LECTURE 31

Magnetic Fields 1

At the end of this lecture you should:

- Understand how a magnetic field is defined implicitly by the *Lorentz force*
- Be able to calculate the magnitude and direction of the force on a conductor of length, l, carrying current, I, in a magnetic field of field strength, B
- Know the formula for the field strength due to a long straight wire carrying current, I, at a distance, r, from the wire
- Understand how the definition of the *ampere* arises and be able to give the definition
- Understand the concept of *field lines* for a magnetic field

Information

- Exam and numerical answers are on Moodle
- All students have labs today and onwards; inductance experiment is “functional”
- NO use of mobile phones or music in labs
- Arrive on time for labs:Students arriving late for labs will get reduced marks. Students arriving 15 or more minutes late will not be allowed top do a lab, and will get a zero mark.

Magnetism

Sources of magnetism

Moving charges

…atomic dipoles…permanent magnets

Magnetic field B

Detect by placing moving charge q at each point

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

This is the definition of B.

Magnetic field B

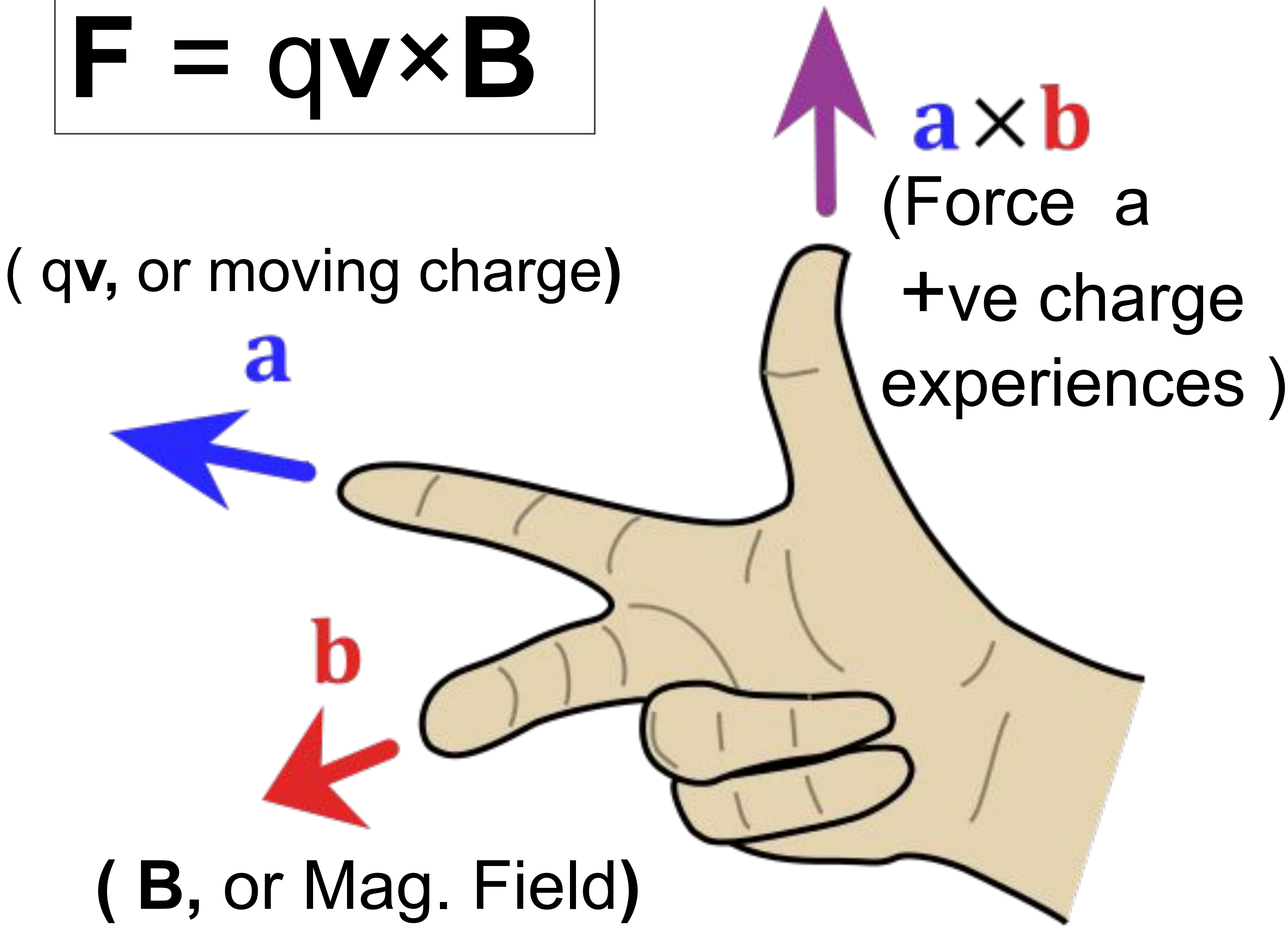
- $F = qvB\sin\theta$ gives the magnitude, while the direction is found either with the right-hand-rule or Fleming's-left-hand-rule.
- Direction and magnitude by vector product:

  $$\mathbf{F} = q\mathbf{v}\times\mathbf{B}$$

- Force is always perpendicular to the plane defined by **v** and **B**
- Units Tesla (T) or Webers per m^2 ($Wb\ m^{-2}$)
- If charge q is negative force is

  in opposite direction

$$\mathbf{F} = q\mathbf{v}\times\mathbf{B}$$



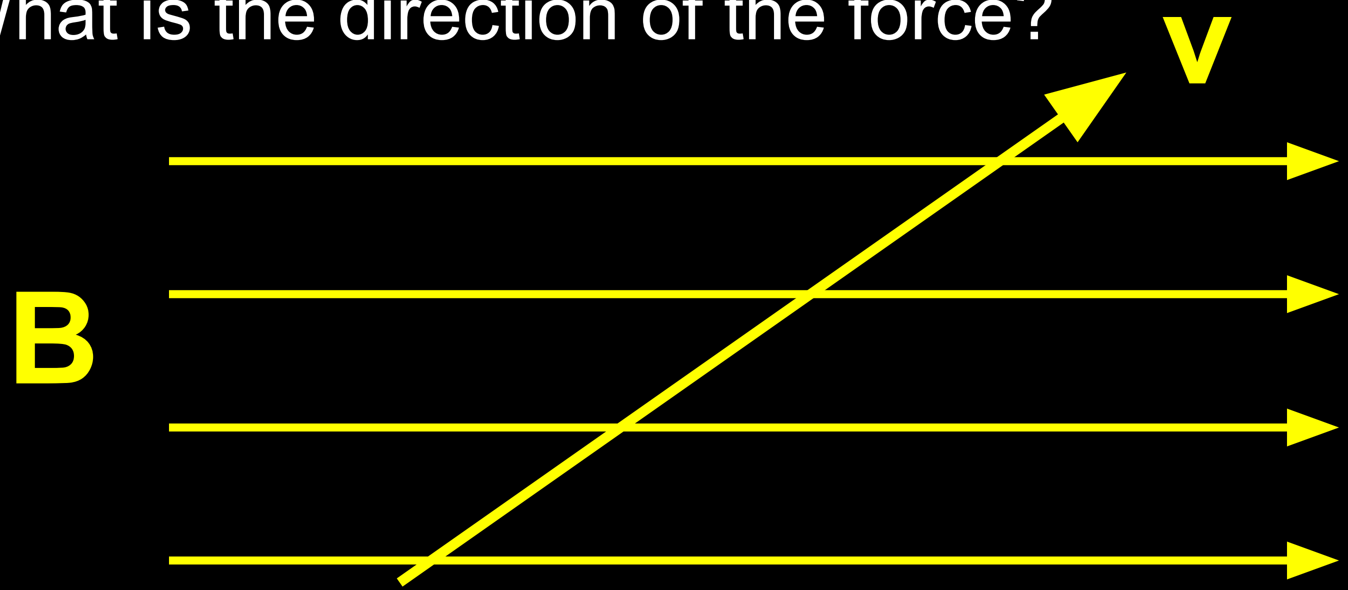
Example 1

A proton moving at 1.00×10^8 ms^{-1} enters a region where the magnetic field is 0.500 T

Evaluate the magnitude of the force on the proton if the angle between the velocity of the proton and the field is

