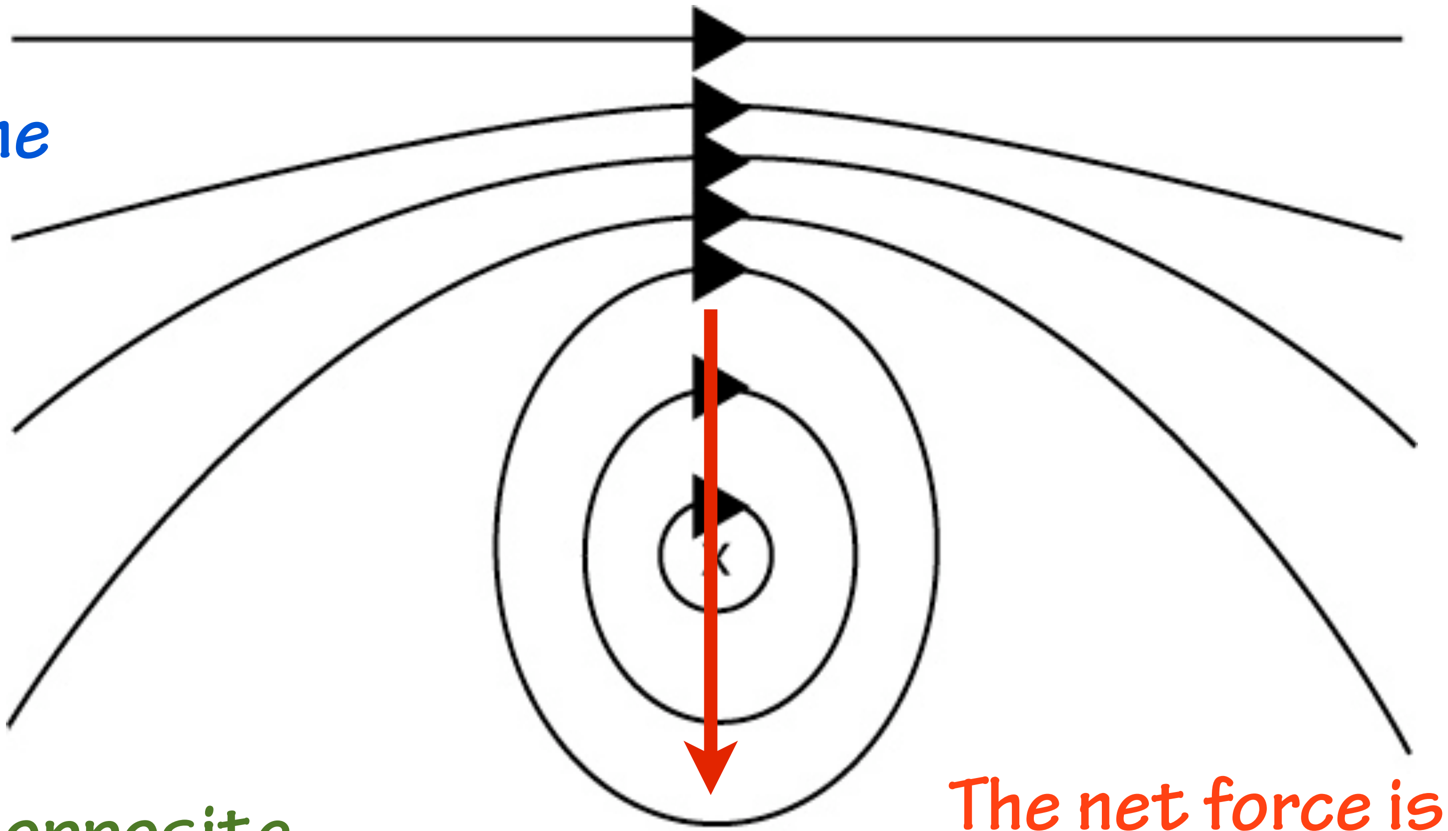
Magnetism and forces

- Force on wires in magnetic fields
- The right-hand slap rule
- Calculating the Lorentz force
- Force on charged particles

Force on wires in magnetic fields

- There will be a net force on current carrying wires in magnetic fields due to the interaction of the two fields.
- Field lines in the same direction repel, attracted if in opposite directions.



