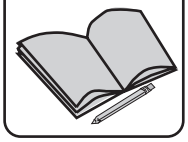
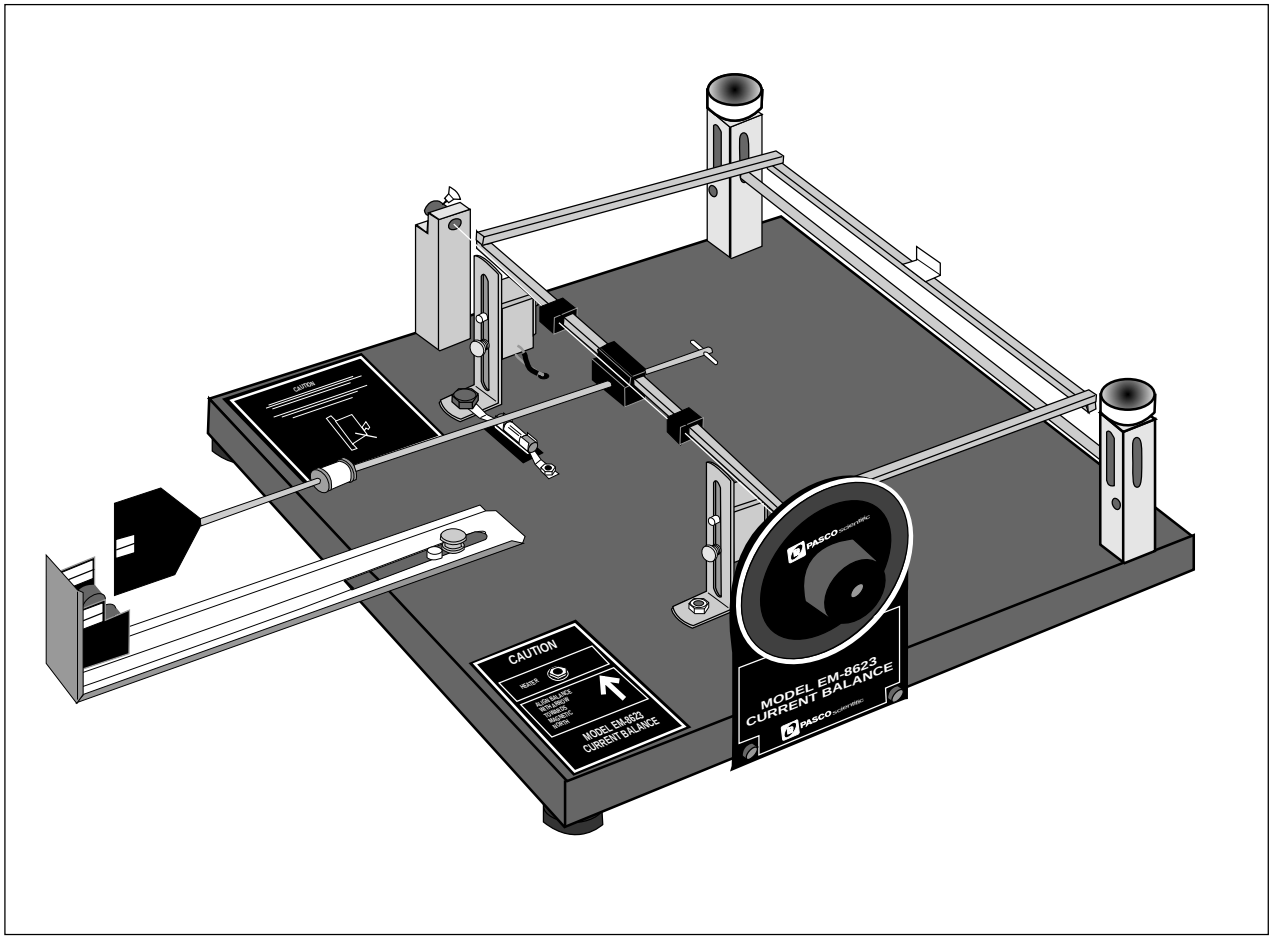
Includes
Teacher's Notes
and
Typical
Experiment Results



# *Instruction Manual and Experiment Guide for the PASCO scientific Model EM-8623*

012-04446D
10/95

# *CURRENT BALANCE*




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# Introduction

The Current Balance is used to measure the force of repulsion between identical oppositely directed currents in parallel conductors. There are three unique features in the PASCO Model EM-8623:

## 1. Torsion Wire Suspension:

This unique suspension system allows the operator to balance the force for any currents rather than using the usual standard masses which require that the current be adjusted to match the force applied. Any force can be obtained on the continuously adjustable dial that controls the amount of torque exerted by the wire.

