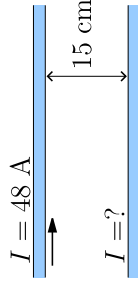# Tutorial 12 Question

- Ch 28: Pr. 52.
- A long horizontal wire carries a current of 48 A. A second wire, made of 2.5 mm-diameter copper wire and parallel to the first but 15 cm below it, is held in suspension magnetically. (a) What is the magnitude and direction of the current in the lower wire? (b) Is the lower wire in stable equilibrium? (c) Repeat parts (a) and (b) if the second wire is suspended 15 cm *above* the first due to the first's magnetic field.
- Information: Density of copper, $\rho = 8.9 \times 10^3$ kg/m^3.

$I = 48$ A

$I = ?$

15 cm

Solution

(a) What is the magnitude and direction of the current in the lower wire?

- The criterion is that the magnetic force $F_m = IlB$ exactly balances gravity $F_g = mg$.
- Using both the RH-field and RH-force rules we see that that F_m will be upwards if the current on the lower wire is to the right.
- Now we need to check its magnitude. The B field due to the top wire is

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(48\ \text{A})}{2\pi(0.15\ \text{m})}$$

$$= 6.4 \times 10^{-5}\ \text{T}.$$

Solution, contd

(a) contd

- The magnetic force on a length l of the bottom wire (with unknown current I) is $F_m = IlB$.
- The gravitational force on the same length of wire (diameter, $d = 2.5$ mm) is $F_g = g\rho V = g\rho l(\pi d^2/4)$.
- To balance these forces we need

$$IlB = g\rho l(\pi d^2/4)$$

$$I = \frac{\pi g\rho d^2}{4B}$$

$$= \frac{\pi(9.8\ \text{m/s}^2)(8.9 \times 10^3\ \text{kg/m}^3)(0.0025\ \text{m})^2}{4(6.4 \times 10^{-5}\ \text{T})}$$

$$= 6.7 \times 10^3\ \text{A}.$$

Solution, contd

(a) contd

- So the wire will be suspended if it carries a current 6.7×10^3 A to the right. (That's *huge!*)

(b) Is the lower wire in stable equilibrium?

- If it's stable then if the wire slips out of position it will be pushed back into equilibrium.
- Let's think about what happens if the wire slips down a bit. Then the top wire is further away so its magnetic field is smaller. That means the magnetic force is smaller.
- So it won't be able to hold the wire up anymore and it will fall even lower.
- So this is **not** a stable equilibrium.

Solution, contd

(c) Repeat if the second wire is suspended 15 cm *above* the first.

- The force has to be repulsive this time so the unknown current should run to the left.
- But the magnitude of the B-field and the force are the same, just in the opposite direction.
- So we just need to check its stability.
- This time, if the wire slips down the magnetic force pushing it back up gets *stronger* so it will move back up to equilibrium.
- So it is **stable** to displacements in the vertical direction.
- But what if it gets knocked to the side?

Solution, contd

(c) contd

- The magnetic force will push it radially away from the lower wire.
- Effectively, it will "slide" off the lower wire. This diagram shows the stability:

$I = 6.7$ kA

15 cm

$I = 48$ A
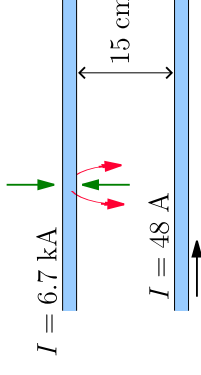
- So it won't be pulled back into equilibrium and, overall, it's still in an **unstable** equilibrium.