Field lines in the same direction oppose.

Field lines in the opposite direction attract.

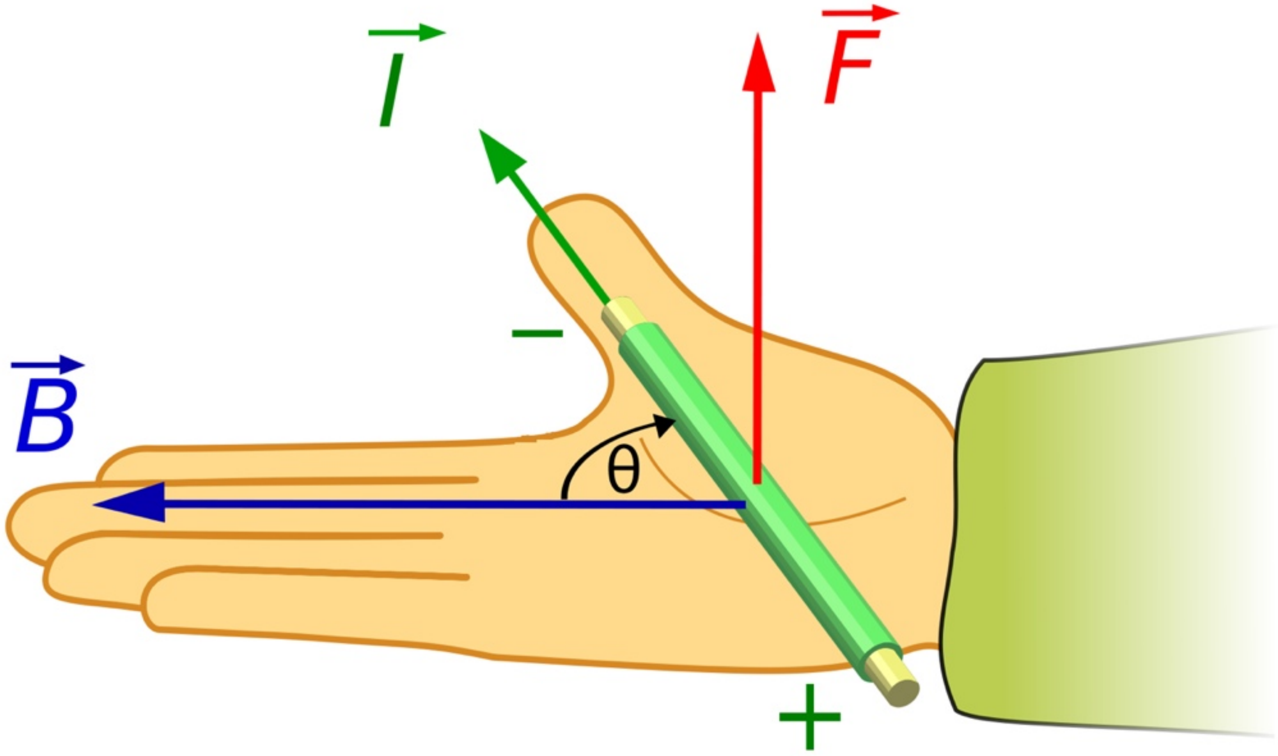
The net force is down

Combined field around wire

Lorentz Force

The right-hand slap rule

- **Right hand slap rule**: shows the direction of the net force for a current flowing perpendicular to the magnetic field.
- **Thumb** indicates the direction of conventional current (+ to -) through the wire.
- **Fingers** indicate magnetic field direction.
- **Palm** indicates the direction of the Lorentz force on the wire.
- (There is also Fleming's left hand rule for a similar outcome)



Calculating the Lorentz force

- Force depends on magnetic field strength, current, length and angle between B and I.
- Strongest force when I & B are at right angles.
- If the current & field are parallel, there is no force on the wire.

