Boğaziçi University

Introductory Phys Labs

FORCE BETWEEN CURRENT CARRYING WIRES

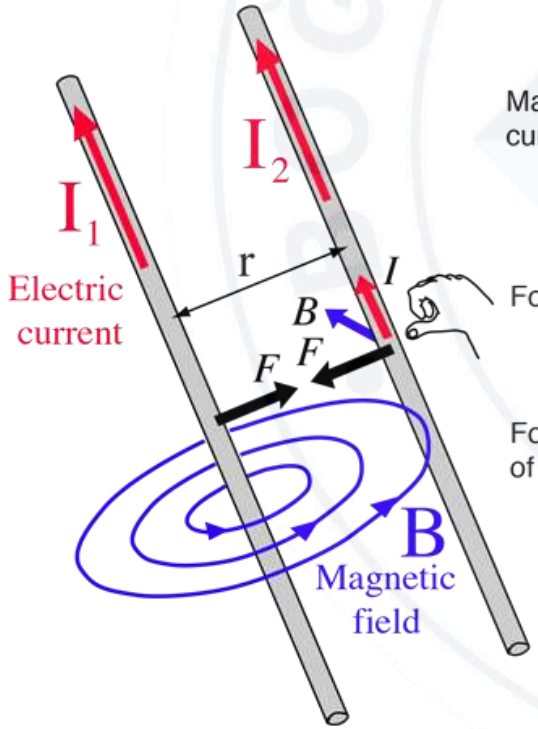
PHYL 201

THEORY

FORCE BETWEEN CURRENT CARRYING WIRES

Objective: Finding the permeability of free space: μ_0

Method: Measure the force between parallel, current carrying wires and to analyze the dependence of this force on the constants of the system.



Magnetic field at wire 2 from current in wire 1:

$$B = \frac{\mu_0 I_1}{2\pi r}$$

Force on a length ΔL of wire 2:

$$F = I_2 \Delta L B$$

Force per unit length in terms of the currents:

$$\frac{F}{\Delta L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

Force between the current carrying wires is given as:

$$F = \frac{\mu_o}{2\pi}\frac{L}{d} I_1 I_2$$

and if the same current is passing through the wires as:

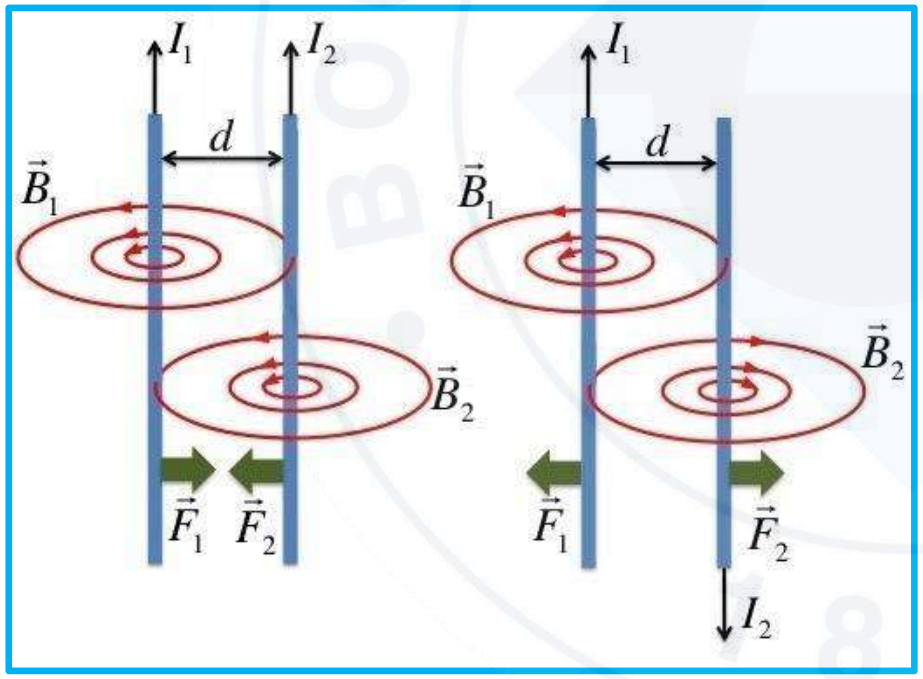
$$F = \frac{\mu_o}{2\pi}\frac{L}{d} I^2$$

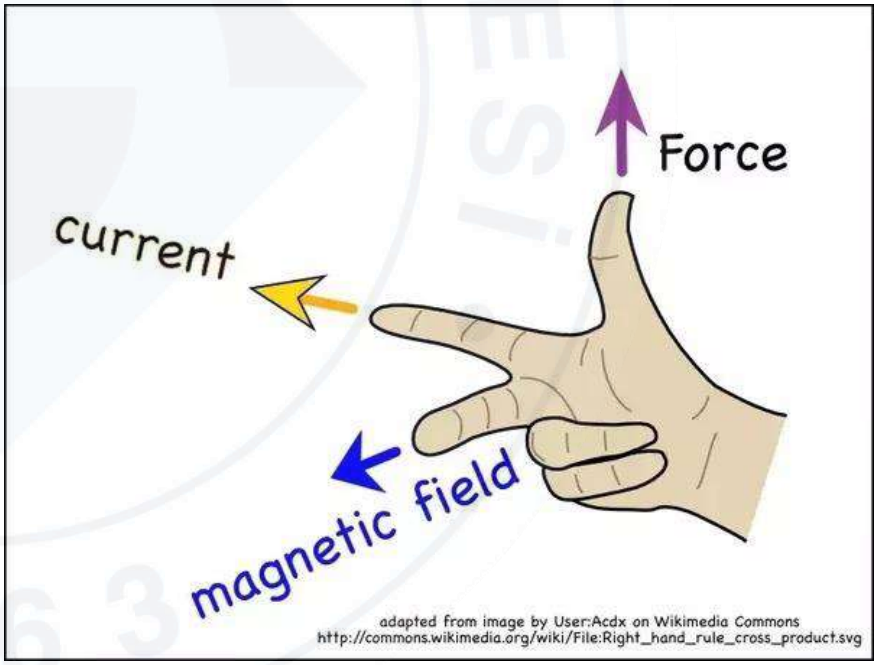
FORCE BETWEEN CURRENT CARRYING WIRES

The following figures show the magnetic field lines (red) generated by the currents flowing in two wires.

Two wires carrying current in the same direction attract each other, otherwise they repel.

The direction of the magnetic force can be found by using the right-hand rule.



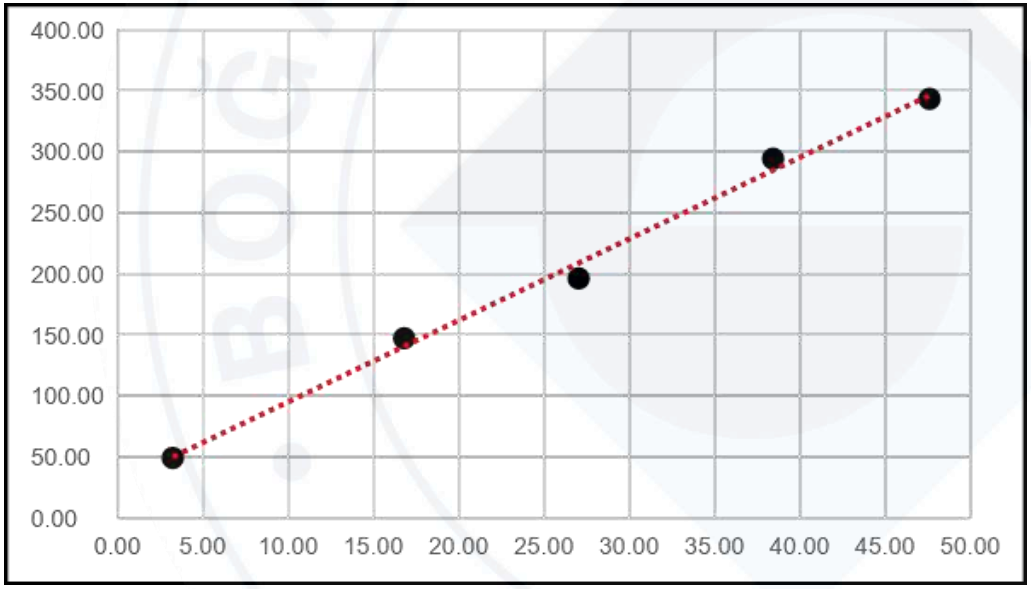


FORCE BETWEEN CURRENT CARRYING WIRES

Objective: Finding the permeability of free space: μ_0

Method: 5 measurements of **F vs I^2**. Make a line fit to data.