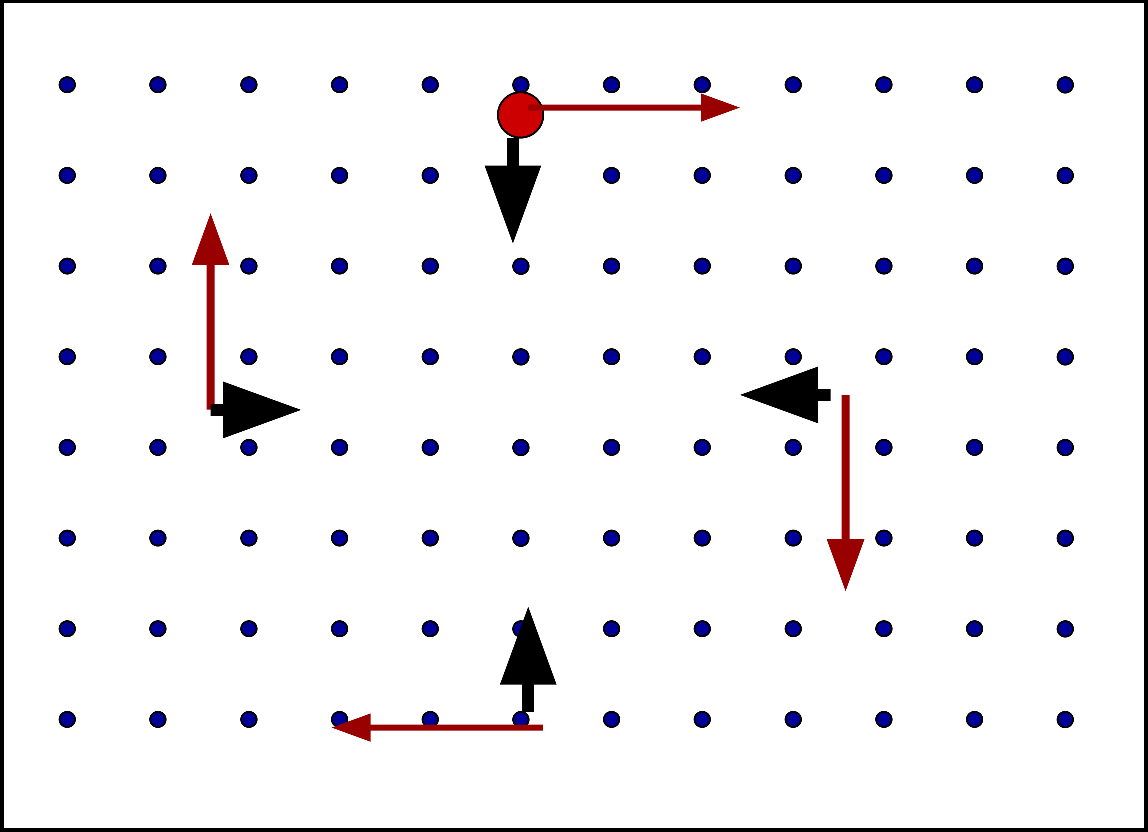
a) 0^0 b) 90^0 c) 45^0 d) 30^0

What is the direction of the force?



Charged particle moving in region of uniform magnetic field:

eg A proton is moving as shown in the B field which is directed out of the plane of the screen/paper



Force on current carrying wire

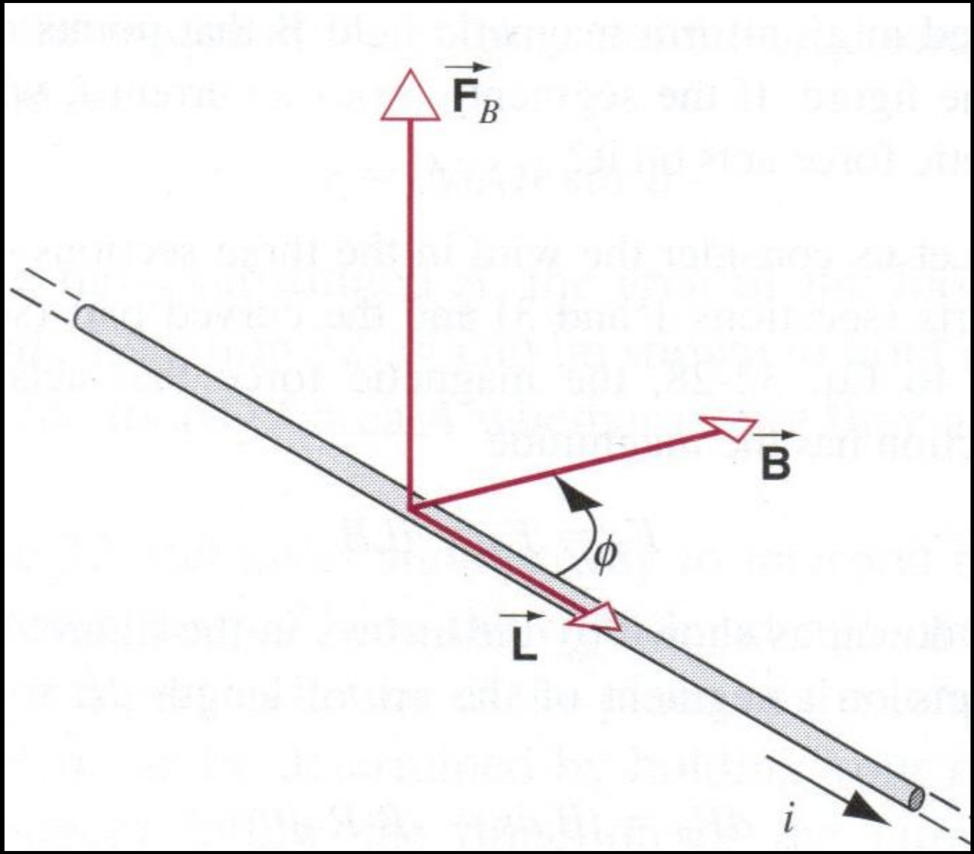
Suppose q passes a point in the wire in time t then current i=q/t . If speed of q is **v** then in time t it moves L=vt

Thus q**v**=i**L**

so **F** = q**v** x **B**

becomes

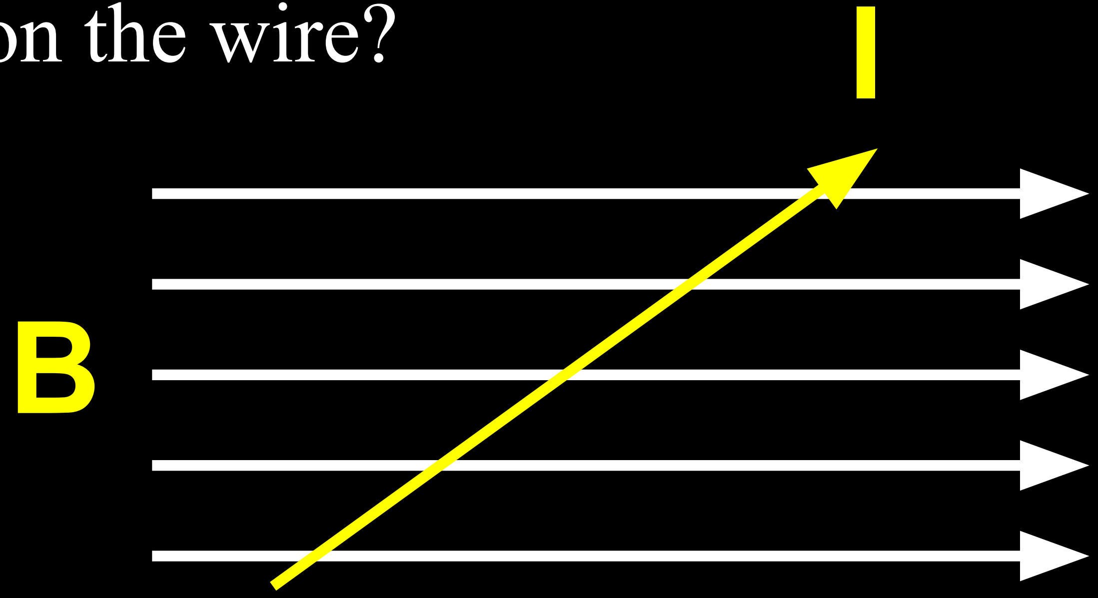
F = i**L** x **B**



Example 2

A straight 0.400 m length of wire carries a current of 2.00 A. It is placed in a B field of 0.250 T as shown. The angle between the wire and the field is 30^0

