University of Nottingham

FACULTY OF PURE SCIENCE

SCHOOL OF PHYSICS

PART II EXAMINATION, 1968

PHYSICS (i)

MONDAY *June 3rd* 2.30—5.30

Answer FOUR *questions*

1. Give an account of the production and properties of Cerenkov radiation. How may this radiation be used for the detection and identification of high energy particles?

A beam of particles of momentum 1 GeV/*c* contain mesons and hyperons of rest energy 500 MeV and 1000 MeV respectively. Design a Cerenkov detector that would only be sensitive to the particles of smaller rest energy.

2. Give a detailed account of the design and theory of operation of a proton synchrotron. What factors are likely to limit the energy which could be reached by this type of accelerator?

Discuss the feasibility of producing π mesons ($m_\pi c^2$ = 140 MeV) by allowing γ quanta of energy 150 MeV to interact with a nucleon at rest ($m_p c^2$ = 938 MeV). You may assume that $p^2 - (E^2 / c^2) = -m_o^2 c^2$ is invariant for a Lorentz transformation, where p, E and m_0 represent the momentum, total energy and total rest mass respectively in a given frame of reference.

3. Describe in detail the methods adopted to establish the existence of the two neutrinos.

A block of iron weighing 1000 kg is placed in a neutrino flux of 10^{14} cm^{-2} sec^{-1} from a reactor. If the activation cross section for the formation of Mn^{56} by inverse beta decay is 10^{-44} cm^2, determine the number of Mn^{56} atoms present after 1 day.

[Half life of Mn^{56} = 2.6 hour, Avogadro number = 6.025×10^{23} rnole^{-1}.

4. Discuss the methods available to investigate the composition and energy spectrum of the primary cosmic ray beam. Comment on the results of such measurements and indicate their relevance to the problem of the origin of cosmic rays.

5. Discuss the factors which determine the binding energies of nuclei. Use these factors to derive a semi-empirical formula for the masses of nuclei in terms of the atomic number *Z* and mass number *A*.

Explain how the analysis of β transformations which involve mirror nuclei leads to an estimate of the radii of such nuclei.

8. Show how the relationship between mass and energy emerges from the four vector formalism of special relativity. Derive an expression for the kinetic energy of a particle in terms of its momentum.

Two particles each of rest mass *m* are moving along the x-axis in the same direction with speeds v_1 and v_2. The faster particle collides with the slower one and-the particles coalesce. Derive an expression for the rest mass *M* of the composite particle. Show that if v_1 and v_2 are small compared with the velocity of light *c,* then.

$$M \simeq 2m\left(1 + \frac{(v_1 - v_2)^2}{8c^2}\right)$$

[*Turn over*

7. Deduce the equations of the relativistic Doppler effect and account for the small variation in the apparent position of distant stars over the year.

Calculate approximate values for the maximum apparent angular variation of the direction of a star if (*a*) the direction is perpendicular to the plane of the earth's orbit round the sun and (*b*) the direction is in the plane of the orbit. What is the corresponding fractional variation in the frequencies of spectral lines of the star's spectrum in each case?

[Radius of earth's orbit 15×10^{11} m, 1 year = 32×10^{7} sec, c = 3.0×10^{8} m sec^{-1}.]

8. Explain how neutrons may be detected, giving examples of the neutron-nucleon interactions involved.

State the connection between the mean and the standard deviation for the Poisson distribution.

A counter records 3600 counts in 100 minutes due to background and 6400 counts in 50 minutes when a source known to have a total emission rate of 200 ± 1 disintegrations per minute is inserted. A second similar source produces 10 000 counts in 50 minutes. Estimate the emission rate of this source, giving the standard deviation of your result.

9. Describe and account for the, shape of the current pulse produced by the passage of an ionising particle in (*a*) a pulse ionisation chamber, (*b*) a junction semiconductor detector and (*c*) a proportional counter.

Discuss how each of these counters may be used to measure (i) the energy of such particles and (ii) their rate of arrival at the counter. Explain in each case what conditions are required if both measurements are to be made simultaneously.

Derive an expression for the best energy resolution obtainable when measuring the energy of 5 MeV protons using a silicon semiconductor detector. The energy required to create an electron-hole pair in silicon is 3.5 eV.

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