Angle between wire & field

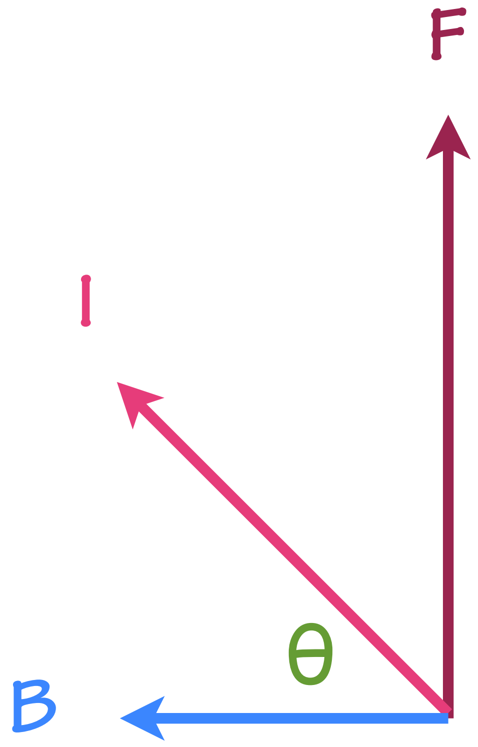
Force (N)

Length of wire (m)

$$F = ILB\sin\theta$$

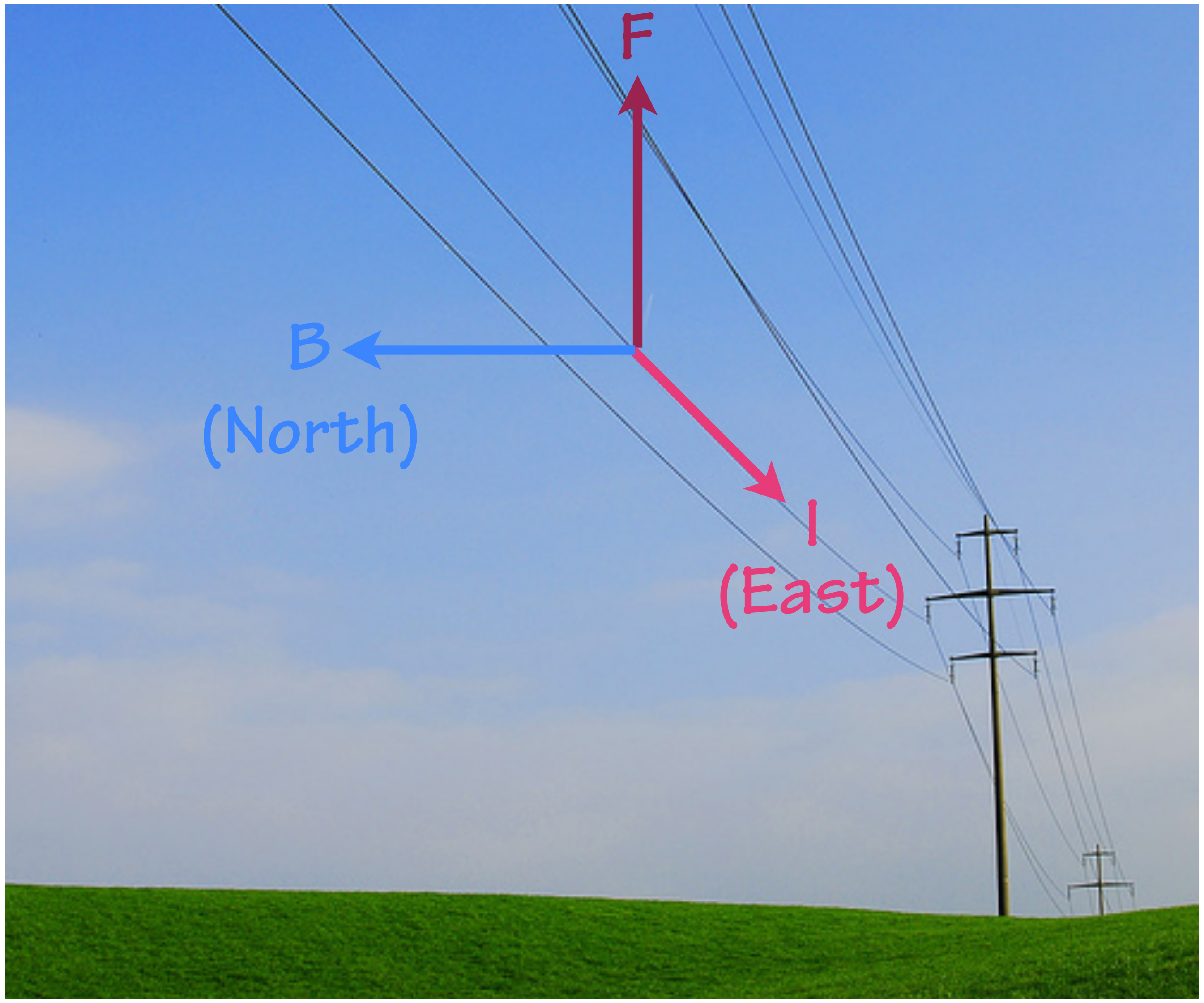
Current (A)