Example plot of F vs I^2



$$F = \underbrace{\frac{\mu_o}{2\pi}\frac{L}{d}}_{\text{Constant, k}} I^2$$

$$\mu_o = \frac{2\pi(slope)d}{L}$$

F is linearly dependent on I^2

EXPERIMENT SETUP

FORCE BETWEEN CURRENT CARRYING WIRES

Behind the laser

Mirror

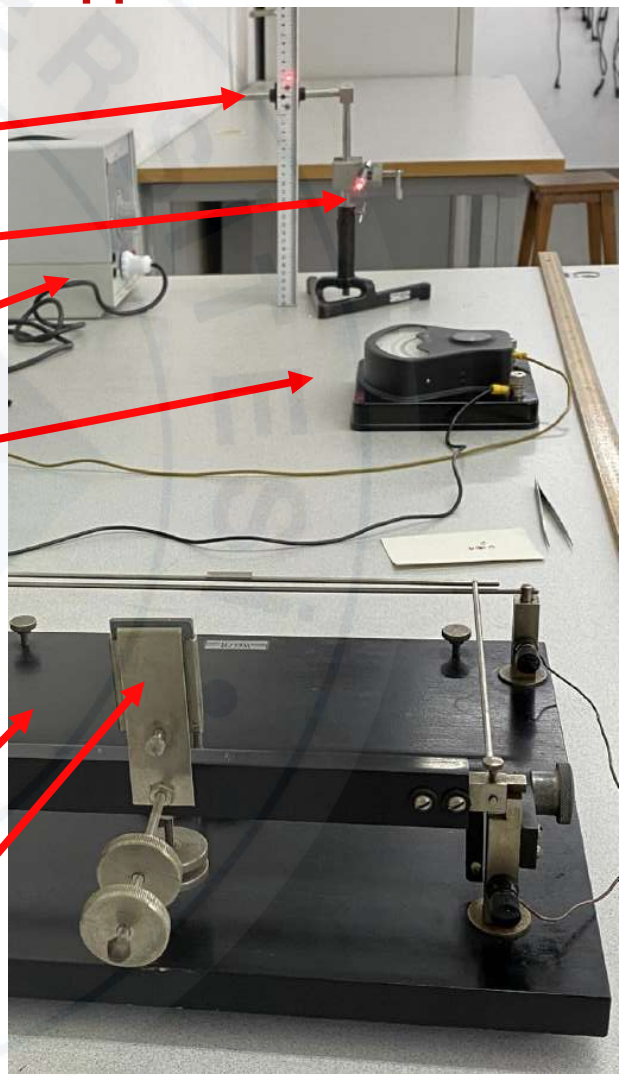
Ruler/Laser Spot

Laser

Power Supply

Ammeter

Behind the parallel wires apparatus



Laser

Parallel Wires Apparatus

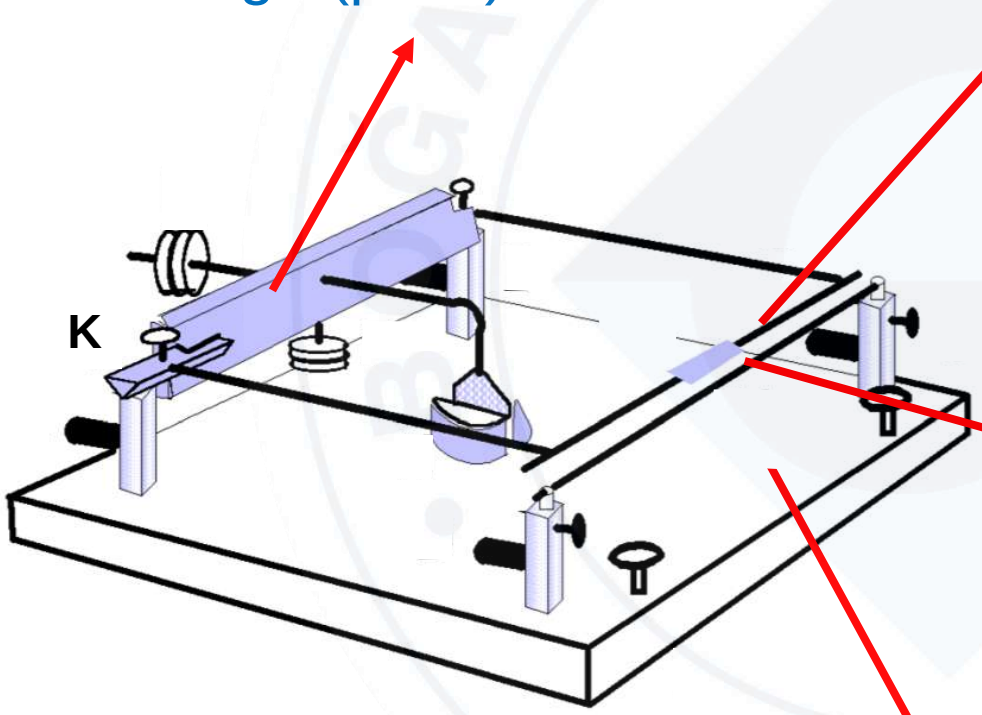
Backside of the Mirror

FORCE BETWEEN CURRENT CARRYING WIRES

Parallel Wires Apparatus (Current Balance)

Pivot axis on knife edge (pivot) K

Upper wire moves up/down about pivot K

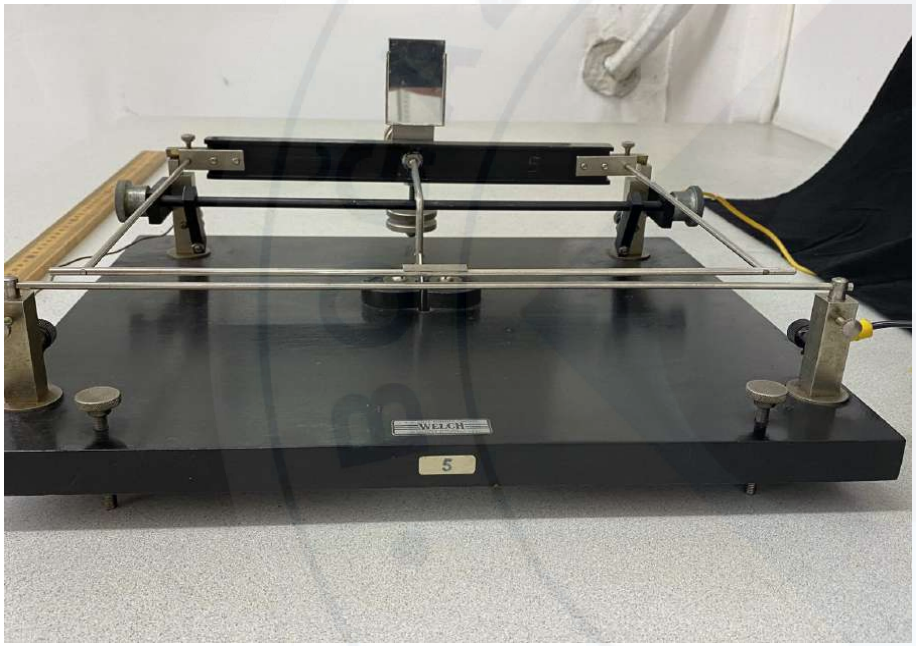


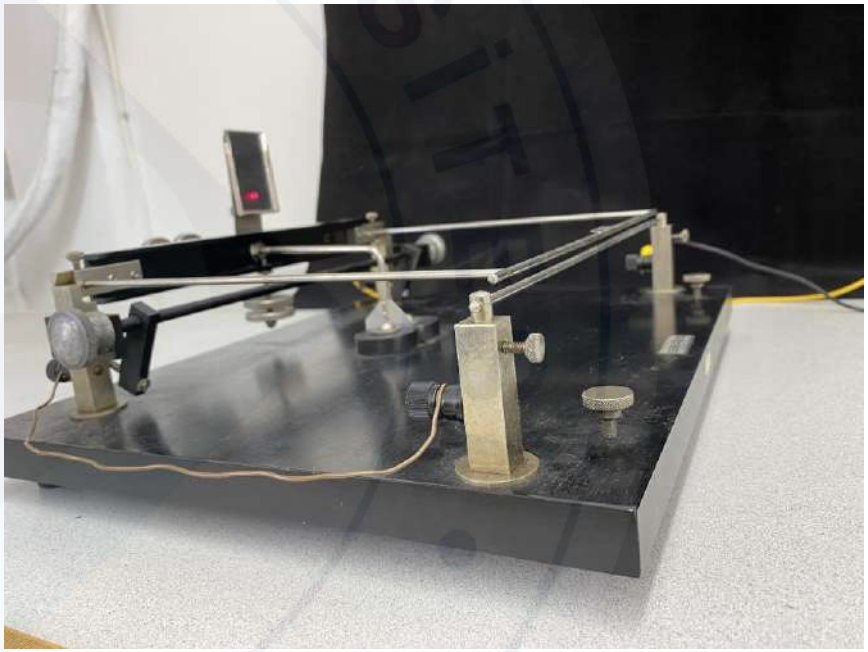
Weight pan on wire

Lower wire is fixed

FORCE BETWEEN CURRENT CARRYING WIRES

Parallel Wires Apparatus (Current Balance)