## 2. Reliable Electrical Contact:

Nontoxic molten gallium metal is used to make the electrical contact reliably continuous and nearly frictionless. This eliminates the traditional problem of intermittent contact of knife-edge connections. The gallium pots are heated electrically because gallium melts at about 30 degrees Celsius, although gallium will often remain in the super-cooled state for long periods of time and thus will remain liquid even below the melting temperature.

## 3. Easy Adjustment of Conductor Separation:

After initially setting the parallel conductor separation, the separation can be easily and precisely changed to any other value using the 1 mm pitch-adjusting screws to raise and lower the bottom conductor.

# Theory

The force on a straight conductor in a magnetic field is given by

$$\vec{F} = L\vec{I_1} \times \vec{B_2}$$

where $I_1$ is the current in the conductor, $L$ is the length of the straight conductor that is immersed in the magnetic field, and $B_2$ is the strength of the magnetic field (see Figure 1). The magnetic field, $B_2$, is produced by the second long straight conductor and is given by

$$B_2 = \frac{\mu_0 I_2}{2\pi r}$$

where $\mu_0$ is the magnetic permeability of free space (1.26 x $10^{-6}$ *H/m*), $r$ is the center-to-center distance between the conductors, and $I_1$ is the current in the second wire. Thus, the force on one conductor due to the other parallel conductor is given by