Magnetic field strength (T)



Calculating the Lorentz force

- 100A running from west to east along a 50 m span of wire.
- Calculate the direction & magnitude of the force on the wire from the Earth's magnetic field.



$$F = ILB\sin\theta$$

$$\sin 90^\circ = 1$$

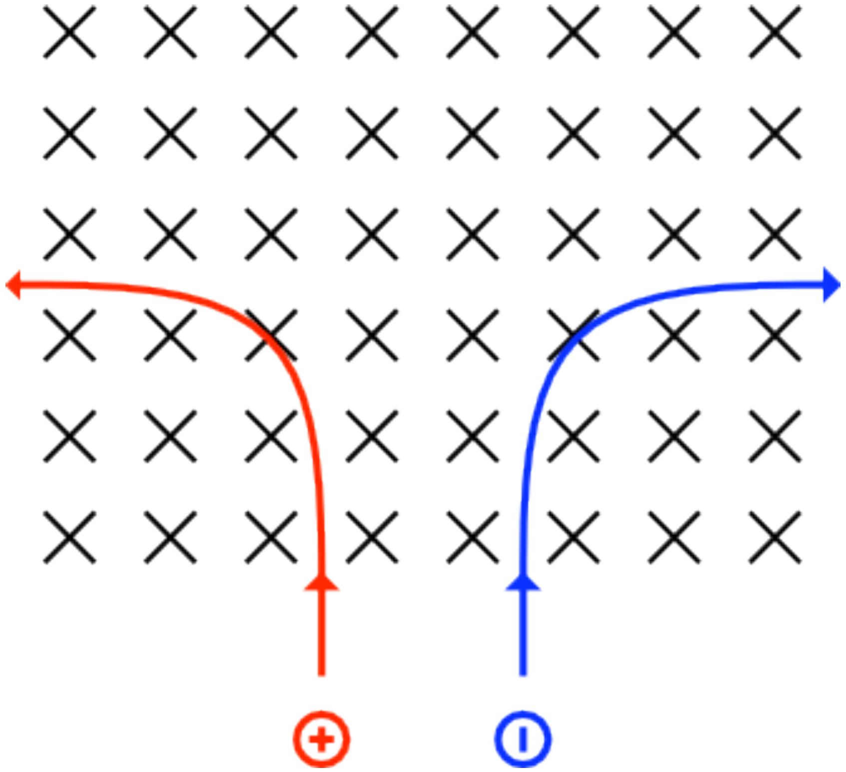
$$F = (100A)\times(50m)\times(5\times10^{-5}T)$$