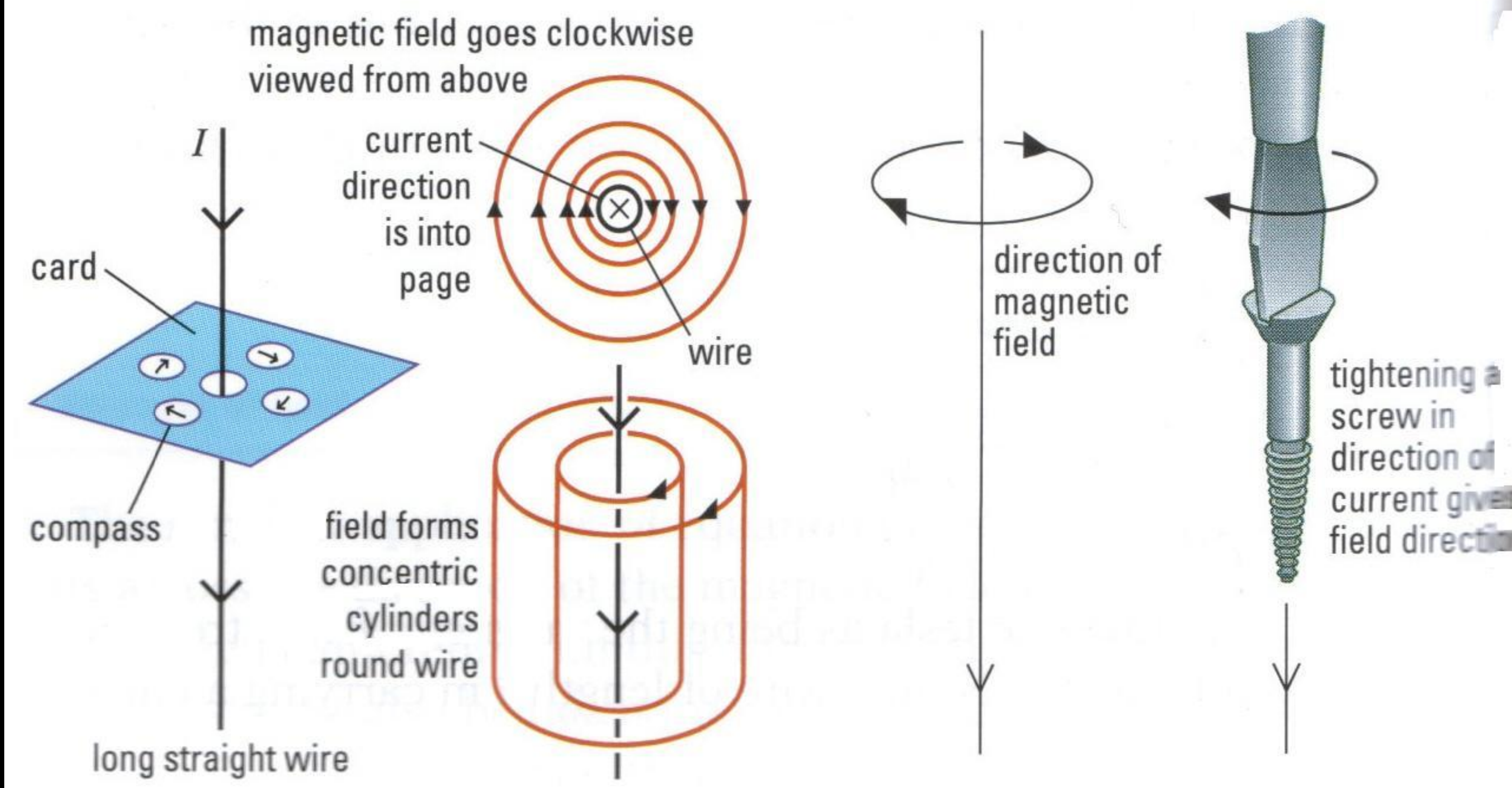
What is the magnitude and direction of the force on the wire?



Visualising a magnetic field
Magnetic "lines of force"

- **Flux**: total number of lines passing through an area.
- **The flux density** gives the magnitude of B field. This is the number of lines passing through unit area placed normally to the lines. Units: Wb m^{-2} equivalent to Tesla
- **Direction** of the magnetic field is the direction of a **tangent to a field line**
- **Magnetic dipole** aligns with field line

Field due to a straight current carrying wire



The magnetic field round a straight wire. *The* ***corkscrew rule***

Field due to current carrying wire is given by:

where μ_0 is the permeability of free space and is defined to be exactly

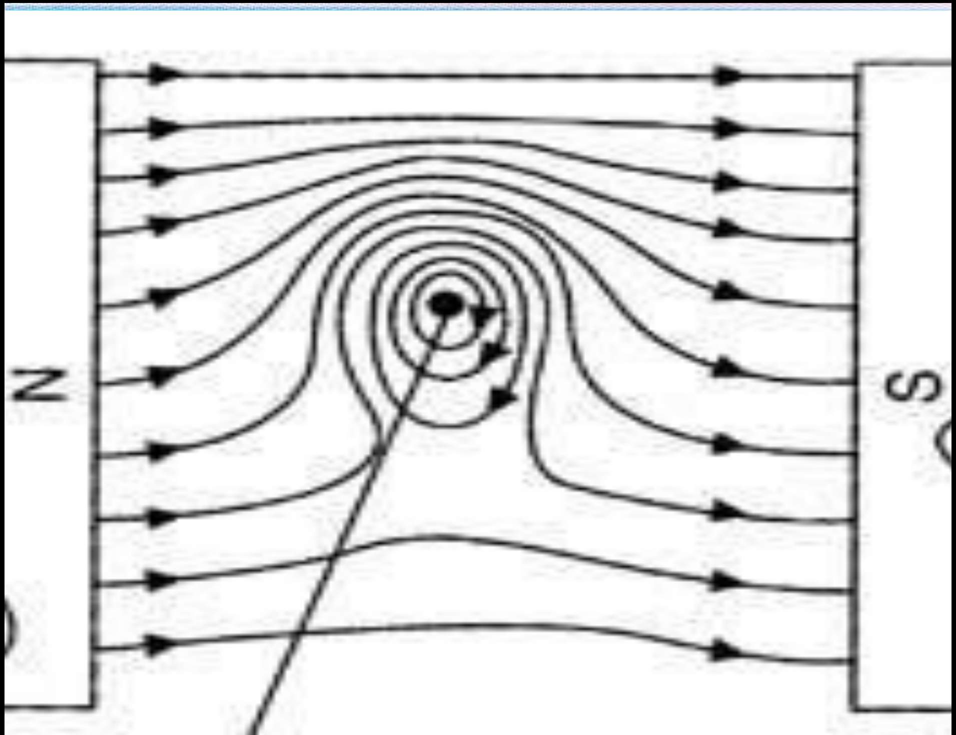
$\mu_0 = 4\pi \times 10^{-7}$ kg m s^{-2} A^2 (or Hm^{-1})

approx value $\mu_0 = 1.26 \times 10^{-6}$ Hm^{-1}

Example 3

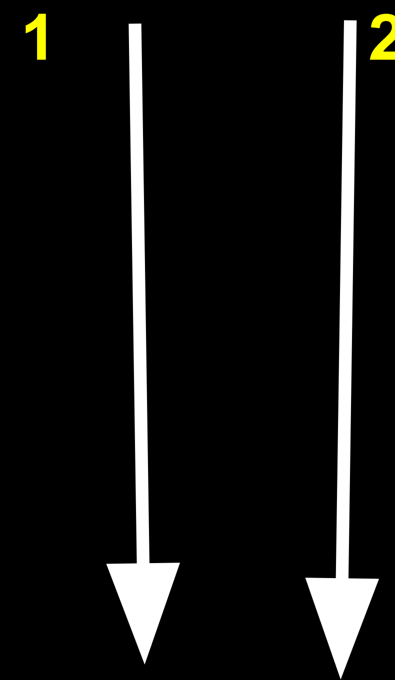
A long straight wire is perpendicular to a uniform magnetic field of strength 2.00×10^{-5} T. If the wire carries a current of 1.00 A what is the total magnetic field at points A and B in the diagram?