$$F = LI_1\frac{\mu_0 I_2}{2\pi r}$$

Since the currents are the same, the magnitude of the force is

$$F = \frac{\mu_0 L I^2}{2\pi r}$$

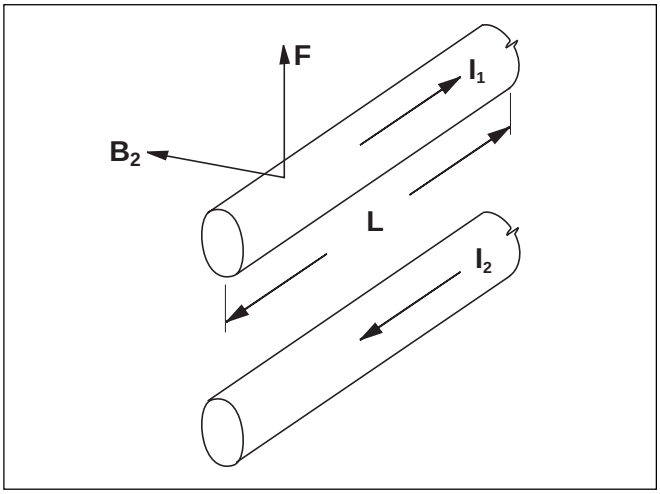



**Figure 1 Parallel Conductors**

# Equipment

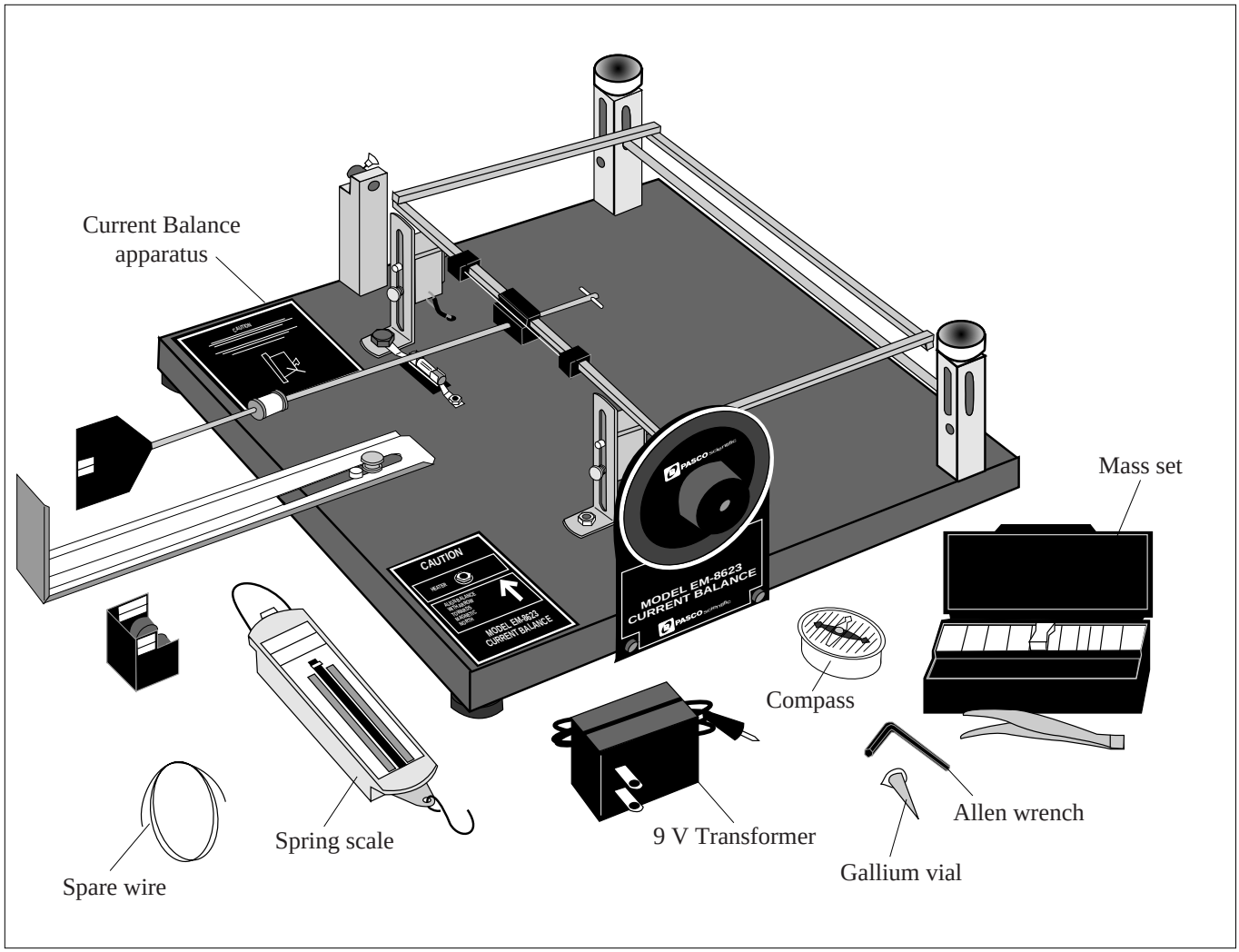
The PASCO Model EM-8623 Current Balance includes the following equipment:

- a Current Balance apparatus
- a 9 V transformer
- a 20 N spring scale
- a 500 x 1 mg mass set
- a compass
- a 0.6 ml vial of gallium
- an allen (hex) wrench, and
- extra torsion wire.

## Equipment Required But Not Supplied:

- a power supply capable of putting out at least 8 Amps (such as the PASCO Model SF-9584 Low Voltage AC/DC Power Supply)
- ammeter (10 A)

➤ **NOTE:** The mass set included contains more masses than required for completion of the experiment.




**Model EM-8623 Current Balance**

# Equipment Configuration

The Current Balance consists of a rectangular conducting frame through which current passes by entering and exiting through liquid gallium (see Figure 2). The entire frame is suspended by a 0.006-inch diameter high-strength torsion wire. The rectangular frame is counterbalanced by a long beam having a movable counter-balance mass on it and a magnetically damped vane on its end. The vane also serves as a zero-position indicator.

Directly below the long side of the rectangular frame is a parallel conductor carrying the same current in the opposite direction. The height of this conductor is adjustable to allow different separations between the conductors. Also either end can be lowered or raised independently of the other to make the two conductors parallel.

The separation adjustment screws have a 1 mm pitch and are used to adjust the center-to-center conductor separation from 3.2 mm to 15 mm in increments of 0.05 mm.

One end of the torsion support wire is fastened to a rotatable degree dial and can be rotated a total of three revolutions, one-and-a-half revolutions in either direction from the center equilibrium position. The other end of the torsion wire can be rotated only about 200 degrees and is used to make fine adjustments in the zero equilibrium position.

The torsion balance has a sensitivity of about 3 degrees per milligram of force. A change of less than 2 degrees on the degree dial is discernible. The balance has a 20 Amp fuse to protect the equipment from damage. Good measurements can be made with a current of 5 A and a maximum working current of 15 A is recommended.

The two gallium pots can be raised to the operating position or lowered and capped for storage.