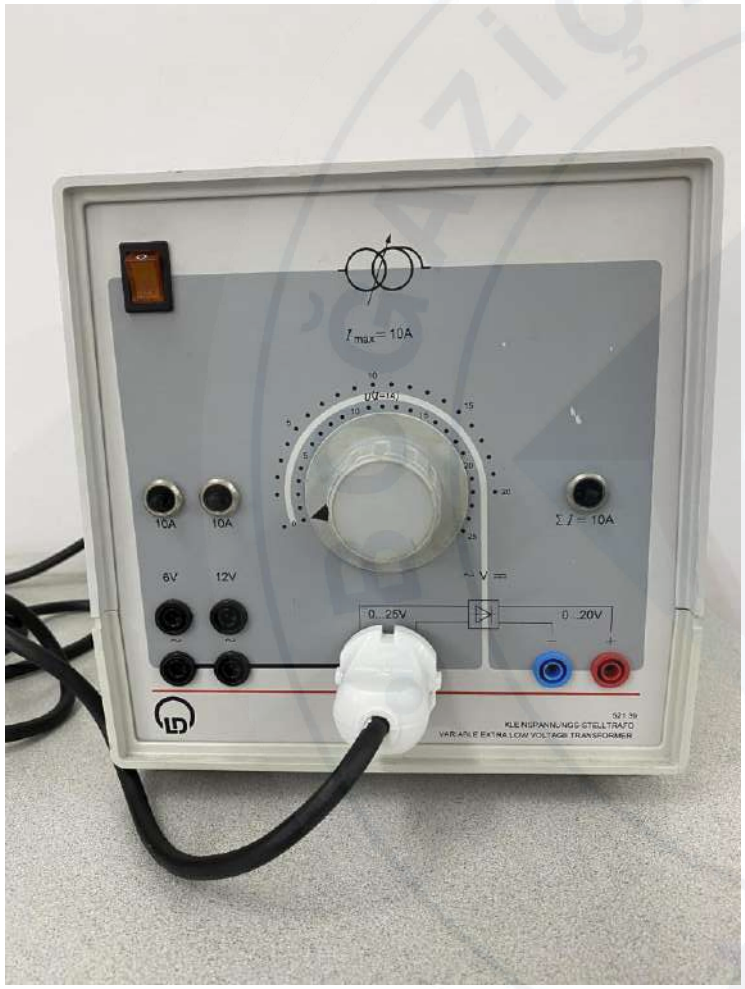


FORCE BETWEEN CURRENT CARRYING WIRES

Ruler and laser

FORCE BETWEEN CURRENT CARRYING WIRES

AC power supply



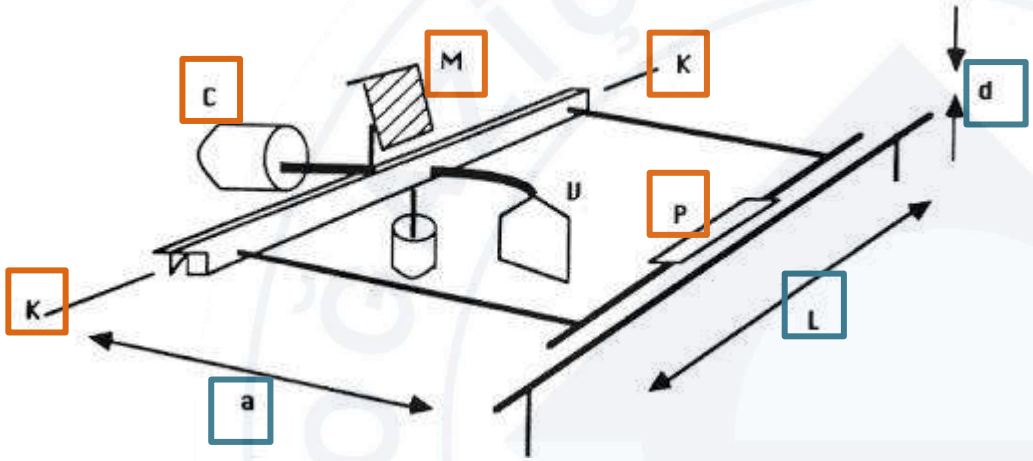
AC ammeter

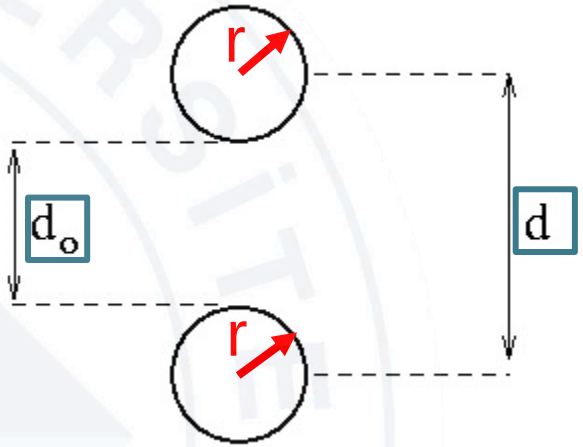
PROCEDURE

How to determine the separation between the wires: d, d_0

FORCE BETWEEN CURRENT CARRYING WIRES

How to measure the separation between the wires: d, d_0





a: Length of the lever arm

L: Length of the wire

d: The separation between the wire centers

d_0: The separation between the wire edges

K: Knife edge

C: Counterpoise

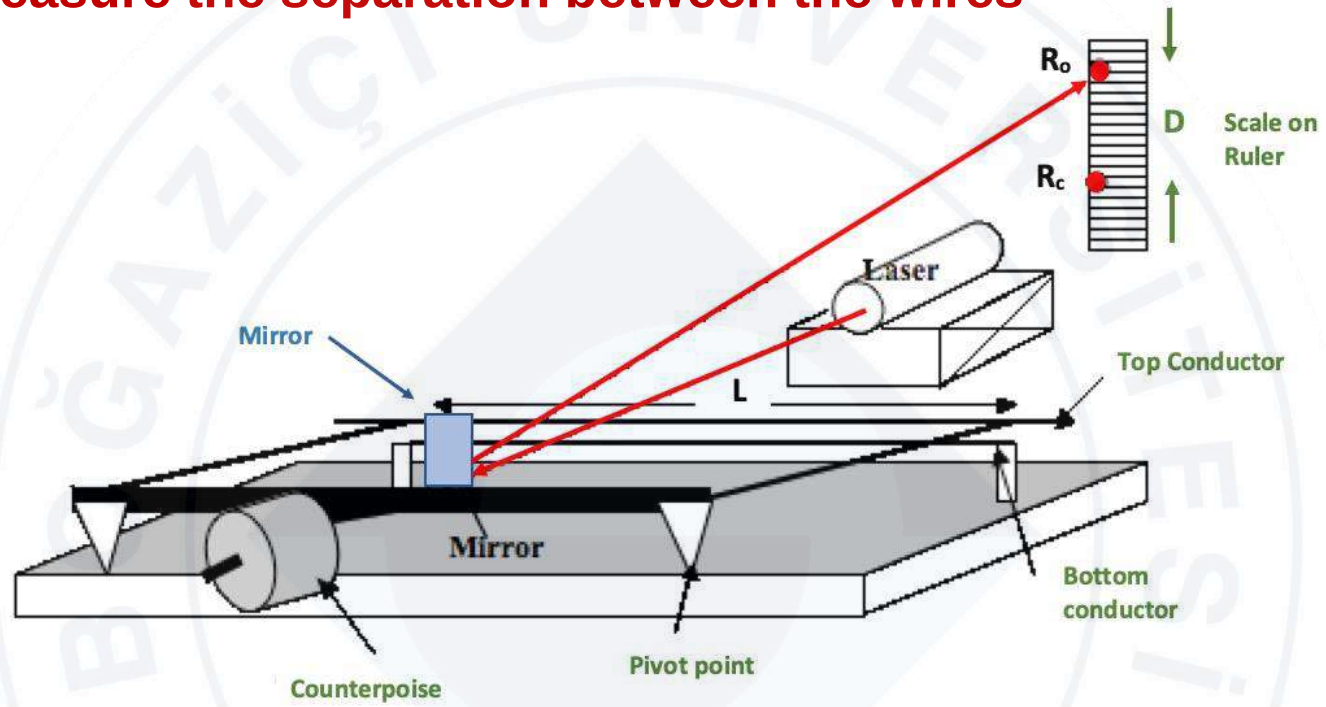
M: Mirror

P: Weight pan

2r: Diameter of the wire

FORCE BETWEEN CURRENT CARRYING WIRES

How to measure the separation between the wires



