocity in the cylinder is c, calculate the duration, τ, of the impact and hence the pressure p.

5 The output of a transmitter, operating at wavelength λ, is connected between earth and a vertical wire of length $\lambda/4$. Assuming perfect matching, describe the radiation process and comment on the likely efficiency.

6 Outline the operation of three different relaxation oscillators.

[TURN OVER

A particle of mass m moves in a potential V of the form $V = \frac{1}{2}kx^2$ for $x > 0$ and $V = \infty$ for $x < 0$. What are the energy eigenvalues?

Explain why a linear Stark effect is observed in some levels of atomic hydrogen, and almost never in other atoms.

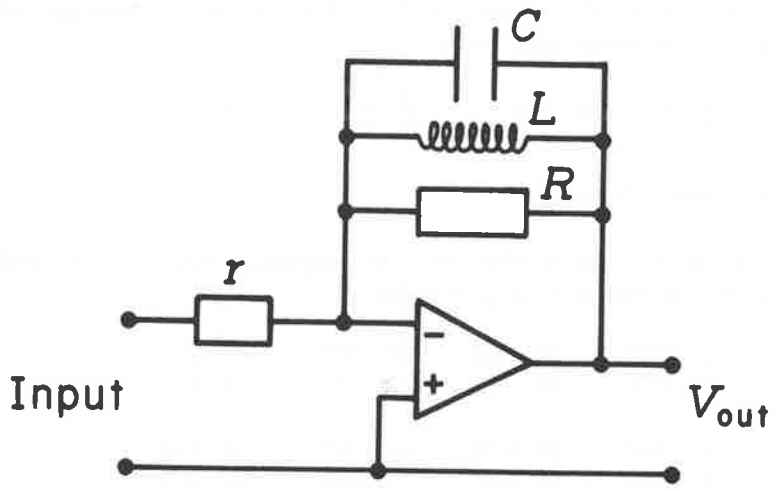
The mass, isospin (I) and spin-parity (J^P) assignments of the $\pi^\pm$, η^0, ρ^0 and ω^0 mesons are listed in the Table.

Particle	Mass/MeVc^{-2}	I	J^P
$\pi^\pm$	140	1	0^-
η^0	549	0	0^-
ρ^0	770	1	1^-
ω^0	780	0	1^-

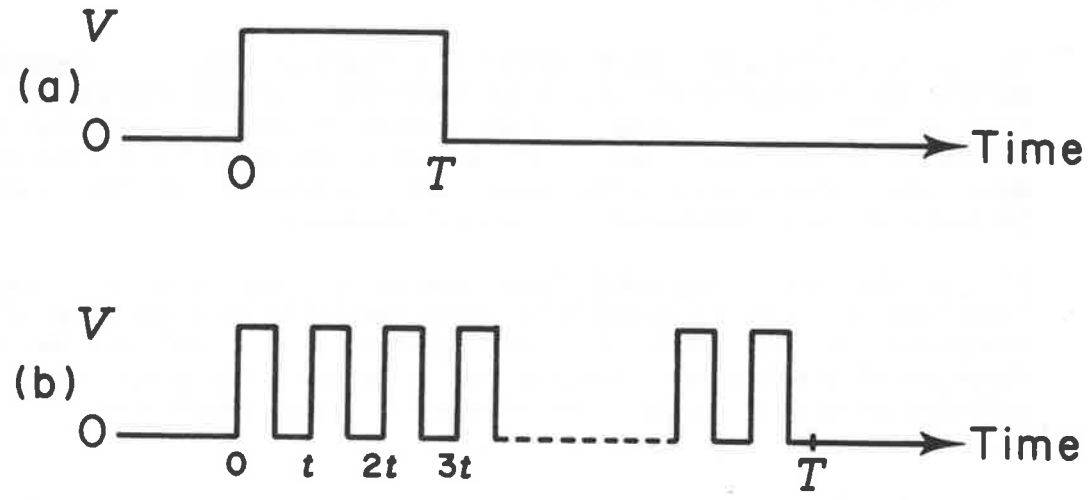
It is theoretically possible for the η^0, ρ^0 and ω^0 particles to decay into two charged pions. Discuss whether the decays are predominantly via the strong, electromagnetic or weak interaction. Which of the decays is likely to be observed experimentally?

SECTION B

10 What outputs, V_{out}, will be obtained from the circuit



for the input waveforms shown below?



You should consider a wide range of t and T and discuss physical interpretations of your results where possible. You may assume that all components are ideal.

11 The following data were obtained during a spectroscopic investigation of the sodium D line doublet. Determine as accurately as possible the average wavelength λ, and the wavelength difference, $\delta\lambda$, for the doublet, and give estimates of the standard errors.

(a) Diffraction grating spectrometer

The grating had 570 150 lines m^{-1}. Pairs of readings of the second order diffraction spectrum were:

D_1	42°40', 42°40'	-41°47', -41°48'
D_2	42°37', 42°38'	-41°44', -41°44'

(b) Michelson interferometer

Pairs of readings of positions of the movable mirror (in mm) for minimum visibility of Haidinger fringes were

26.198	26.495	26.782	27.078	27.367
26.198	26.491	26.781	28.079	27.367
27.688	27.940	28.235	28.527	28.814
27.652	27.942	28.237	28.522	28.817.

[If δl is the path difference for two positions of minimum visiblity, then $\delta\lambda = \lambda^2/\delta l$.]

SECTION C

12 A high-intensity spark source is required which is capable of delivering a sequence of sparks of duration 1 μs and energy 1 J at a rate of 10^5 s^{-1}. A high voltage supply charges a capacitor until breakdown at the spark gap. The duration and repetition rate depend upon the capacitance, resistance and inductance in the circuit. Estimate suitable values of the circuit parameters.

13 It has been suggested that charge constancy under a Lorentz transformation can be established experimentally to 1 part in 10^{10} by observing that the apparent charge carried by a conductor is not a function of temperature. Discuss the principles and practicality of a suitable experiment using a copper sphere of mass about 1 kg.