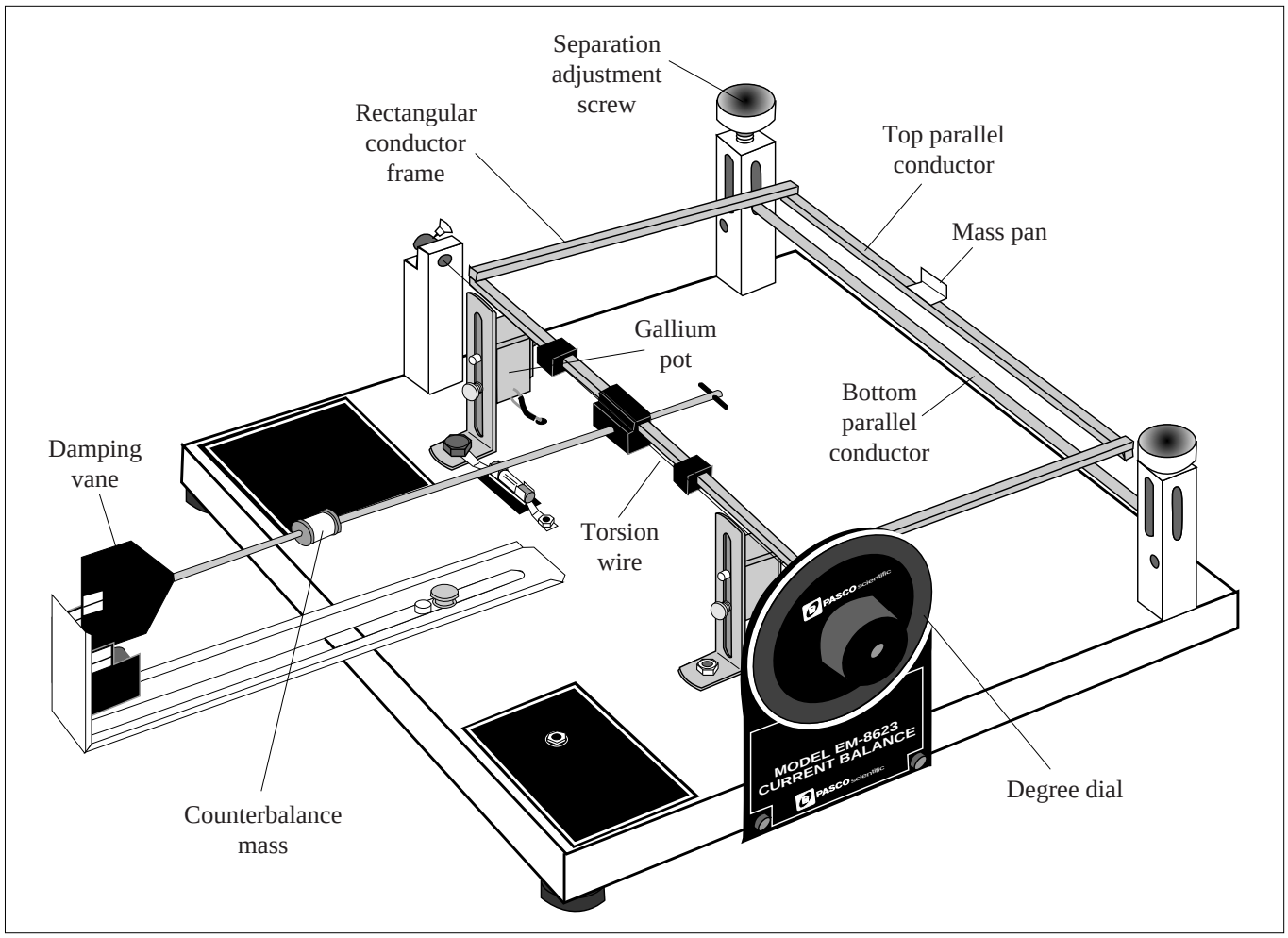



**Figure 2**

# Assembly

The following steps need only be performed once when the Current Balance is unpacked for the first time.

## Suspension Wire Adjustment

① Carefully remove the Current Balance from its shipping carton and remove any temporary balance support material.

② The balance is shipped with the covers clamped over the gallium pots (see Figure 3). To adjust the tension in the suspension wire, first lower the gallium pots, allowing the rectangular frame to rest on the gallium pot covers while the other side is supported by the bottom conductor. To lower the gallium pots, loosen the position thumb screws and push the pots down.