a: Length of the lever arm

b: Distance from the scale with the mirror to the ruler

d: The separation between the wire centers

d_0: The separation between the wire edges

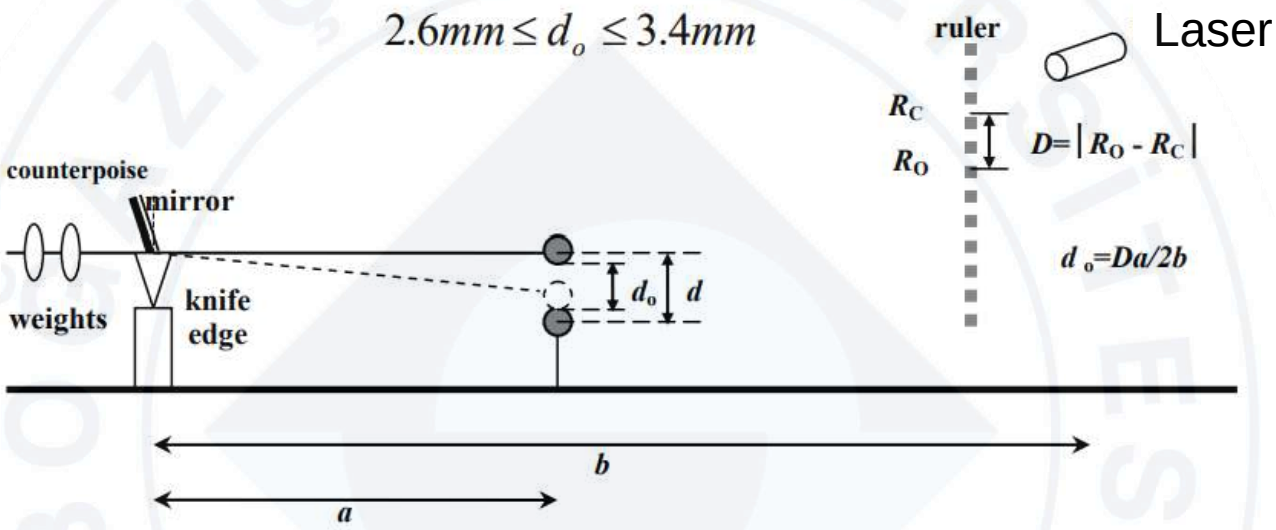
R_O: Reading when the wires are open

R_C: Reading when the wires are closed

$$D = |R_O - R_c|$$

FORCE BETWEEN CURRENT CARRYING WIRES

Side-view:



a: Length of the lever arm

b: Distance from the scale with the mirror to the ruler

d: The separation between the wire centers

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R_O: Reading when the wires are open

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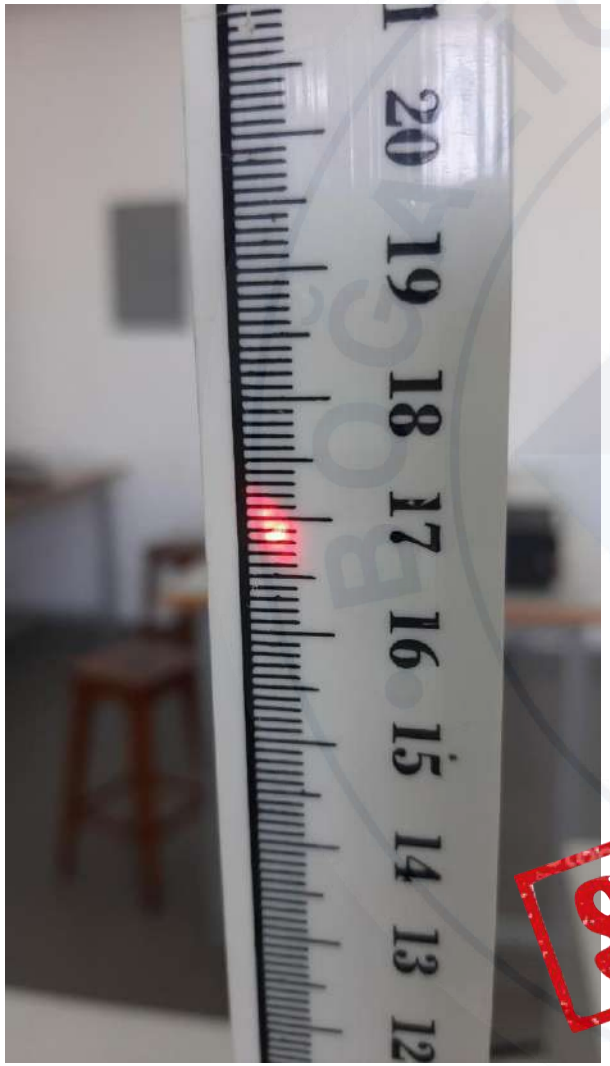
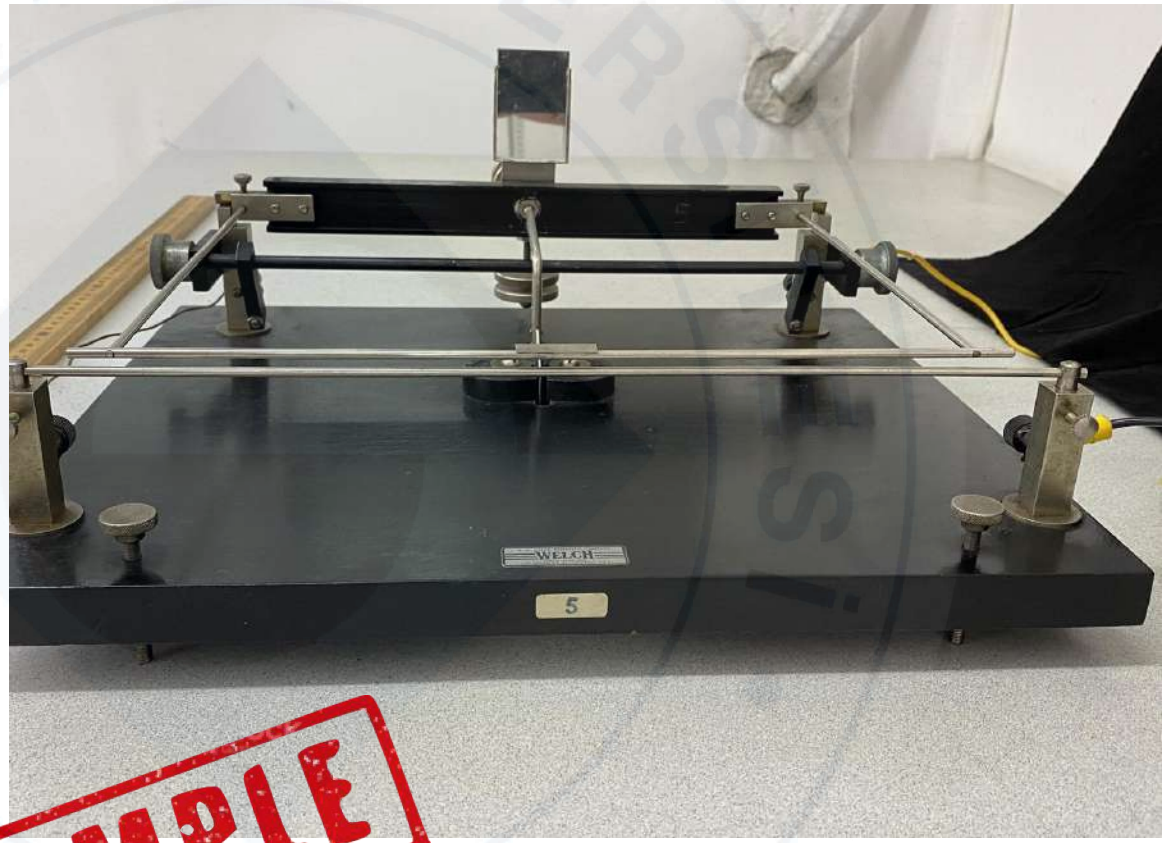
$$D = |R_O - R_c|$$