$$F = 0.25N$$

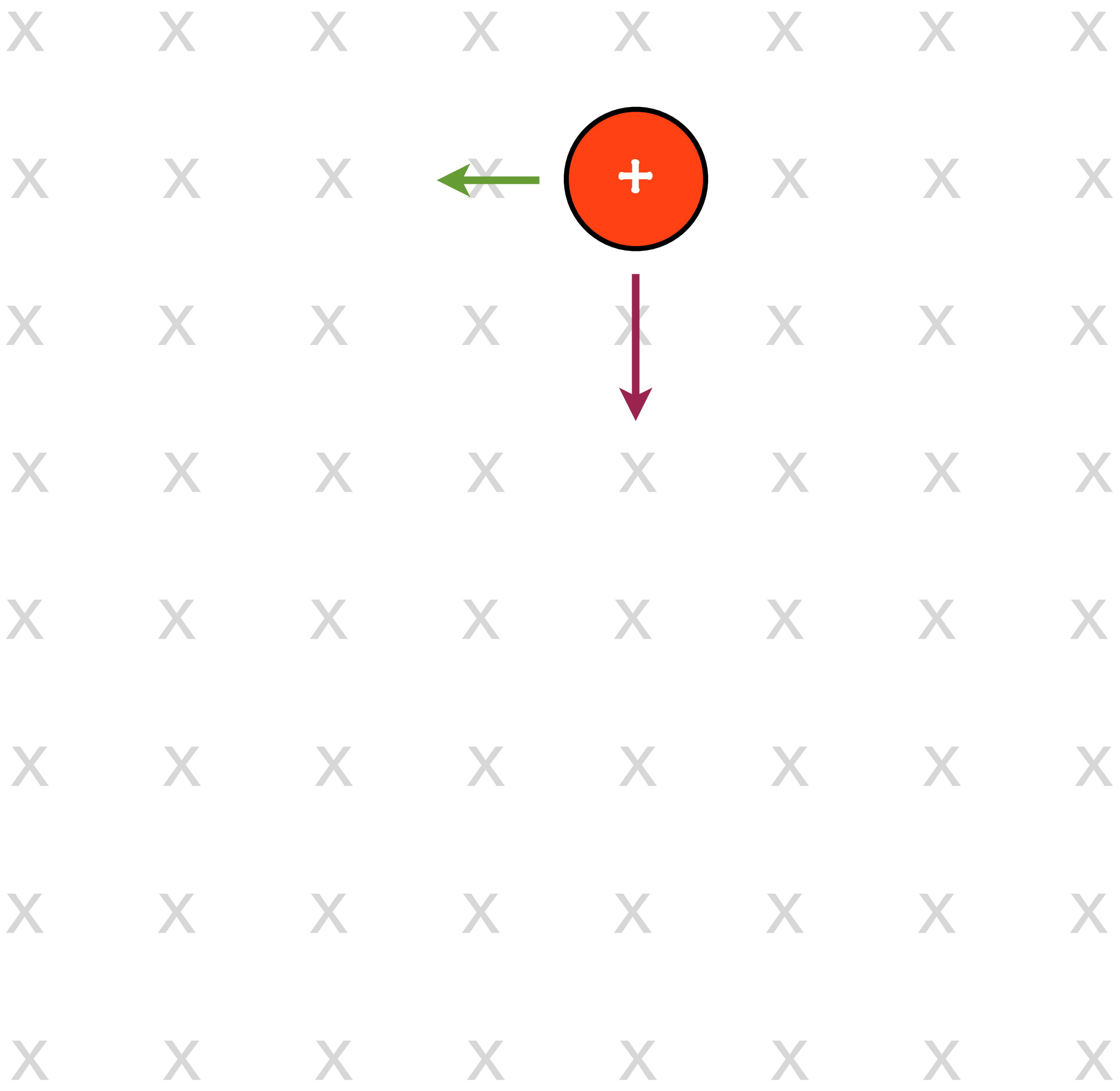
This will be reversing direction every 1/100th of a second!

Force on charged particles

- Recall that the force on a wire due to a current is F = ILB.
- This can be described in terms of the number of charges moving along the length.
- L = vt & I = n(q/t)
- Force per single charge is F = (q/t)x(vt)xB : **F = qvB**
- This is a force that always acts at **right angles** to the motion to change the direction of motion.
- This motion will be a circle or in a helix if the motion is not a right angles to the magnetic field.