Sketch the field lines which represent the resultant field near the wire



Force between two current carrying wires

attractive



Consider force on wire 2

Wire 2 is in the field B_1 due to wire 1

$= F_{1\ on\ 2}/L =$

Therefore

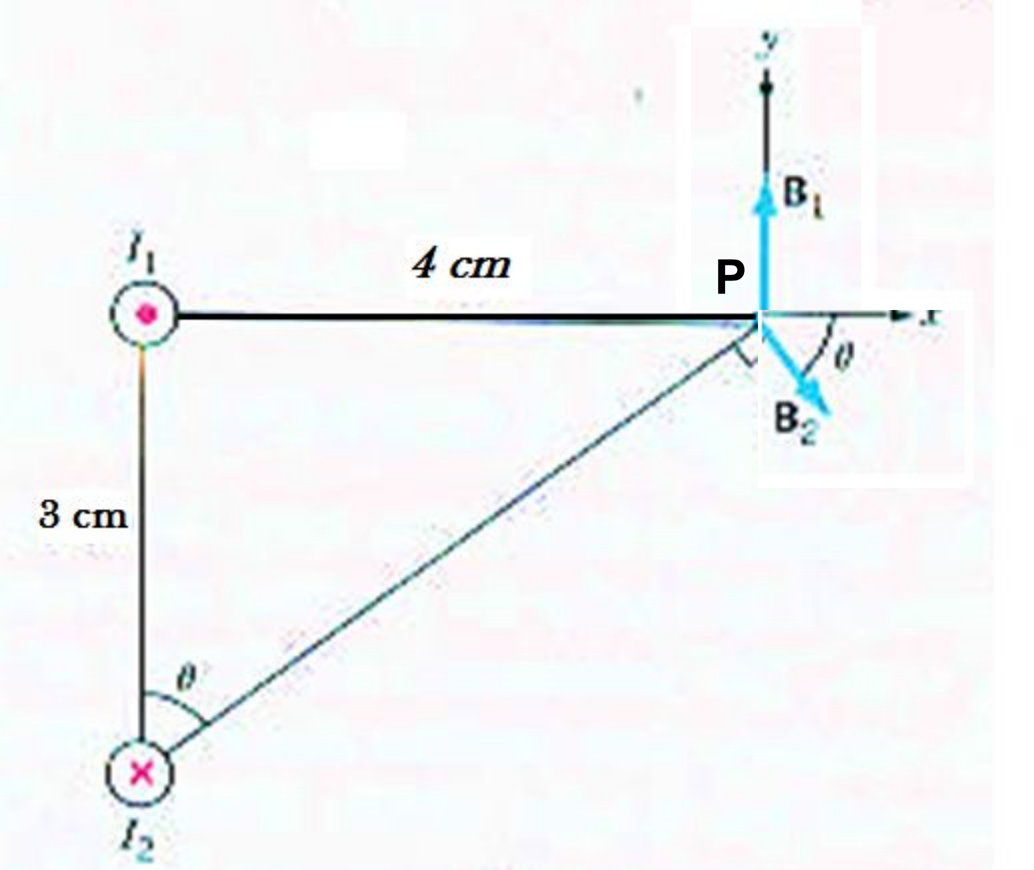
If two long parallel wires 1 m apart carry the same current, and the magnetic force per unit length on each wire is 2×10^{-7} N/m, then the current is defined to be 1 A.

Example 4

Two long, straight, parallel wires are 3.00 cm apart. I_1 = 3.00 A and I_2 = 5.00 A in opposite directions.

(a) Find B field strength at point P

(b) At what point, besides infinity, is the B field strength zero?



LECTURE CHECK LIST

LECTURE 31 Magnetic Fields

READING Adams and Allday: 5.14, 5.15, 5.16

Serway ch. 19.1-19.3

At the end of this lecture you should:

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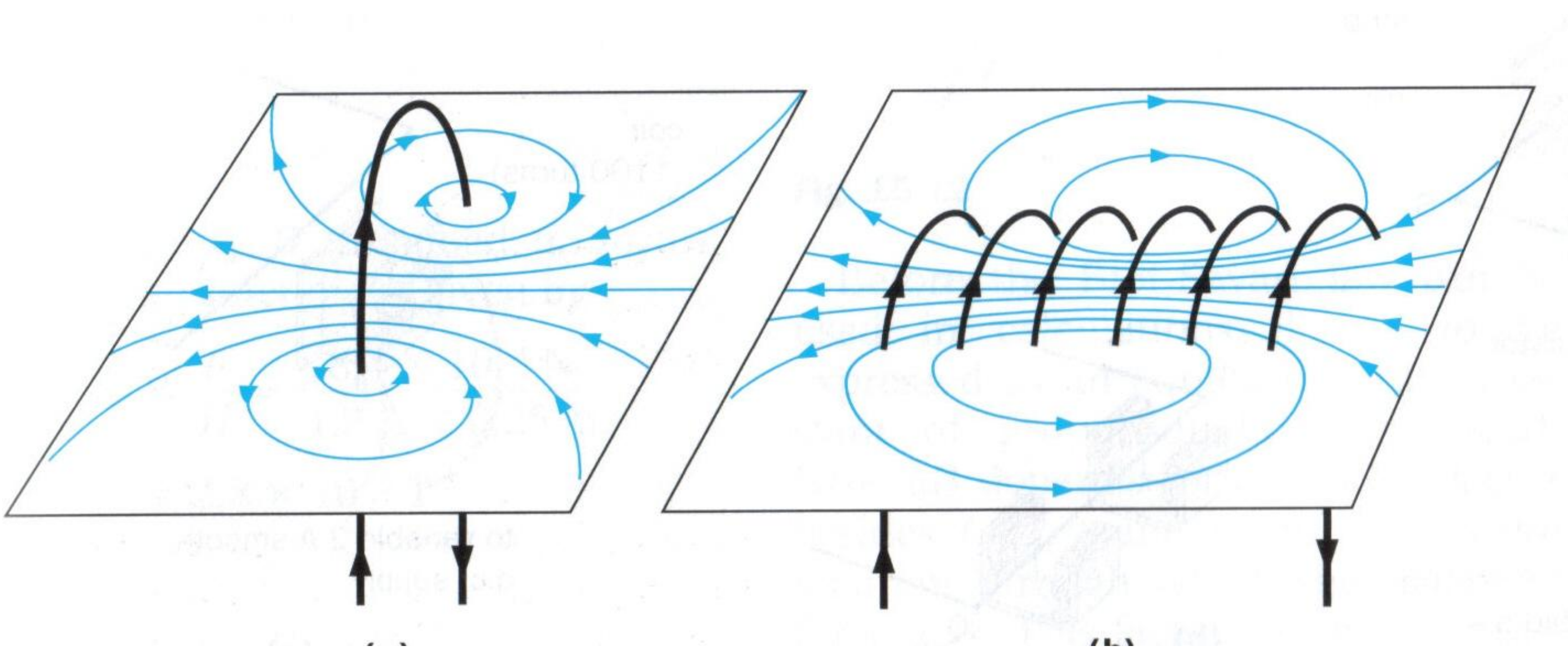
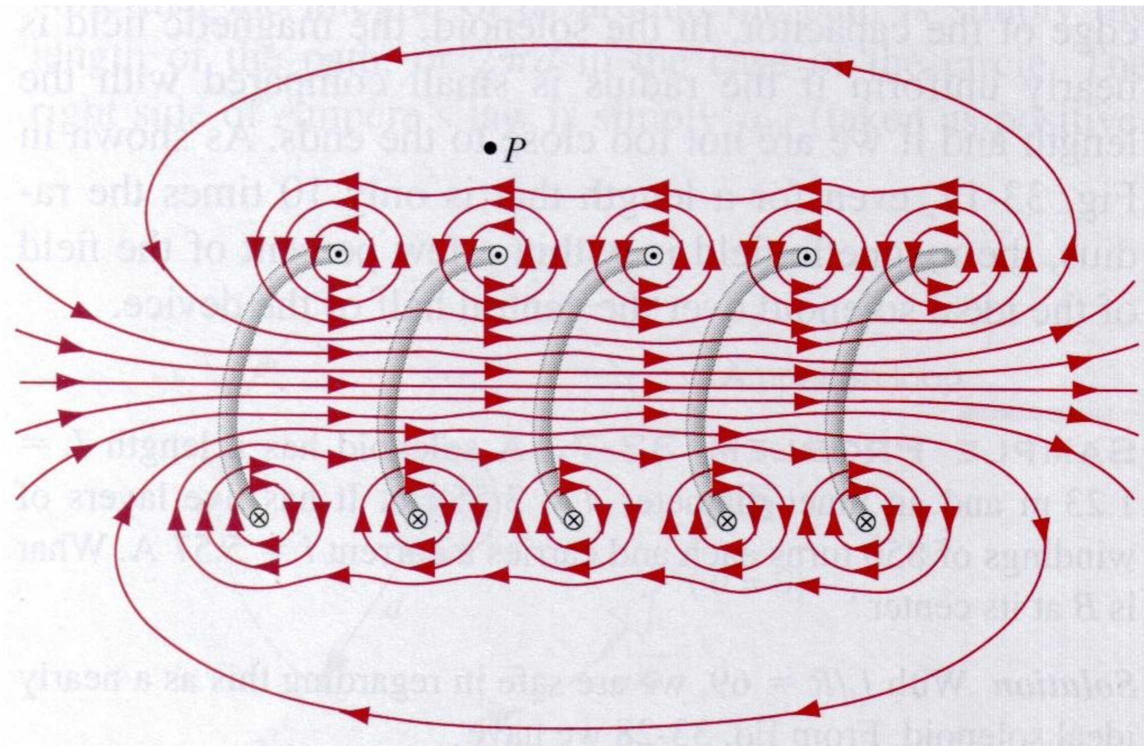
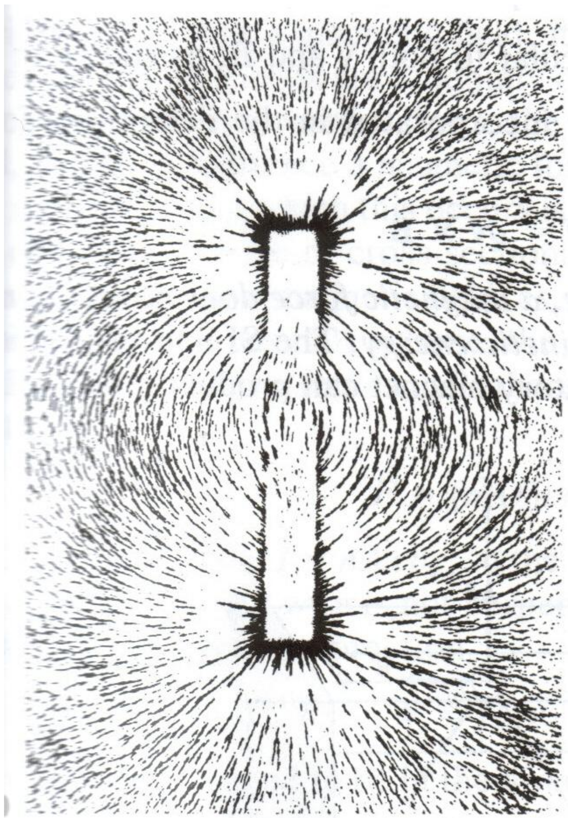
Fields due to coil and solenoid