FORCE BETWEEN CURRENT CARRYING WIRES

The laser spot position for R_{open}

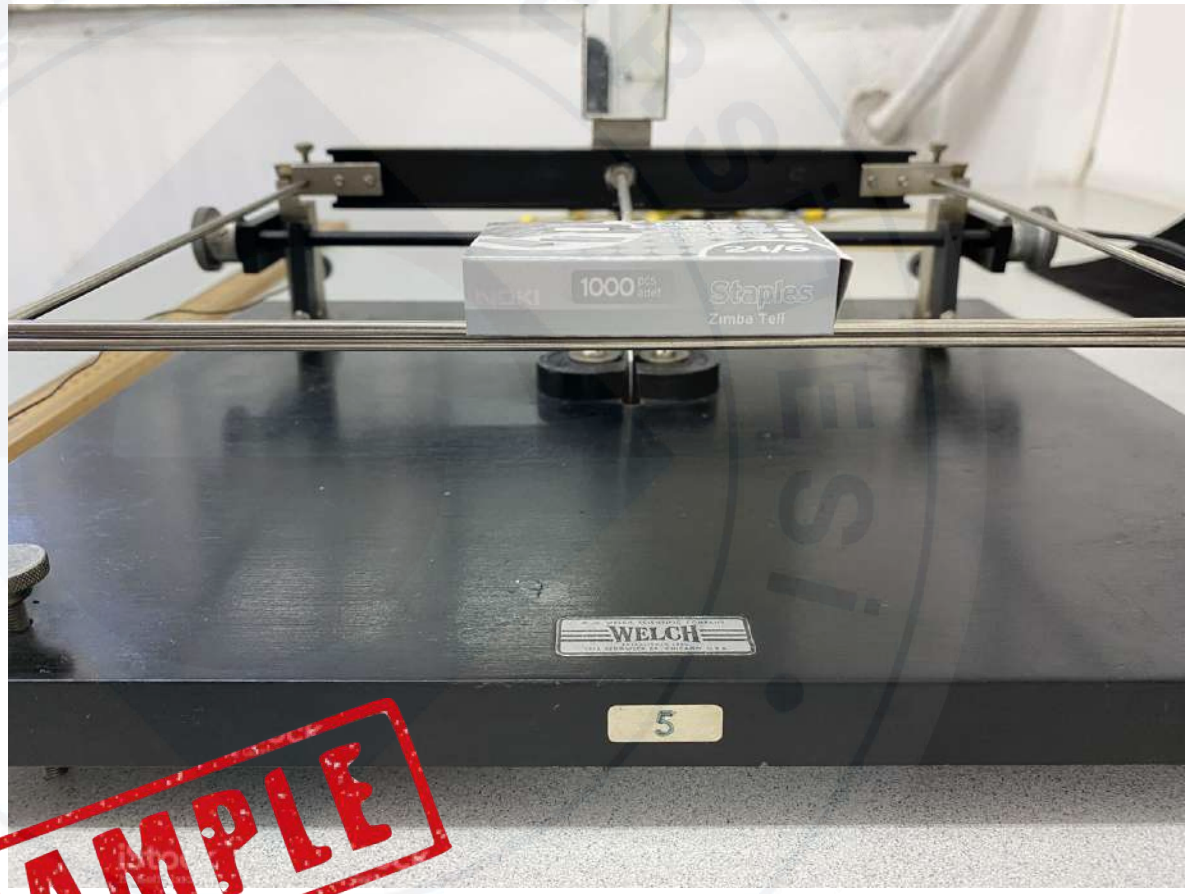




SAMPLE

FORCE BETWEEN CURRENT CARRYING WIRES

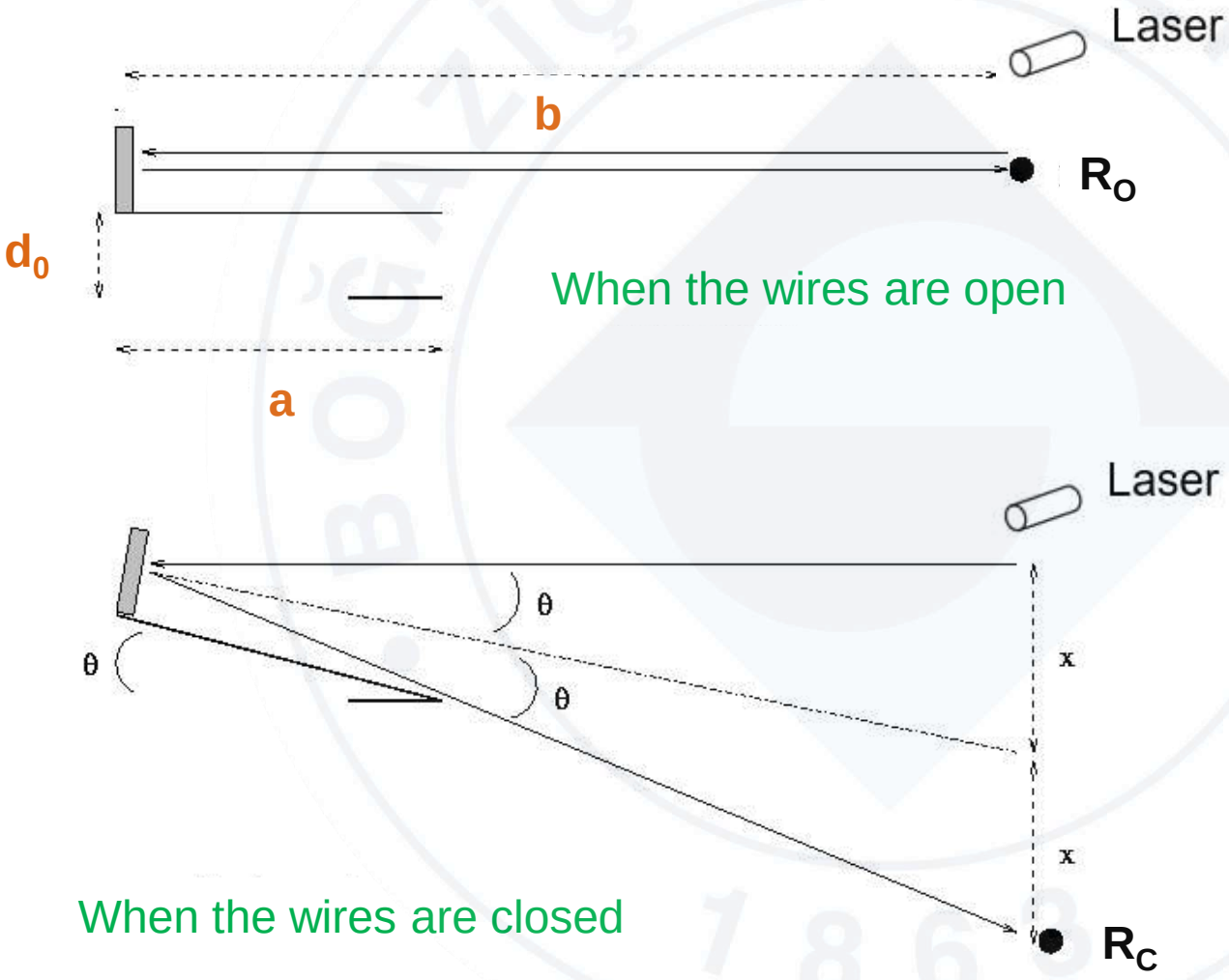
The laser spot position for R_{closed}



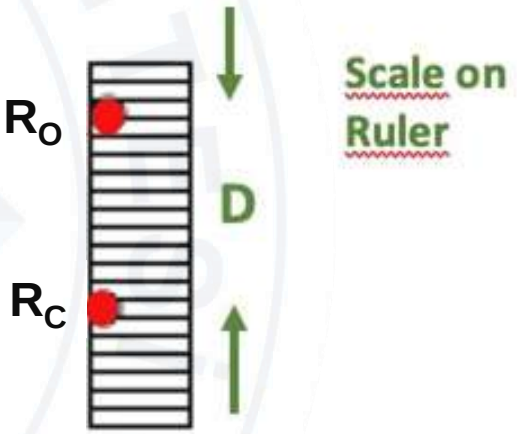
SAMPLE

FORCE BETWEEN CURRENT CARRYING WIRES

Side-view:



Laser spots on ruler:



$$D = |R_O - R_c|$$

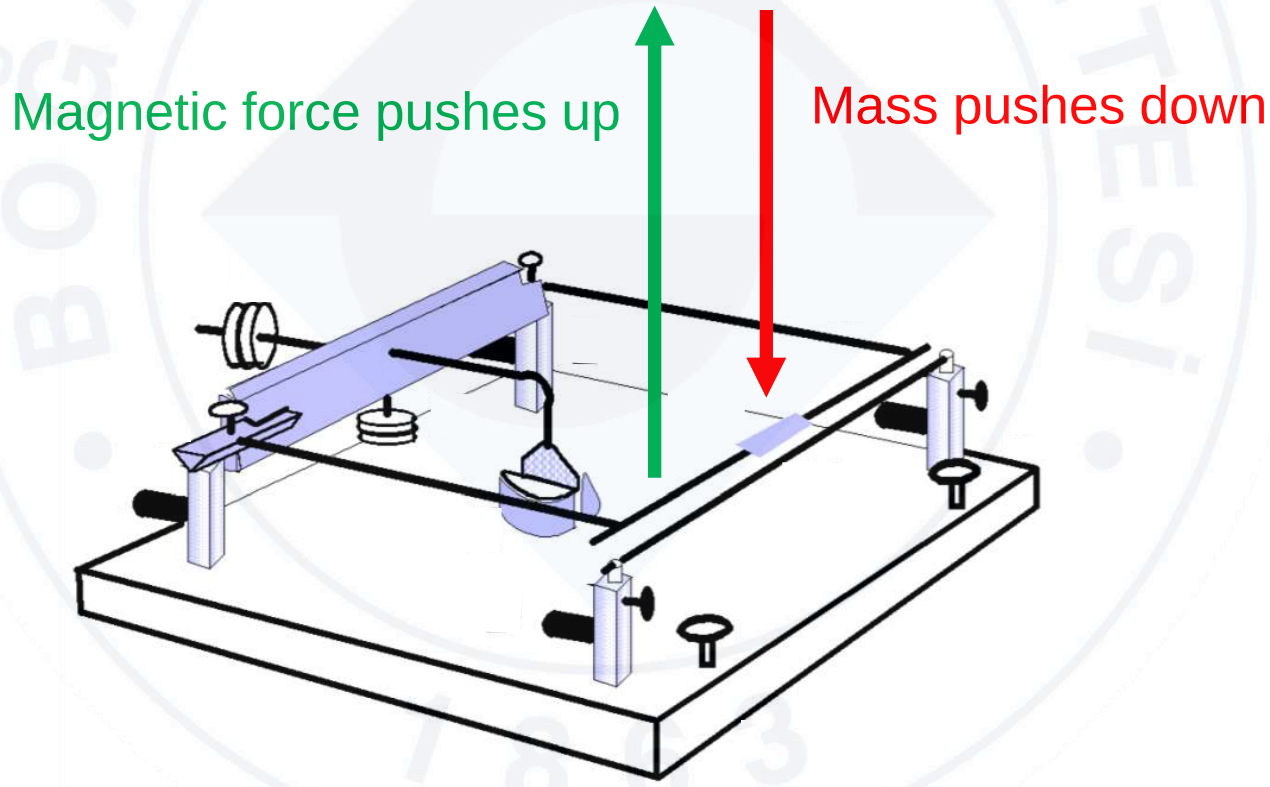
$$d_0 = Da/2b$$

How to measure the electromagnetic force

Parallel Wires Apparatus (Current Balance)

Lower wire is fixed, upper wire moves up and down around the knife edge.

Currents in upper/lower wires have same magnitude and opposite direction

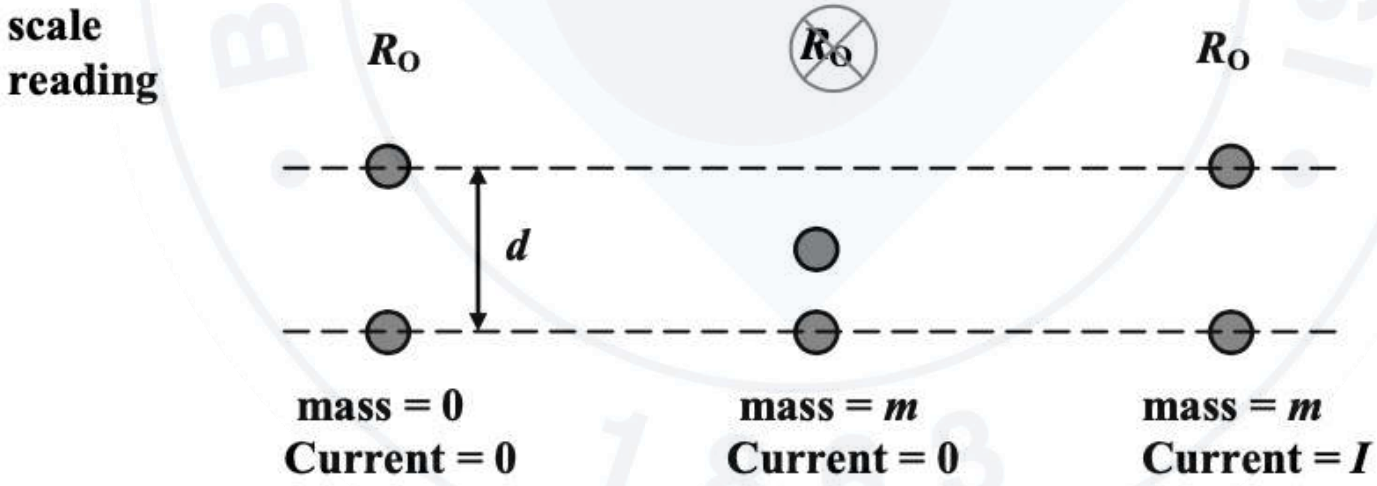


Parallel Wires Apparatus (Current Balance)

Lower wire is fixed, upper wire moves up and down around the knife edge.

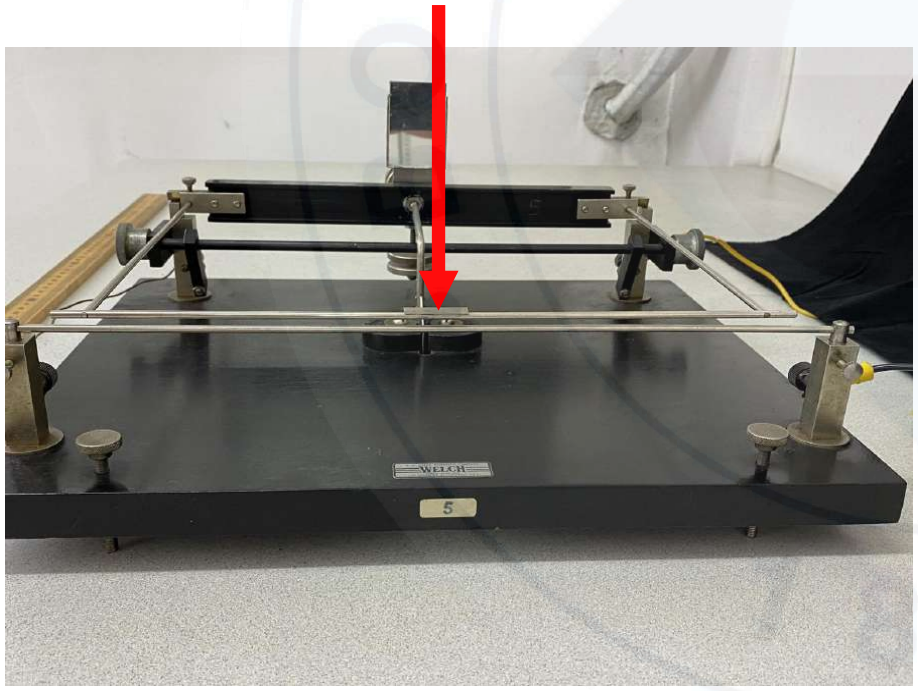
Currents in upper/lower wires have same magnitude and opposite direction

Step 1: System is in balance
Step 2: We put a mass on the pan, balance is broken.
Step 3: We apply a current, magnetic force lifts the upper wire to restore the balance.

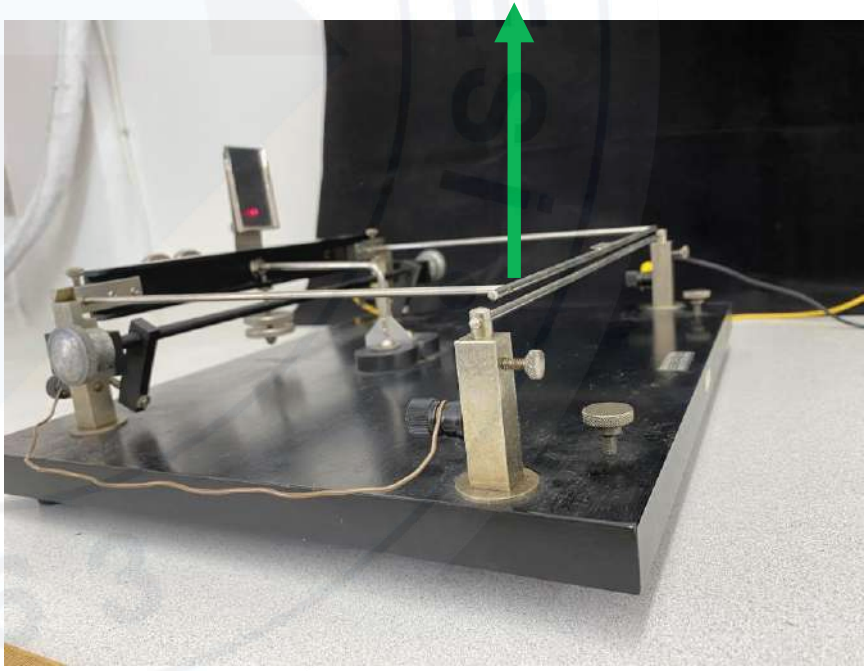


Breaking and restoring the balance

- Weight pushes down
- BALANCE IS BROKEN
- Laser is deflected from R_O



- Current is applied. Magnetic force pushes up.
- BALANCE IS RESTORED
- Laser points R_O again.



