PART II

This part carries 35% of the total examination marks.

You should attempt **ALL** *the questions 12–16 in this Part. The marks allocated to each question are shown.*

Write your answers in the thick answer book provided. Do **NOT** *use the same answer book for this part as for either question in Part III.*

Question 12

(7 marks)

(*a*) What name is given to the shape of the trajectory of a projectile travelling close to the Earth's surface with negligible air resistance? What can be said about the horizontal and vertical components of the acceleration vector of such a projectile?

(*b*) A man at the top of a tower throws a stone horizontally at $10.0\,\mathrm{m\,s^{-1}}$. It lands 20.0 m away from the base of the tower. How long does it take to drop and what is the height of the tower? You may ignore air-resistance and spin.

Question 13

(8 marks)

(*a*) Explain briefly what is meant by the statement that two waves of equal amplitude suffer *complete destructive interference* at a given point.

(*b*) If light from one torch were shone onto a screen and light from another torch shone onto the same area of the screen, would you expect to see interference fringes? Explain your answer very briefly.

(*c*) A diffraction grating is illuminated at normal incidence by light of frequency $6.4 \times 10^{14}\,\mathrm{Hz}$ from a monochromatic source. If the grating spacing is 700 lines per millimetre, how many orders of diffraction can be seen on each side of the straight-through (zeroth) order?

Question 14

(6 marks)

(*a*) Write down an equation describing the electrostatic potential energy E_{el} of a positive point charge q which is located on the x-axis with position coordinate x and is in the electric field due to another positive charge Q situated at the origin. Define any additional symbols you use.

(*b*) Sketch the shape of the graph of electrostatic potential energy versus x.

(*c*) By differentiating the expression you wrote in (*a*), derive the x-component of Coulomb's law.

Question 15

(6 marks)

(*a*) State the two postulates of Einstein's special theory of relativity.

(*b*) A rod of mass 0.50 kg is initially at rest in an inertial frame S, where its length is measured to be 1.00 m. The rod is rapidly accelerated until it is finally moving at a constant speed parallel to its own length. A physicist in frame S then observes the length of the rod to be 0.60 m. According to this physicist, how much energy was used in accelerating the rod from rest to its final constant speed?

Question 16

(8 marks)

(*a*) Give a brief statement that distinguishes between fermions and bosons.

(*b*) Eight identical fermions each of mass M are trapped in a three-dimensional infinite potential well (a cubic container with impenetrable walls, each of whose sides has length D). The quantum state of each fermion is characterized by three spatial quantum numbers n_1, n_2 and n_3 (which have possible values 1, 2, 3 ...) and a spin magnetic quantum number m_s (which is equal to $\pm\frac{1}{2}$). Given that the energy levels of a particle of mass m in a three-dimensional infinite potential well with sides of length D are given by

$$E_{n_1,n_2,n_3} = \frac{h^2}{8mD^2}\left(n_1^2 + n_2^2 + n_3^2\right),$$

show that the lowest possible *total energy* of this system E_{tot} is given by $E_{\mathrm{tot}} = \dfrac{21h^2}{4mD^2}$.

(*c*) Suppose that the eight fermions fuse to form four composite particles, each consisting of a bound pair of the original fermions. Ignoring any energy associated with this binding, what is the lowest possible total energy of the new system?

TURN OVER