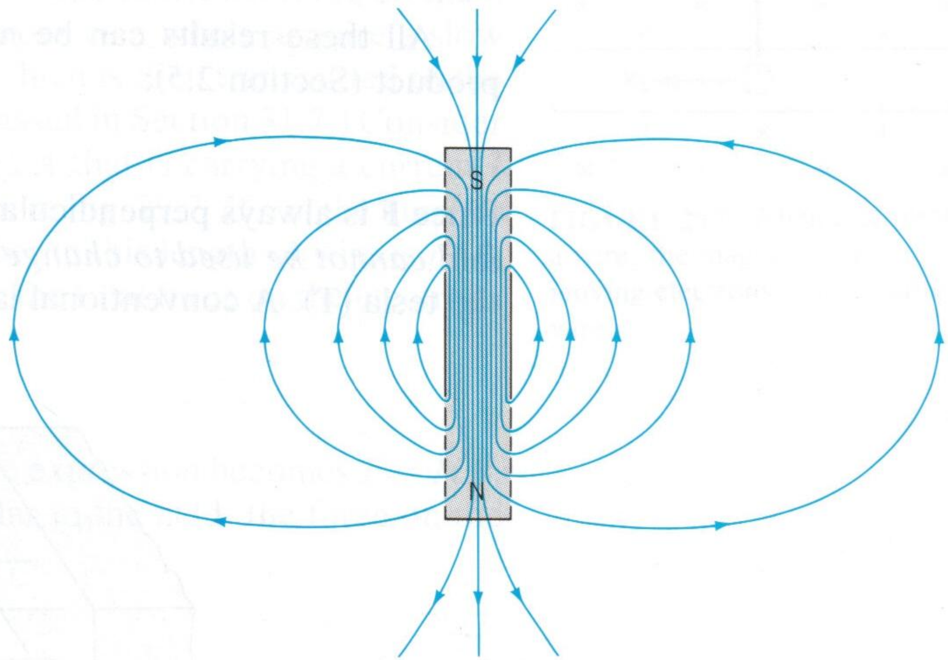


Field due to wires in solenoid



Magnetic fields due to permanent magnet



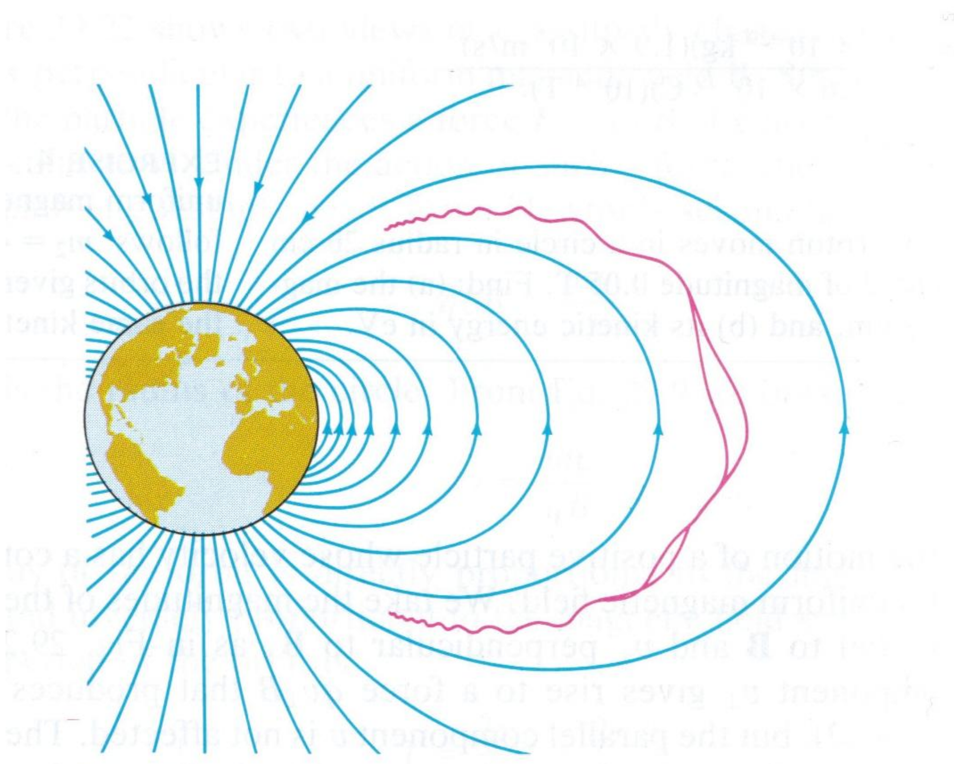


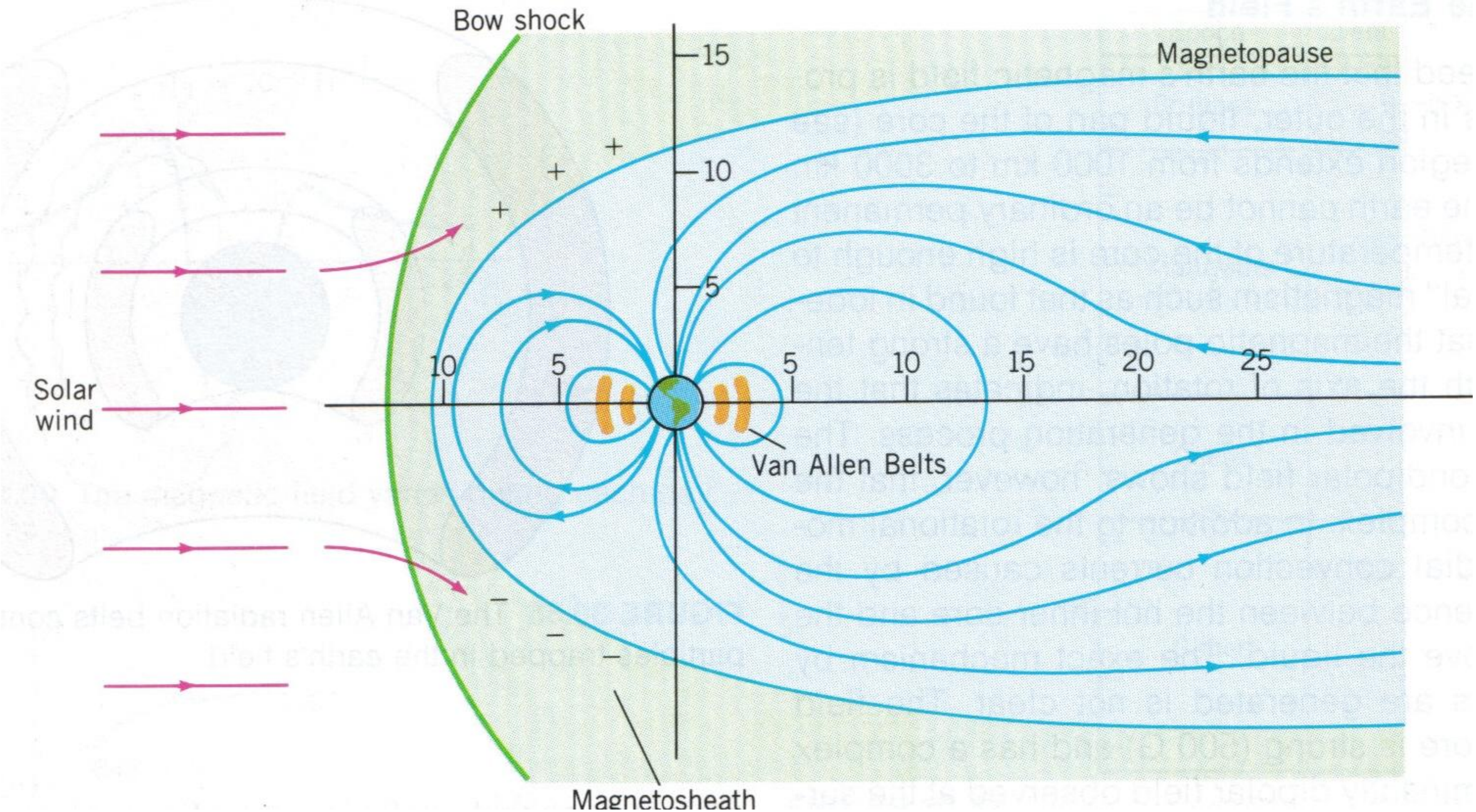
(b)

