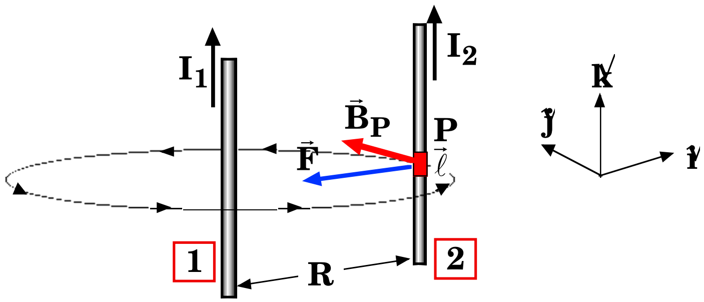
Force between two straight wires

See also pages 868-870 in 27-2 of the textbook.



The magnetic field due to [1] at position P is:

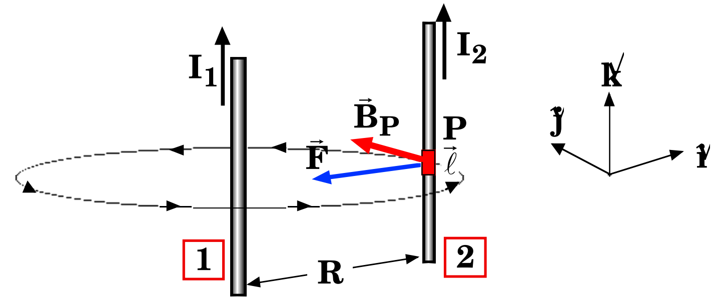
$$B_P = \frac{\mu_\circ I_1}{2\pi R}.$$

(We remember it is circular, i.e., along $\hat{j}$.)

Since [2] carries a current, I_2, there is a force:

$$\vec{F} = I_2 \vec{\ell} \times \vec{B}_P$$

acting on the segment $\vec{\ell}$ (along the $\hat{k}$ direction).
Note that $\vec{B}_P$ and $\vec{\ell}$ are perpendicular.



Therefore the force at P has magnitude:

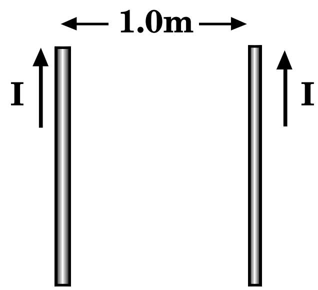
$$F = I_2 \ell B = \mu_\circ \frac{I_1 I_2 \ell}{2\pi R}$$

acting ***TO THE LEFT***, i.e., in the $-\hat{i}$ direction.
The force per unit length is:

$$\frac{F}{\ell} = \mu_\circ \frac{I_1 I_2}{2\pi R}.$$

A similar analysis indicates that the magnetic field caused by the current in [2] produces a force ***TO THE RIGHT*** on [1], i.e., in the $+\hat{i}$ direction. Consequently, two parallel wires carrying currents in the ***same direction*** are ***attracted*** to each other.

Definition of the *AMPÈRE*:



If the wires carry the same current,

i.e., $I_1 = I_2 = I$,

the force per unit length is:

$$\frac{F}{\ell} = \mu_\circ \frac{I^2}{2\pi R}.$$

Since $\mu_\circ = 4\pi \times 10^{-7}$ T.m/A, a current of one *AMPÈRE* can be defined as:

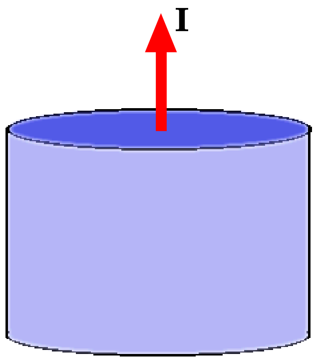
... the current in two parallel wires of infinite length placed 1m apart that produces a force on each wire of 2×10^{-7} N *per meter of length.*

i.e., if $I_1 = I_2 = 1A$,

$$\therefore \frac{F}{\ell} = 4\pi \times 10^{-7} \times \frac{1}{2\pi} \Rightarrow 2 \times 10^{-7} \text{ N/m}$$

TWO QUESTIONS TO THINK ABOUT

Question 1:



Gedanken ("thought") experiment .... Imagine that a "jello wire" is carrying a current as shown above. If the wire is free to deform - i.e., expand or contract, shorten or lengthen - what effect, if any, will the current will have on the wire?

Question 2:

Identify the forces acting on the windings of a current carrying solenoid ...