Force on charged particles



$F = qvB$

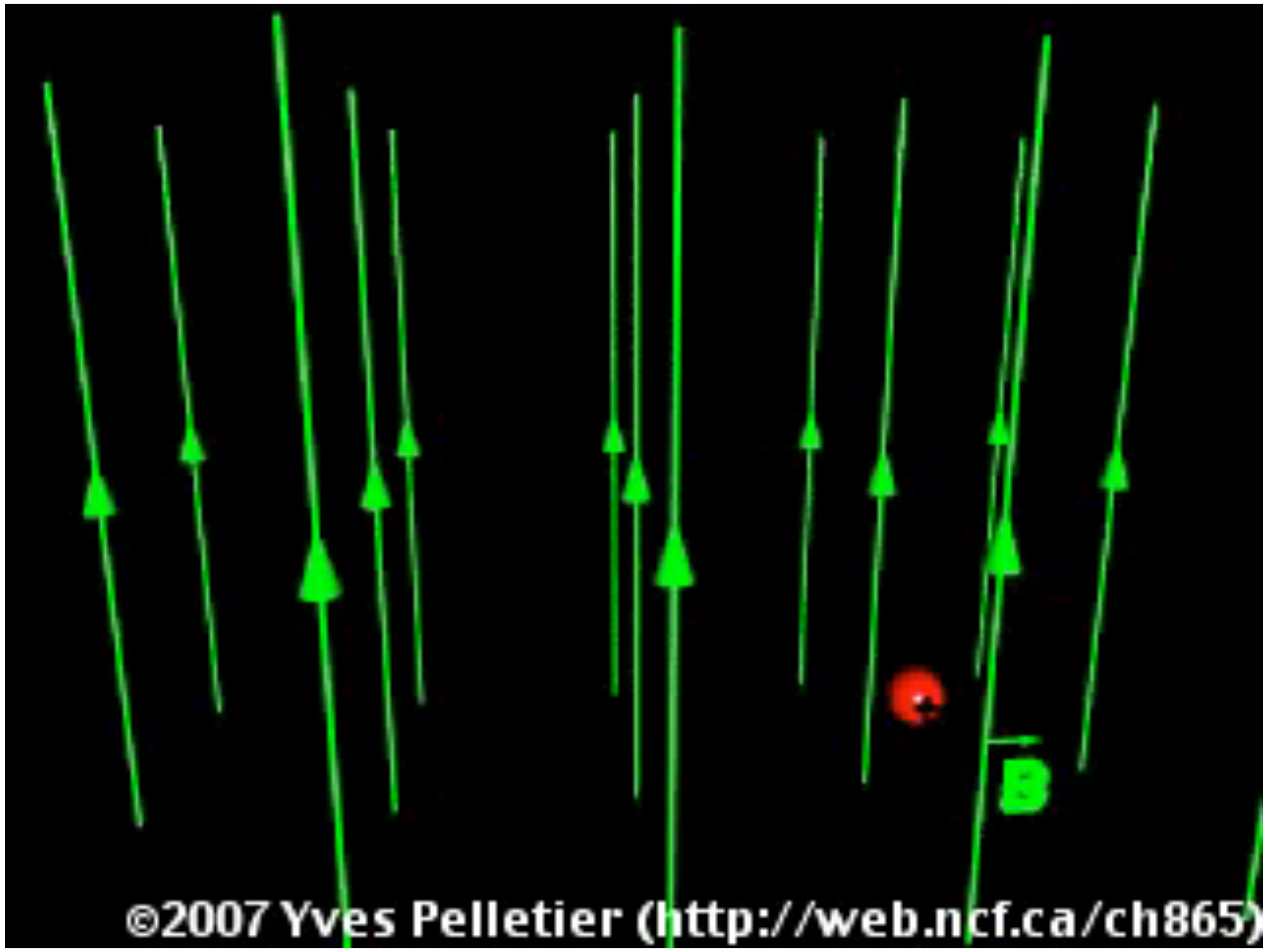
Force: into centre of circle

Velocity: forwards

Magnetic field: into page

Remember to reverse the direction of movement for - charge!

Force on charged particles



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Force on charged particles

- An electron moving at 10^7 m/s at right angles to a 0.1T magnetic field.
- Find the force on the electron & the radius of the circle it moves through.

$$F = qvB$$

$$F = (1.6\times10^{-19}C)(1.0\times10^{7}m/s)(0.1T)$$

$$F = 1.6\times10^{-13}N$$

$$F = qvB = \frac{mv^2}{r} \longrightarrow r = \frac{mv}{qB}$$

$$r = \frac{(9.1\times10^{-31}kg)\times(1.0\times10^{7}m/s)}{(1.6\times10^{-19}C)\times(0.1T)}$$

$$r = 5.6\times10^{-4}m$$

Force on charged particles

- **Auroras** are caused by the charged particles of the solar wind being funnelled by the Earth's magnetic field. Interactions with atmospheric atoms causing a release of energy.
- **Cathode ray tube television** - electrons are deflected by a magnetic field to hit the different coloured phosphors on the inner side of screen.
- **Mass spectroscopy** - Particles are ionised and deflected by a magnetic field. Used to determine molecular / atomic masses in an unknown sample. The amount of curvature is determined by the charge to mass ratio (higher mass is deflected less).