MEASURE SETUP PARAMETERS

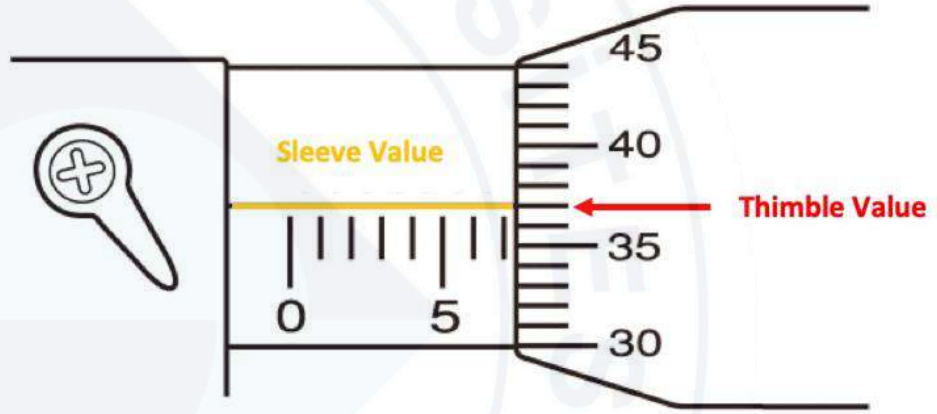
Length of the lever arm (a)

FORCE BETWEEN CURRENT CARRYING WIRES

Distance from mirror to ruler (b)

FORCE BETWEEN CURRENT CARRYING WIRES

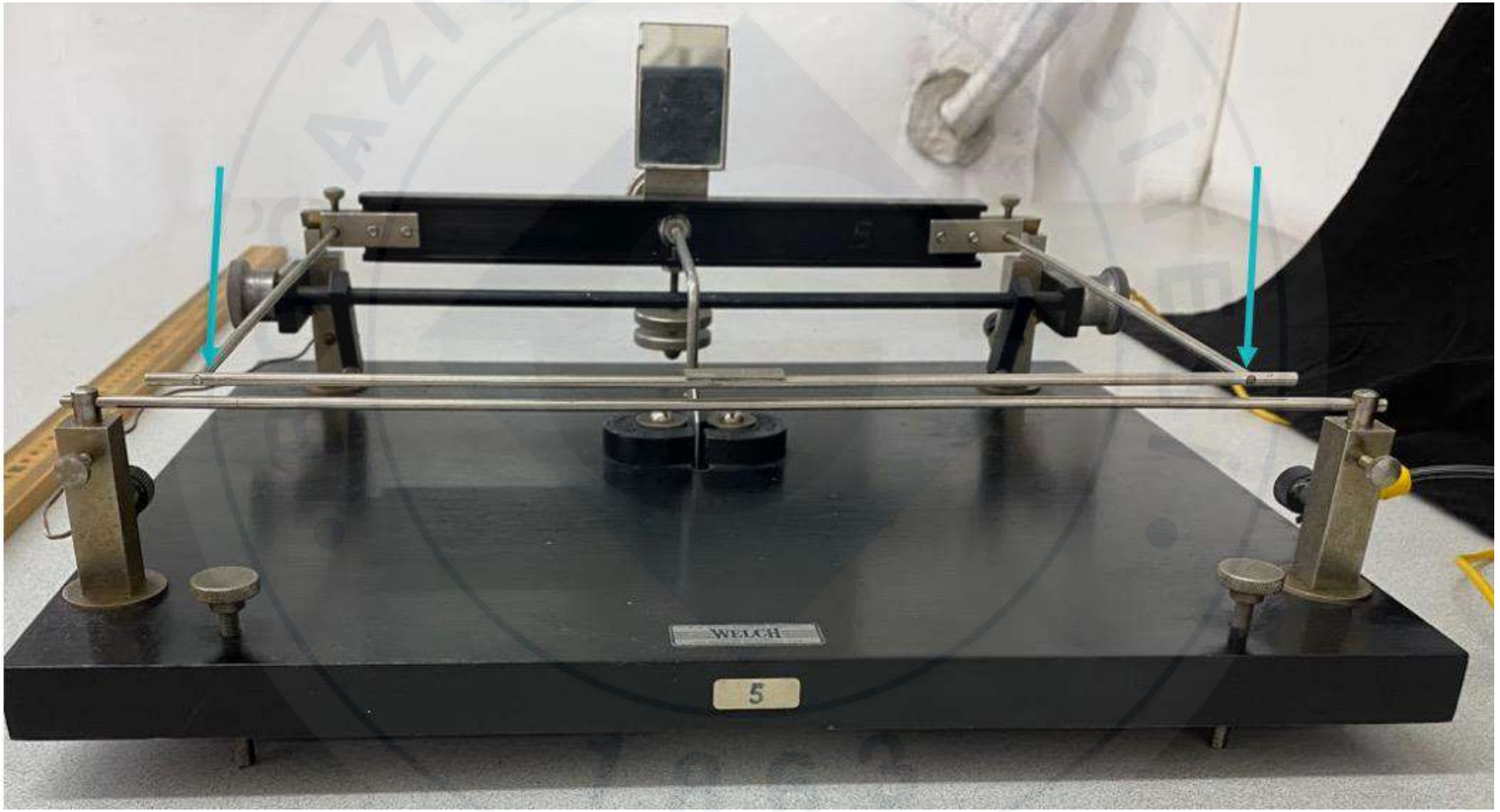
Use a micrometer to measure the diameter of the wire (2r)



Sleeve value	7
Thimble value	0.37
Reading value	7.37(mm)

FORCE BETWEEN CURRENT CARRYING WIRES

Length of the wire (L)



DATA-TAKING

FORCE BETWEEN CURRENT CARRYING WIRES

Overview

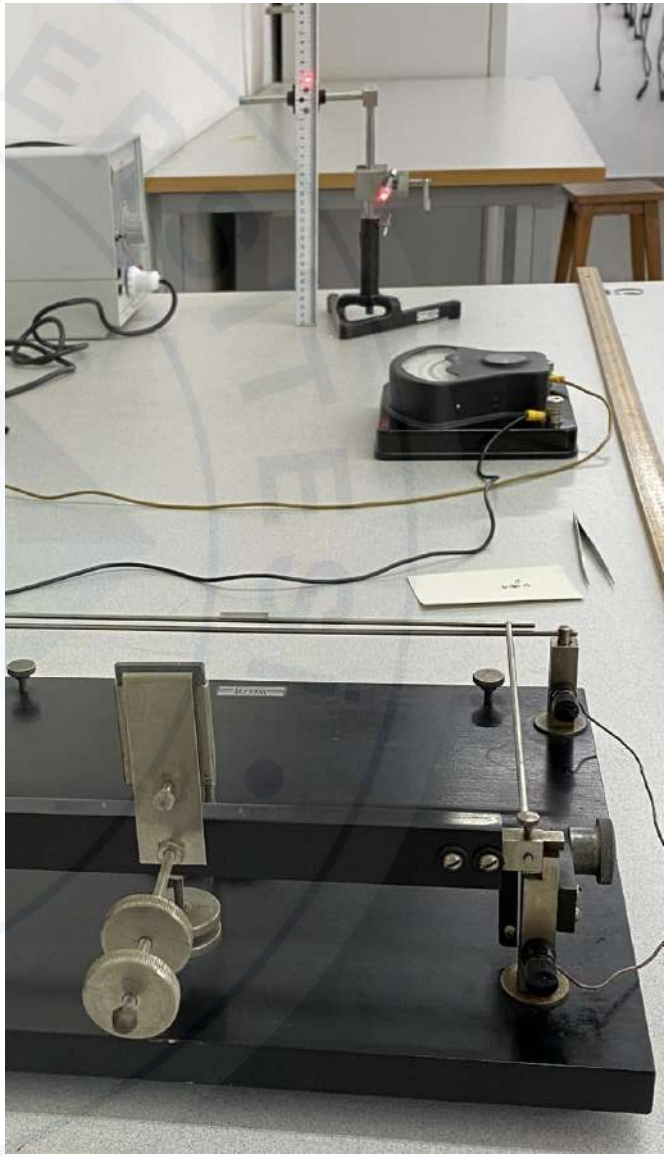
1. Put a mass on the weight pan.

