Teacher notes

Topic D

The aurora

The image shows the magnetic field of the Earth.

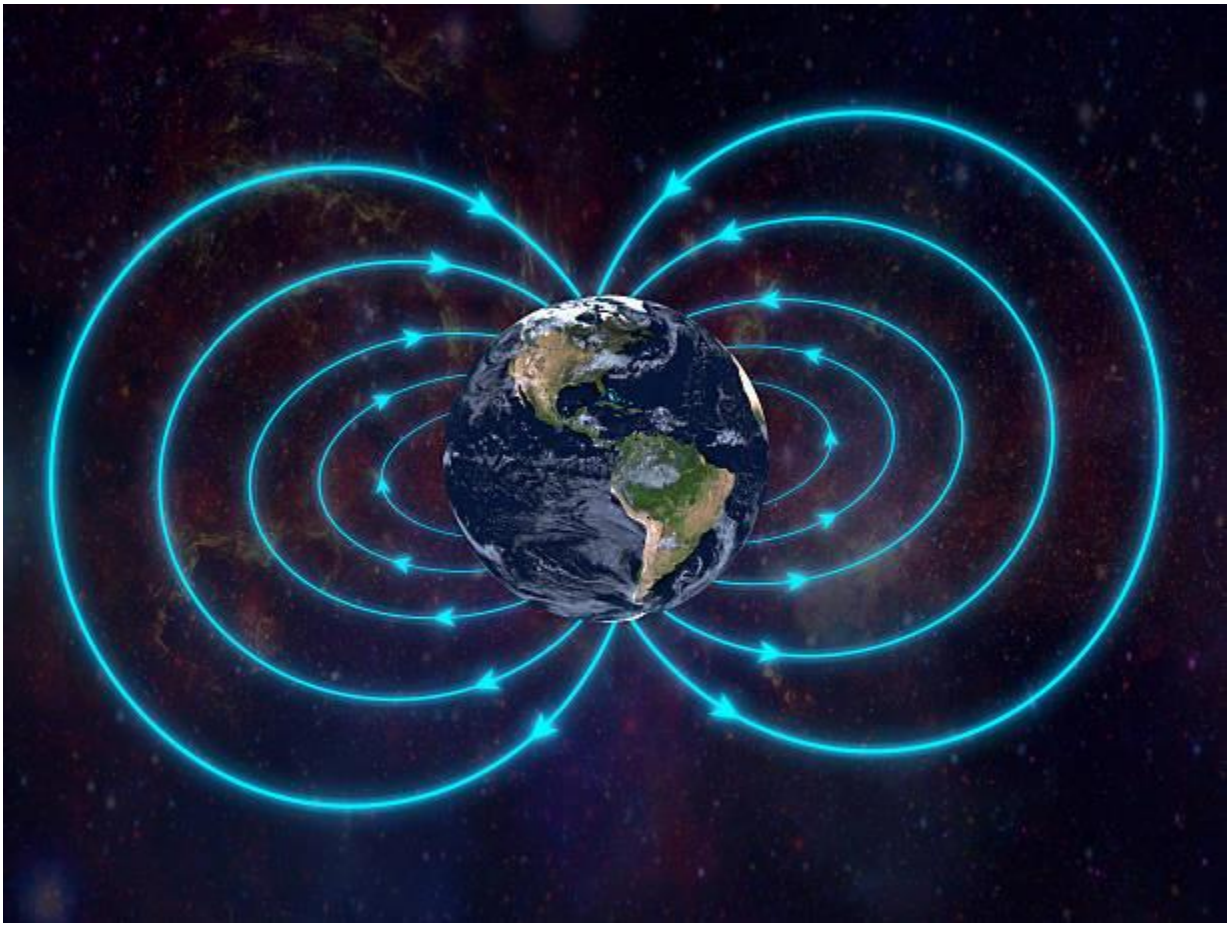
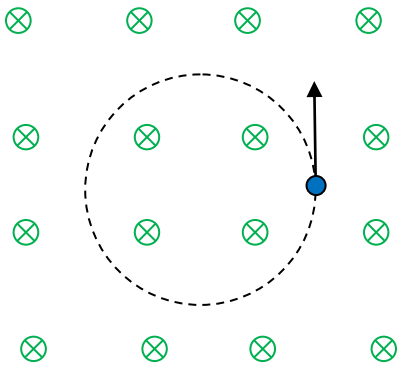


Image from: http://www.nasa.gov/

(a) Label, on the diagram, the magnetic north pole of the earth's magnetic field.

