## PART III

*This part carries 32 per cent of the total examination marks.*

*You should attempt* **TWO** *questions from this part, either Question 17 or Question 18* **and** *either Question 19 or Question 20. Questions are equally weighted, but note that about one-third of the marks for each question are awarded for good problem solving techniques with Preparation, Working and Checking stages.*

**Each** *question in this part* **must** *be answered in a separate single-question answer book.*

**EITHER** **Question 17**

A projectile of mass 50 kg is launched at 60° to the horizontal and with an initial speed of $30\,\mathrm{m\,s^{-1}}$ from a point that is surrounded by perfectly level ground. 4.0 seconds after launch, the projectile explodes, breaking into just two portions of equal mass. Immediately following the explosion, one part travels vertically downwards, and the other travels horizontally. What is the distance between the points at which the two parts hit the ground? (*Hint*: Calculate the height at which the explosion takes place and then concentrate on the part that moves off horizontally.)

**OR** **Question 18**

A vertical spring of negligible mass is attached to the ceiling and hangs vertically downwards. A weight is gently attached to the bottom of the spring and temporarily held in position, so that the spring remains at its natural length and does not yet stretch to its new equilibrium length. The mass is then released from rest and is found to oscillate simple harmonically about its new equilibrium position, with a maximum speed of $0.45\,\mathrm{m\,s^{-1}}$. Calculate the amplitude and period of these simple-harmonic oscillations.

**AND**

**EITHER** **Question 19**

A stream of negatively charged particles is accelerated by a potential difference of 200 V and injected into a partially evacuated chamber, where the path taken by the particles shows up as a visible beam. When the chamber is placed in a uniform magnetic field of magnitude 1.2 mT, the beam is observed to travel in a circular path of radius 3.9 cm. What is the charge-to-mass ratio of the particles? (You may ignore effects due to gravity or the Earth's magnetic field.)

**OR** **Question 20**

A particle of mass $m$ is confined to a one-dimensional infinite square well of width $L$, which stretches from $x = 0$ to $x = L$. Schrödinger's equation for this particle takes the form

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}(E_{tot} - E_{pot}(x))\psi = 0$$

where $E_{pot}(x)$, the appropriate potential energy function, is equal to zero inside the well. In the region from $x = 0$ to $x = L$, the wavefunction solutions to this equation can all be written in the form

$$\psi(x) = A\sin(kx) \qquad (1)$$

where $A$ and $k$ are constants.

(*a*) By differentiation, show that the wavefunction given in Equation 1 does satisfy Schrödinger's equation in the region from $x = 0$ to $x = L$. Deduce an expression for the total energy.

(*b*) State any extra constraints that must be applied to the wavefunction if it is to be a satisfactory solution to Schrödinger's equation. Hence deduce an expression for the allowed values of the total energy of the particle.

(*You need only offer a check to one (either) part of this problem.*)

[END OF QUESTION PAPER]