1. Observe that the laser spot on the ruler is deflected from R_0. That is, the balance is broken.

1. Increase the current from the power supply

1. Observe that the laser spot on the ruler is back on R_0. That is, the balance is restored.

1. Repeat these steps for 5 times with different masses.



FORCE BETWEEN CURRENT CARRYING WIRES

Breaking the Balance

We now put a certain amount of mass, such as shown on the left image, and break the balance, as you can see.

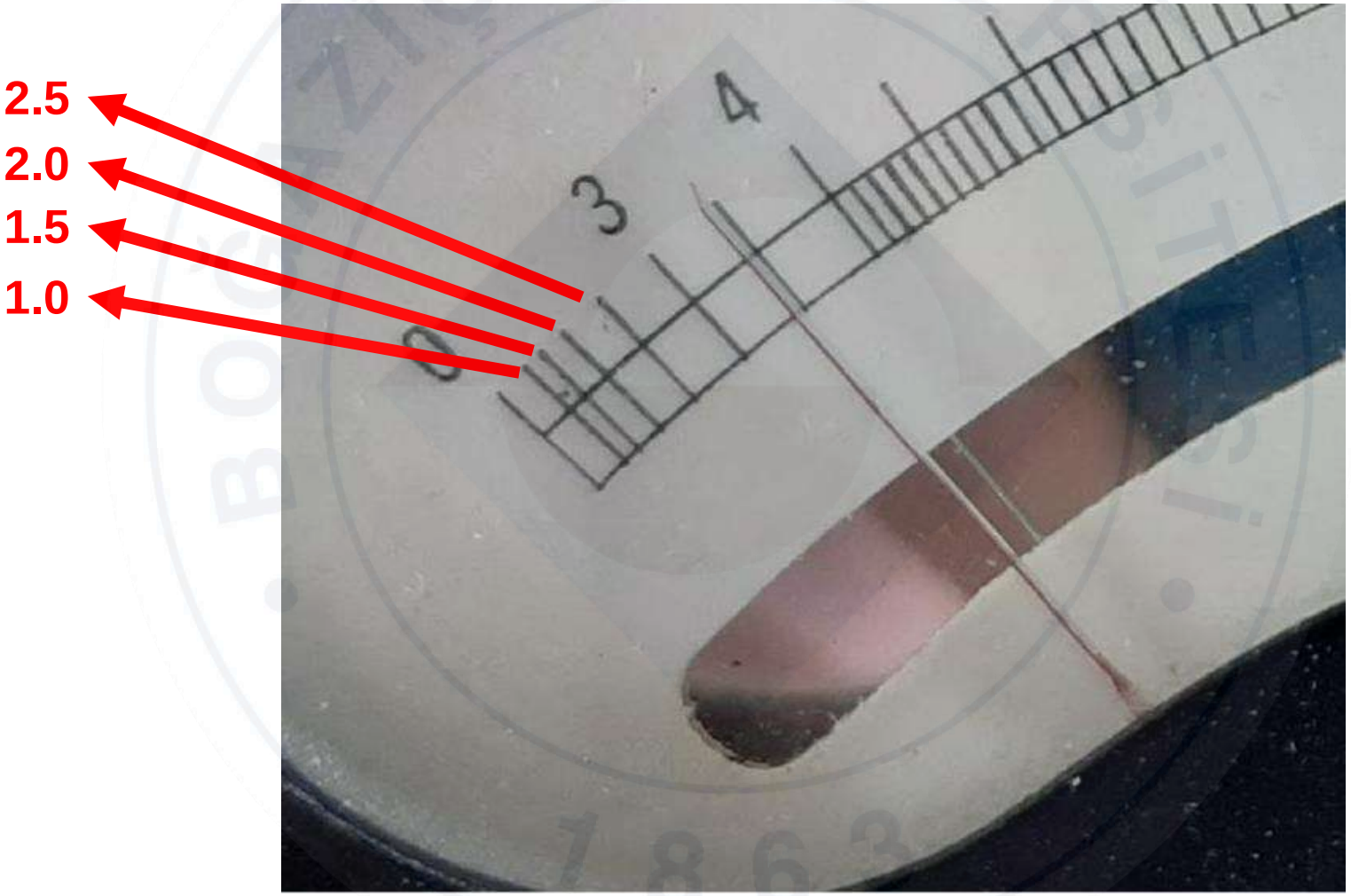
Restoring the Balance

Then we apply a current through the wires, so that they push on each other and restore the balance. Note that the laser spot hits exactly where the initial balance was, Ro.

Ammeter reads Ampere units.

FORCE BETWEEN CURRENT CARRYING WIRES

How to read ammeter in 0-3 A range



CALCULATIONS

Calibration of the setup

Difference in readings $$D = |R_O - R_C|$$

Separation between the wires $$d_o = Da/2b$$

Separation between the wire centers $$d = d_0 + 2r$$

FORCE BETWEEN CURRENT CARRYING WIRES

Fill the table

Mass m ( )	Current I ( )	$F_m = m.g = k\,I^2$ ( )	Square of the Current I^2 ( )

V: 5 mg (each)

U: 10 mg (each)

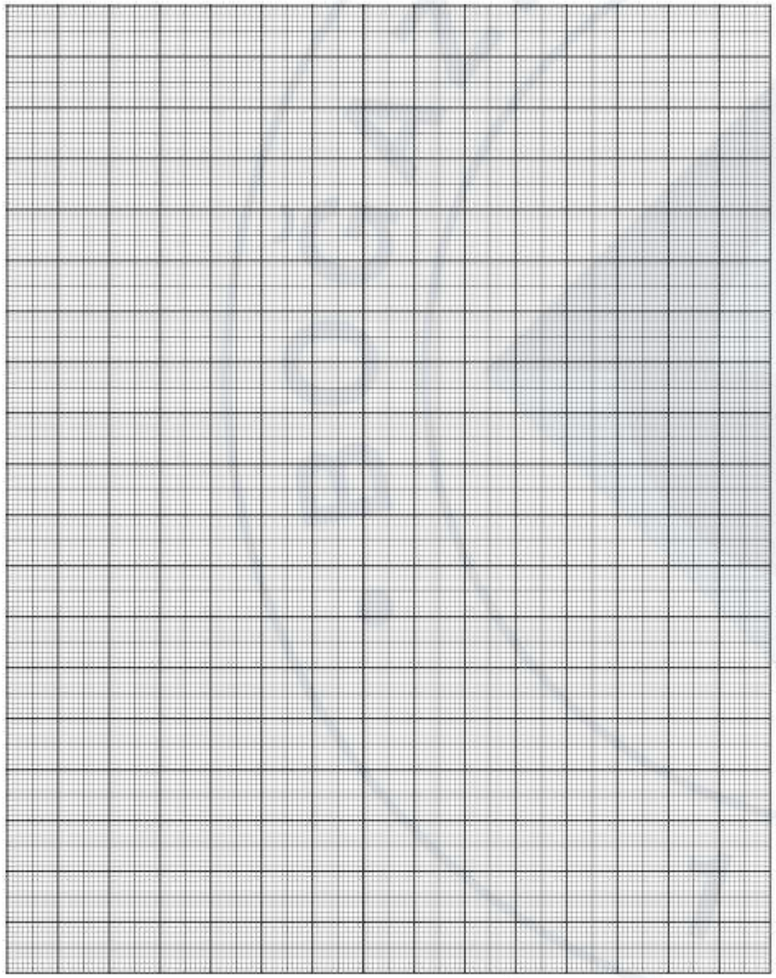
O: 20 mg (each)

ALL DIGITS SIGNIFICANT

FORCE BETWEEN CURRENT CARRYING WIRES

Draw a plot of 5 datapoints, fit a line, choose 2 points to calculate slope

Plot F_m versus I^2:



From the graph, choose two SLOPE POINTS other than data points,

SP_1 : (;)

SP_2 : (;)

FORCE BETWEEN CURRENT CARRYING WIRES

Description		Calculation (show each step)	Result
SLOPE	=	.....	.....
		.....	
$(\mu_o)_{EV}$	=	.....	.....
		.....	
% Error for μ_o	=	.....	.....
		.....	

Calculate from 2 slope points

$$\mu_o = \frac{2\pi(slope)d}{L}$$

$\mu_{oTV} = 4\pi \times 10^{-7}\ N/A^2$