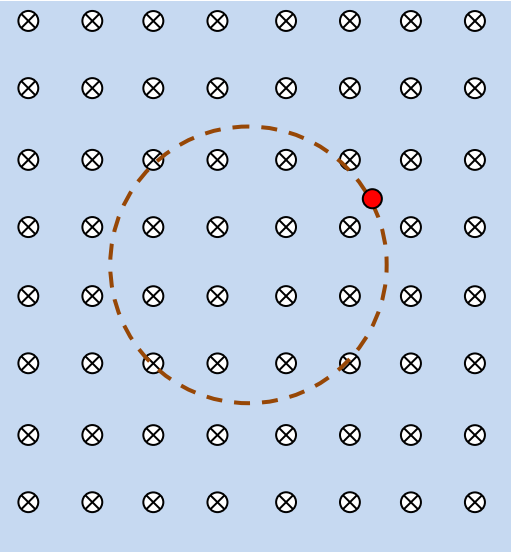
Teacher notes
Topic E

Quantized angular momentum and magnetic fields

The condition of angular momentum quantization, $mvr = n\frac{h}{2\pi}$, can be applied to electrons moving in circular paths in a magnetic field.



We know that $qvB = m\frac{v^2}{r}$ and so $r = \frac{mv}{qB}$. From $mvr = n\frac{h}{2\pi}$ we find $v = n\frac{h}{2\pi mr}$ and so

$$r = \frac{m}{qB} \times n\frac{h}{2\pi mr}$$

i.e.

$$r = \sqrt{\frac{h}{2\pi qB}n}$$

This means that the magnetic flux through one of the allowed orbits is $\Phi = \pi r^2 B = \pi \frac{hn}{2\pi qB} B = \frac{h}{2q}n$ and so magnetic flux too is quantized in units of $\frac{h}{2q}$!

It is instructive to show that $\frac{h}{2q}$ has units of flux:

$$\left[\frac{h}{q}\right]=\frac{\text{J s}}{\text{C}}=\frac{(\text{N m})\,\text{s}}{\text{C}}=\frac{\text{N m}^2}{\text{C m s}^{-1}}=\text{T m}^2=\text{Wb}=\left[\Phi\right].$$

Its numerical value is $\frac{h}{2q}=\frac{6.34\times10^{-34}}{2\times1.6\times10^{-19}}=2.07\times10^{-15}$ Wb .

The quantization of magnetic flux was predicted in 1948 and discovered experimentally in 1961 in the context of studies on superconductors.