Iron filings scattered near short bar magnet

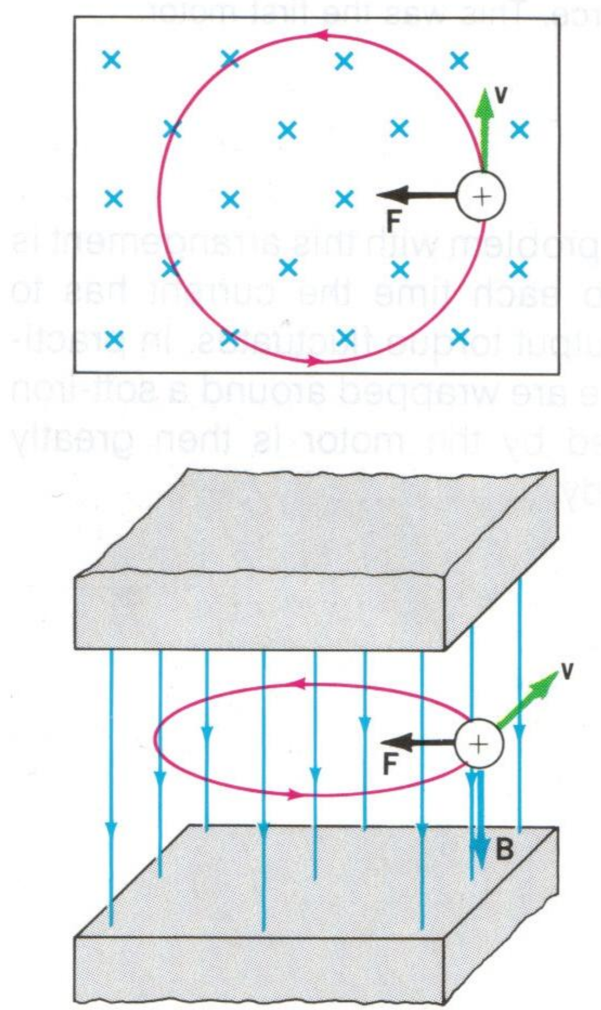
Field lines due to solenoid (long coil of wire carrying current)

Earth’s magnetic field




Bow shock
Magnetopause
Solar wind
Van Allen Belts
Magnetosheath
15
10
5
10
5
5
10
15
20
25
+
+
+
–
–
–

Circular Path of charge moving perpendicularly to B field

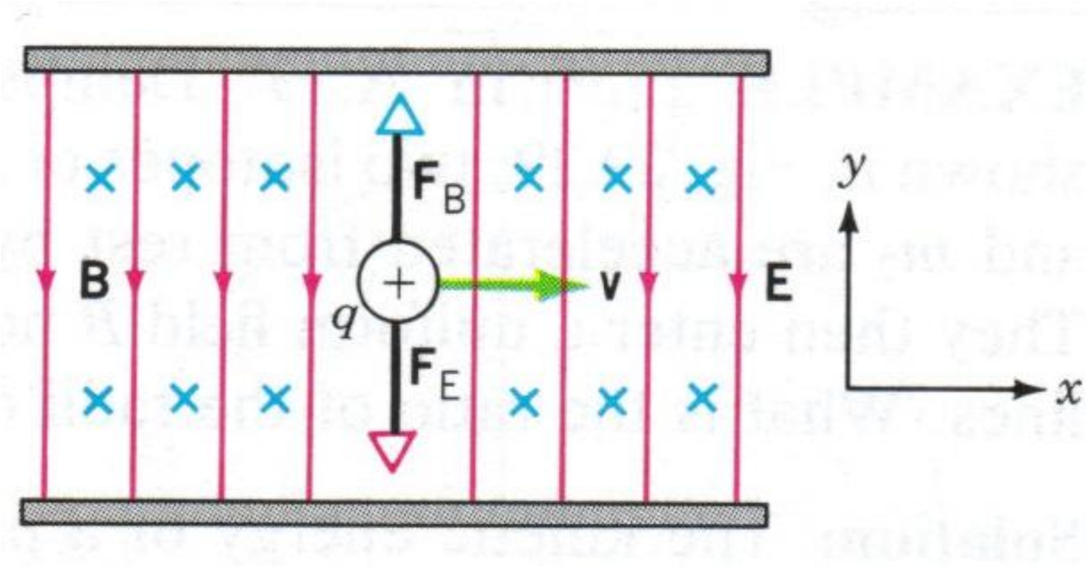


$$qvB = m\frac{v^2}{r}$$

Therefore:

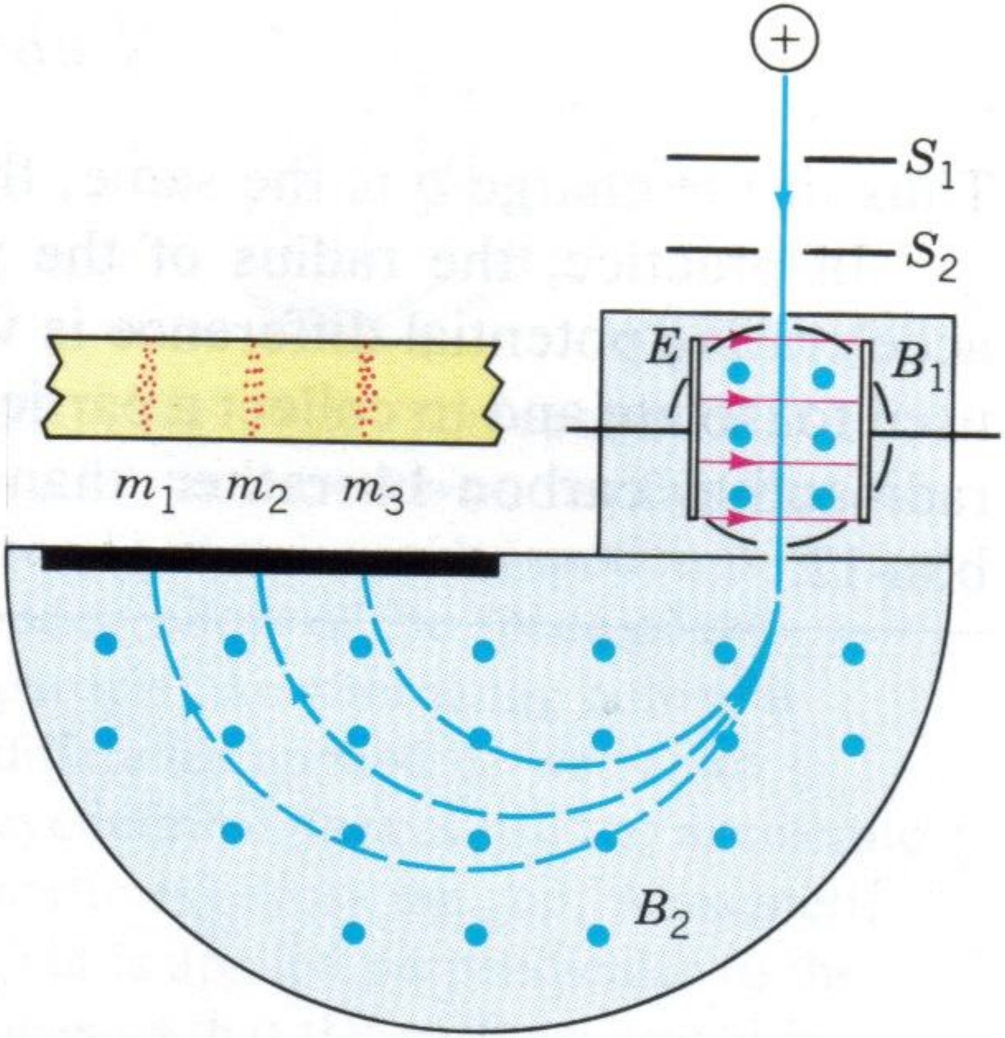
$$\omega = -$$

Velocity selector

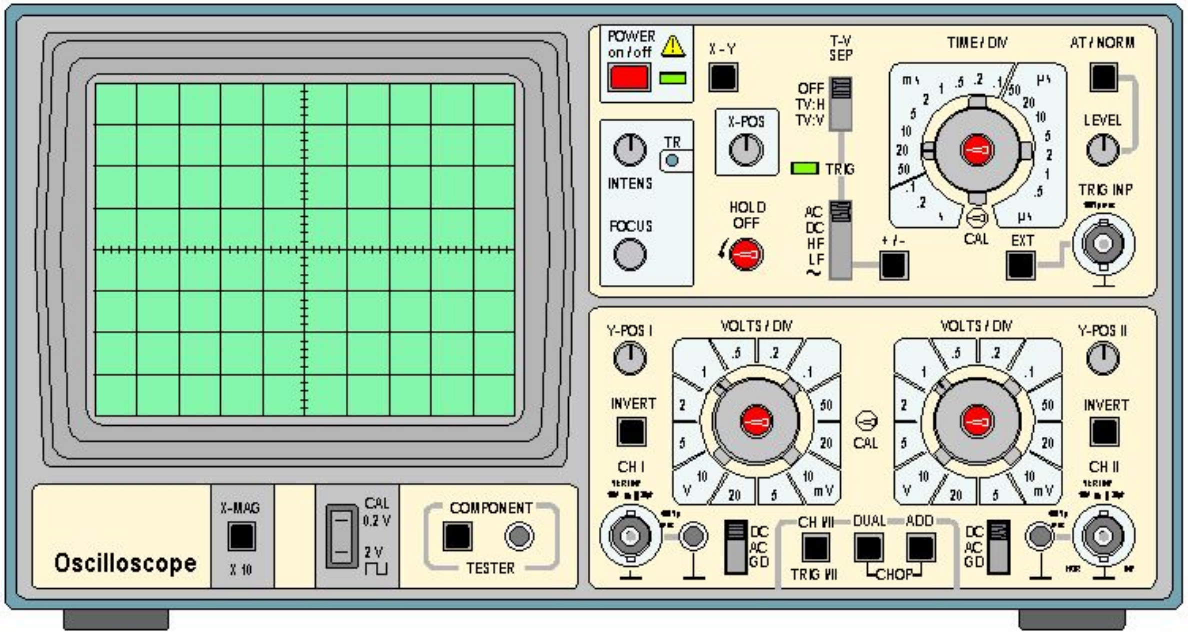


$$v = \frac{E}{B}$$

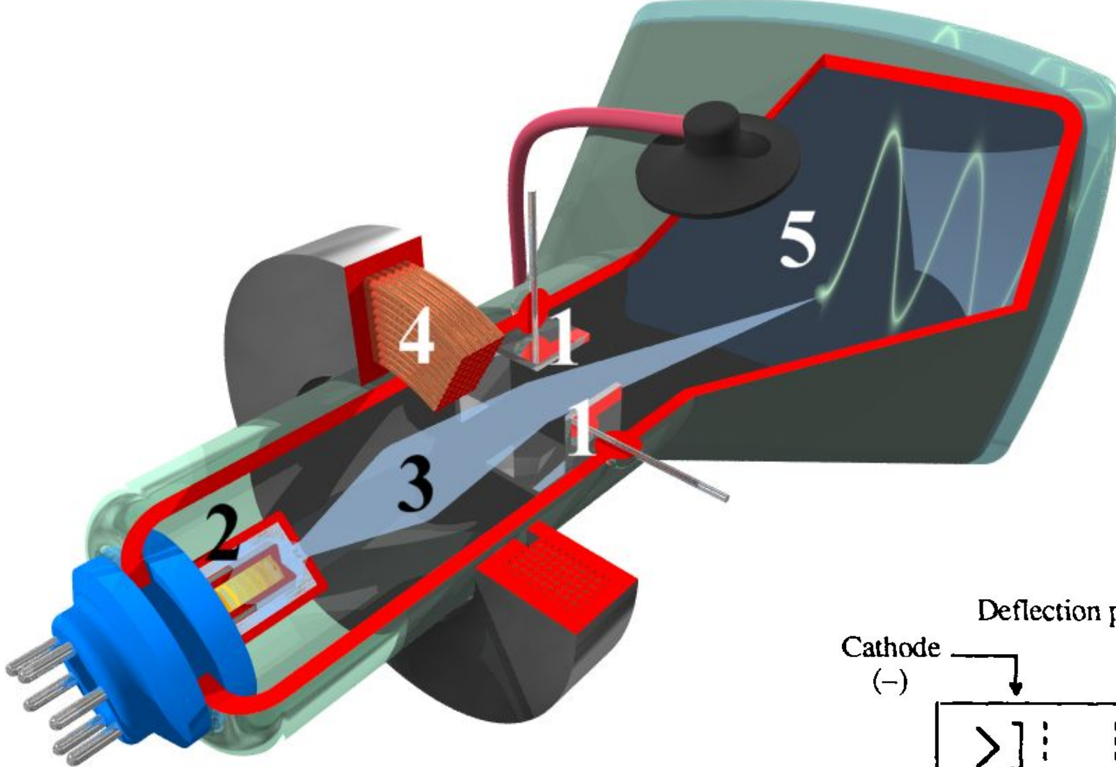
Mass spectrometer

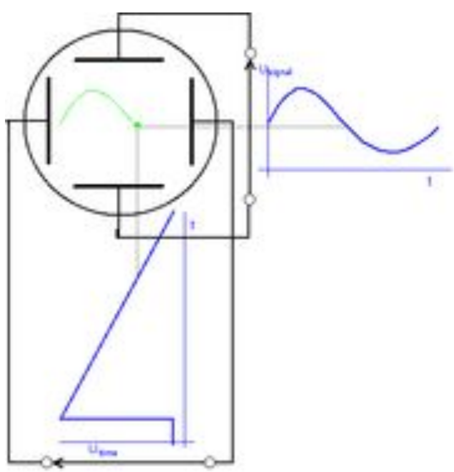


$$r = \frac{mv}{qB}$$



Cathode Ray Oscilloscope





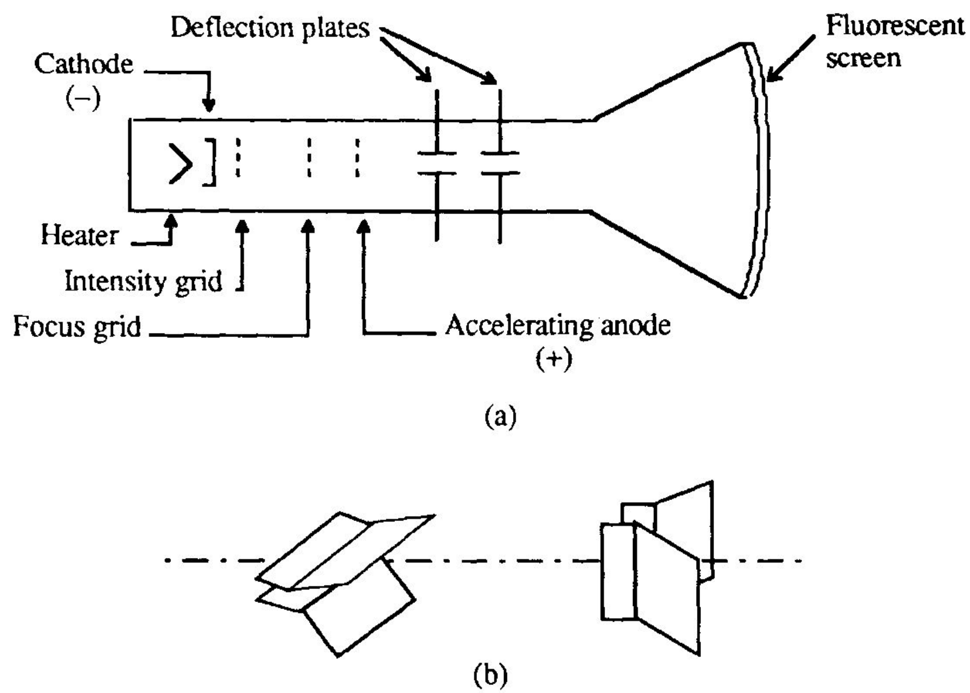
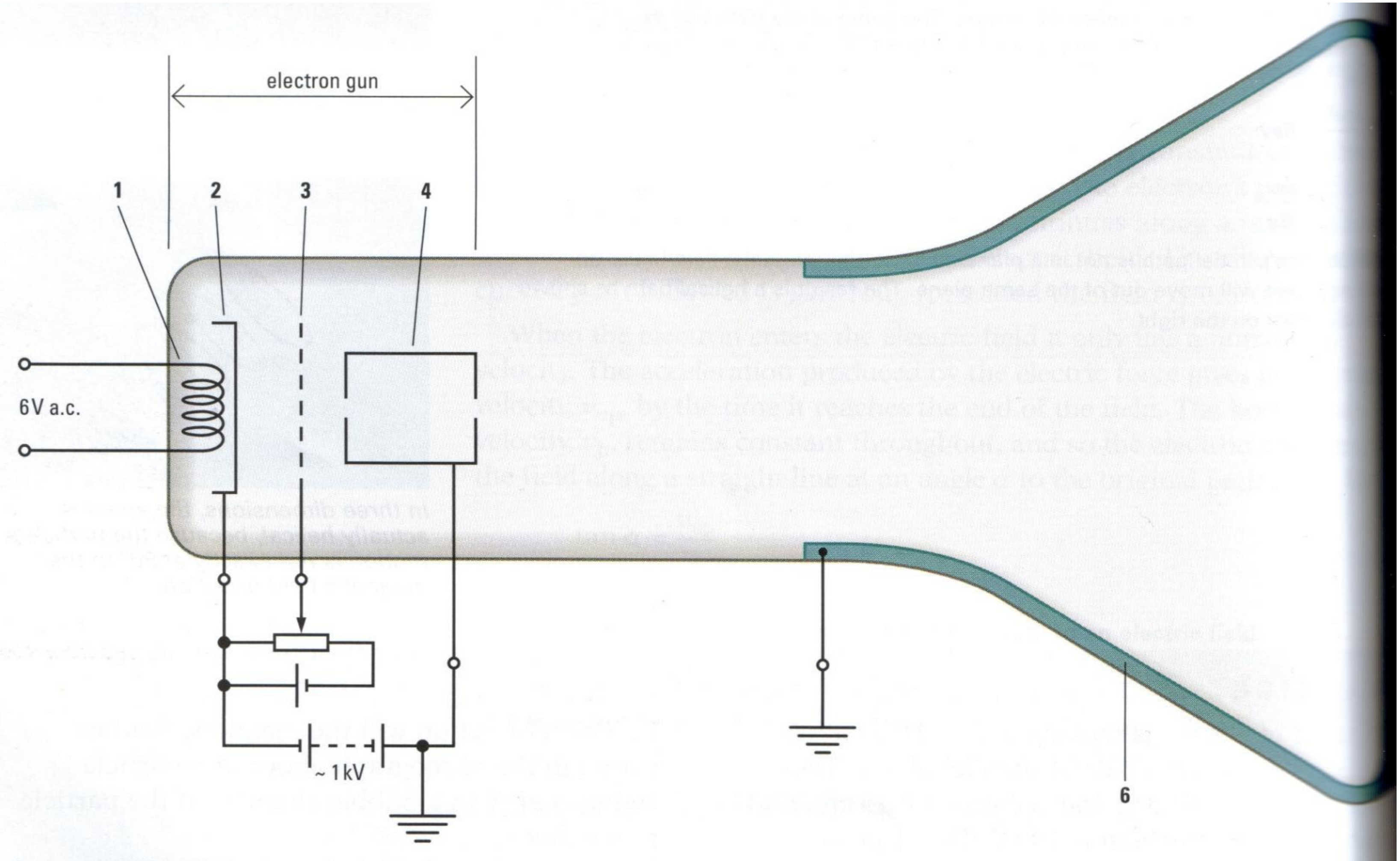


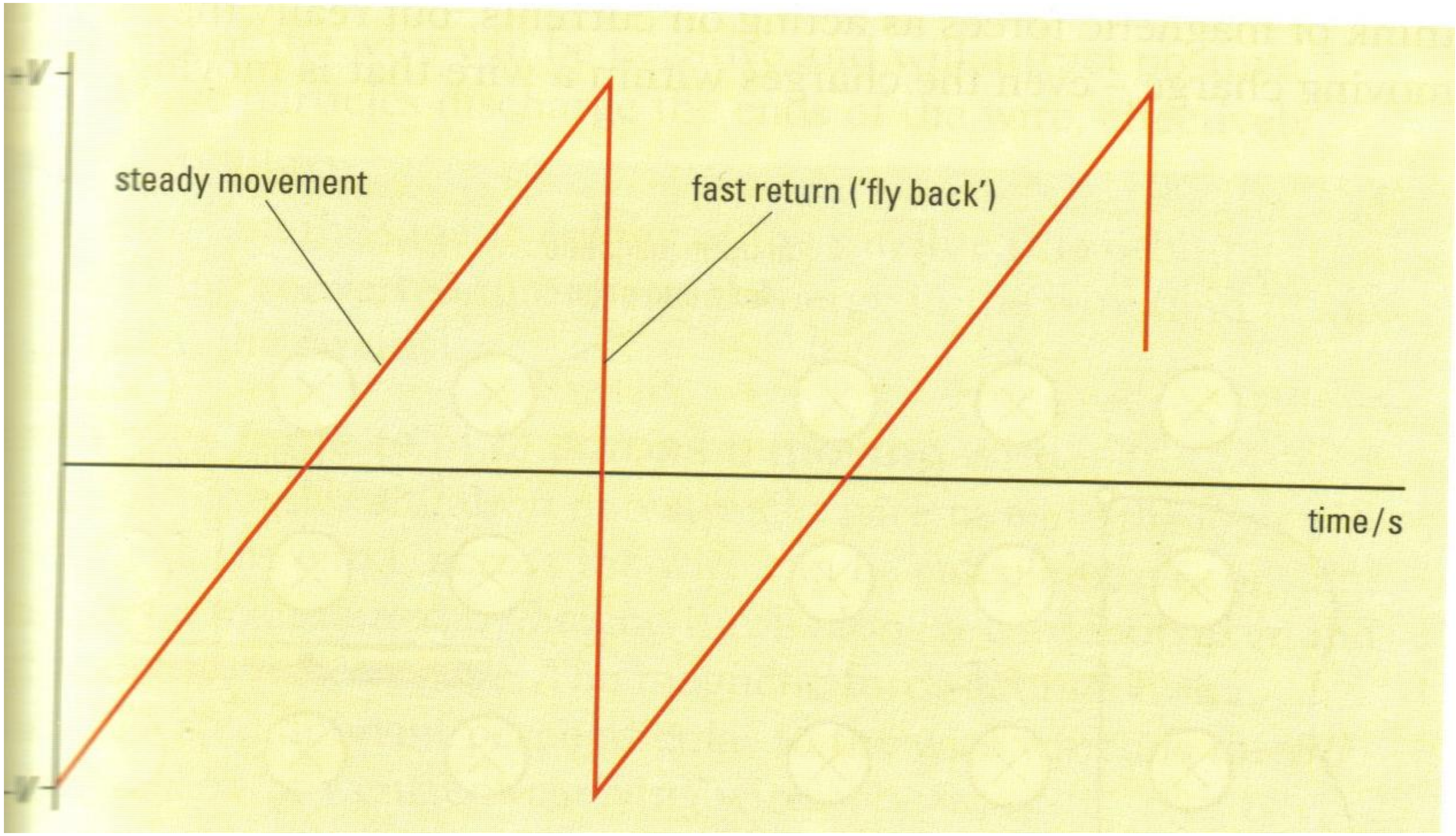
Figure 1. Cathode-ray tube: (a) schematic, (b) detail of the deflection plates.

Cathode Ray Oscilloscope



A cross-sectional diagram of a typical cathode-ray tube.

Time-base voltage



LECTURE CHECK LIST

LECTURE 27 Magnetic Fields

READING Adams and Allday: 5.14, 5.15, 5.16

At the end of this lecture you should:

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- Know the formula for the field strength due to a long straight wire carrying current, I, at a distance, a, from the wire
- Understand how the definition of the *ampere* arises and be able to give the definition
- Understand the concept of *field lines* for a magnetic field
- Know the formula for the magnetic field strength due to a solenoid and be able to perform calculations using that formula
- Have an understanding of the form of the Earth's magnetic field and understand that this field resolves into two components

LECTURE CHECK LIST

LECTURE 28 Applications of Electric and Magnetic Fields

READING Adams and Allday: 5.19, 5.20 8.3, 10.16

At the end of this lecture you should:

- Understand the principles behind the *mass spectrometer* and be able to perform calculations which demonstrate that understanding

- Understand the workings of the *Cathode Ray Oscilloscope (CRO)*
- Appreciate that a television works on the same principles as a CRO