marks

The diffraction maxima occur at angles θ_n given by

$$\sin\theta_n = \frac{n\lambda}{d} = \frac{n \times 1.83 \times 10^{-7}\,\mathrm{m}}{7.20 \times 10^{-7}\,\mathrm{m}} = n \times 0.254.$$ 1

This has solutions $\theta_0 = 0°$ for $n = 0$, $\theta_1 = 14.7°$ for $n = 1$, $\theta_2 = 30.5°$ for $n = 2$ and $\theta_3 = 49.6°$ for $n = 3$, with no other solutions less than 90°. 4

On the screen, the corresponding bright spots are at distances $(2.00\,\mathrm{m}) \times \tan\theta_n$ from the undeflected beam. This gives a total of seven spots, symmetrically arranged along a horizontal line. Placing the origin at the central spot and taking the x-axis to point along the line of spots, maxima occur at $x_0 = 0\,\mathrm{m}$, $x_1 = \pm 0.52\,\mathrm{m}$, $x_2 = \pm 1.18\,\mathrm{m}$ and $x_3 = \pm 2.33\,\mathrm{m}$. 2

Marks for working: 11

Checking

Using the outer (second-order) pair of spots from the initial laser beam, we obtain

$$\tan\theta_2 = \frac{3.83\,\mathrm{m}}{2.00\,\mathrm{m}} \quad \text{so} \quad \theta_2 = 62.4°,$$

giving a grating spacing of

$$d = \frac{2\lambda}{\sin\theta_2} = \frac{2 \times 3.19 \times 10^{-7}\,\mathrm{m}}{\sin 62.4°} = 7.20 \times 10^{-7}\,\mathrm{m},$$

consistent with our previous answer.

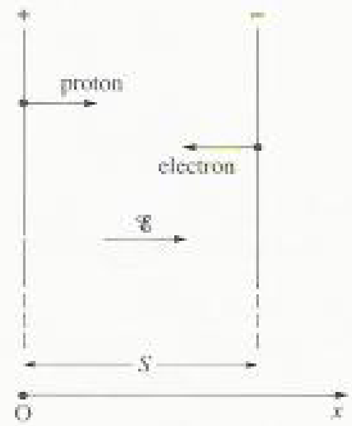
(*Alternatively*: The second laser has a higher frequency than the first and hence a smaller wavelength. It is therefore reasonable that the maxima in the diffraction pattern are closer together than for the first laser.)

Marks for checking: 2

Total for Q18: 16

Question 19

Preparation



2

Figure 5

Near the centre of the plates, ℰ will be uniform. 1

Known quantity: plate separation $S = 3.7\,\mathrm{cm}$.

Useful equations:

$\boldsymbol{F}_{\mathrm{el}} = q\boldsymbol{\mathscr{E}}$

$\boldsymbol{F} = m\boldsymbol{a}$

the constant acceleration equations, especially $s_x = u_x t + \frac{1}{2}a_x t^2$ 2

Marks for preparation: 5

Working

If the direction of ℰ defines the x-axis, then all motion takes place along this axis. Suppose the particles pass each other at time t after release, the proton having travelled a distance d from the positive plate.

$$a = q\mathscr{E}/m.$$ 1