(b) A particle of mass *m* and charge *q* enters a region of magnetic field *B* with speed *v*. The particle follows a circular path.

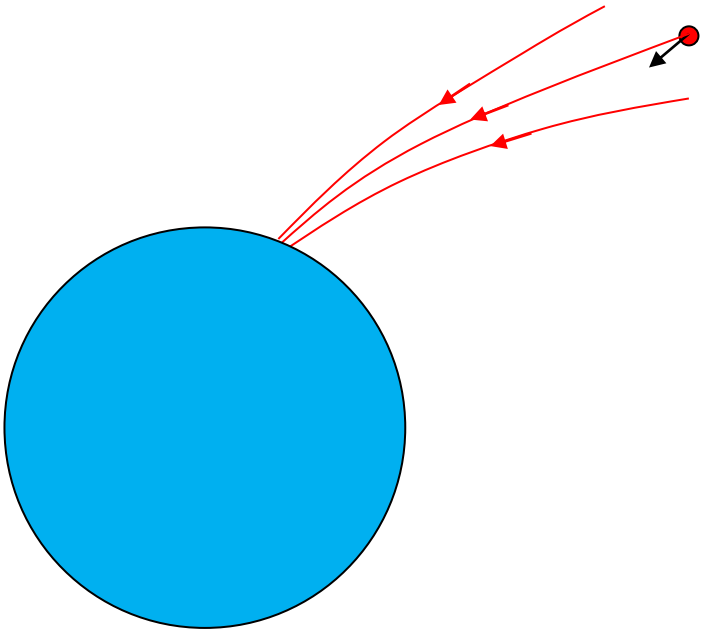


(i) Explain why the particle follows a circular path.

(ii) Show that the radius R of the circular path followed by the particle is given by $R = \frac{mv}{qB}$.

(iii) Explain why the speed of the particle stays constant.

(c) A charged particle approaches Earth as shown. Three magnetic field line are shown in red.



(i) Explain why the particle will follow a spiral path around the field lines.

(ii) Suggest **two** reasons why the radius of the spiral will get smaller as the particle gets nearer to the surface.

(d) A charged particle colliding with oxygen molecules in the atmosphere ionizes oxygen molecules.

(i) What does this mean?

(ii) As a result, green light of wavelength 558 nm is emitted from oxygen. Suggest why light is emitted from oxygen.

(iii) Calculate the difference in energy of the levels involved in the transition that gives rise to the 558 nm photons.

(e) An electron creates about 10 ions per mm of its path in air. The energy needed to ionize an oxygen atom is of order 10 eV. The energy of an electron coming from the Sun is about 5 keV.

(i) How many ions will this electron produce?

(ii) Over what distance will these ions be produced?

Answers

(a) The geographic south pole.

(b)

(i) Because the magnetic force is at right angles to the velocity.

(ii) $qvB = \frac{mv^2}{R} \Rightarrow R = \frac{mv}{qB}$.

(iii) From $W_{\text{net}} = \Delta E_{\text{K}}$ and $W_{\text{net}} = 0$ since the magnetic force is at right angles to the velocity it follows that $\Delta E_{\text{K}} = 0$ and hence speed is constant.

(c)

(i) The velocity can be decomposed into a component along the field lines and at right angle to the field lines. The component along the lines stays constant because there is no magnetic force in that direction. The component at right angles to the field lines experiences a force at right angles to the velocity and forces the particle in a circular path around the field lines. The combination of the two motions is a spiral.

(ii) We use $R = \frac{mv}{qB}$ to deduce that *R* will get smaller because (a) as the particle gets closer to the surface the magnetic field gets stronger and (b) because of collisions with air molecules the speed gets smaller.

(d)

(i) Electrons are ejected from the atoms of oxygen as a result of collisions of incoming electrons with oxygen electrons.

(ii) Electrons ejected from the atom create vacancies in energy levels. Electrons in higher energy levels make transitions to fill the vacancy and emit light in the process.

(iii) $E = \frac{hc}{\lambda} = \frac{1.24 \times 10^{-6}}{558 \times 10^{-9}} = 2.2 \text{ eV}$

(e)

(i) $\frac{5 \times 10^3}{10} = 500$.

(ii) $\frac{500}{10} = 50 \text{ mm}$.