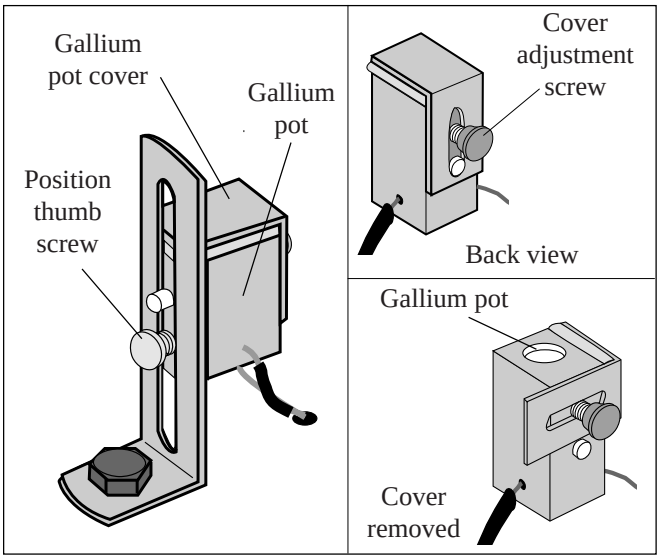



**Figure 3 Adjusting the gallium pots**

③ Check that the wire clamp is properly seated in the end support post and is free to rotate (see Figure 4). Set the degree dial to zero degrees, checking the back-side of the dial to ensure that the dial is in the center of its range (see Figure 5). Rotate the thumb screw protruding from the wire clamp to the vertical position. This wire clamp will be used later during the zeroing procedure to make fine adjustments. Make sure the wire is free to slide through the three wire clamps [two clamps are located on the rectangular conductor (Fig. 9) and the third is on the back side of the dial (Fig. 5)]. If not, use the allen (hex) wrench to loosen the set screws in the top and bottom of each of the clamps.

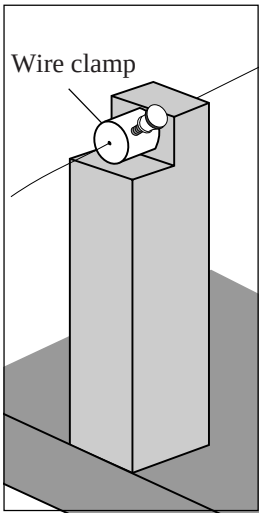



**Figure 4**

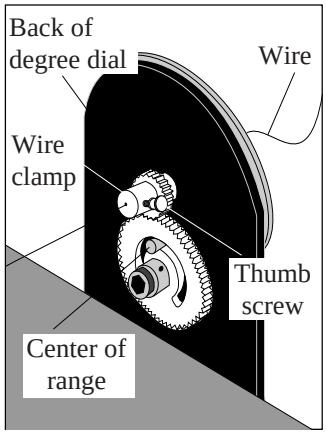



**Figure 5**

④ Connect the end of the wire that protrudes from the front of the degree dial to the spring balance (provided with apparatus) by tying a knot around the spring balance hook. Carefully pull on the spring balance and hold it at a tension of about 18 N (4 lb). It may be safest to have a second person assist in this procedure. While holding the proper tension, clamp the wire by cautiously tightening the thumb screw on the back side of the degree dial (see Figure 5).

➤ **CAUTION:** Over-tightening may cut the wire and require threading a new wire through the holes. (See Appendix for wire replacement instructions.) Also, under- tightening may allow the wire to slip.

⑤ Raise the gallium pots until they support one side of the rectangular frame. Tighten the position thumb screws on the gallium pots to hold them in place.

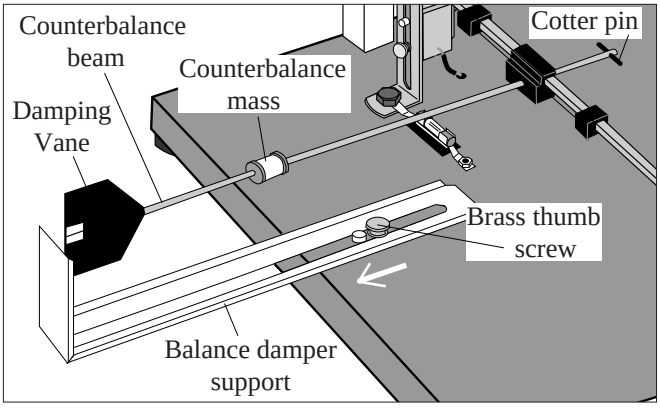



**Figure 6 Installing the Damping Vane**

## Installing the Damping Vane

① Loosen the brass thumb screw located on the Current Balance base (see Figure 6) and move the balance damper support to its outermost position so there is room to install the vane.

② Place the sliding mass on the counterbalance beam. Orient the vane so that the index mark on the vane faces the side of the balance that has the degree scale. Then carefully insert the beam through the square hole in the center black plastic block on the rectangular frame. Insert the small cotter pin in the end hole to prevent the counterbalance beam from slipping out.

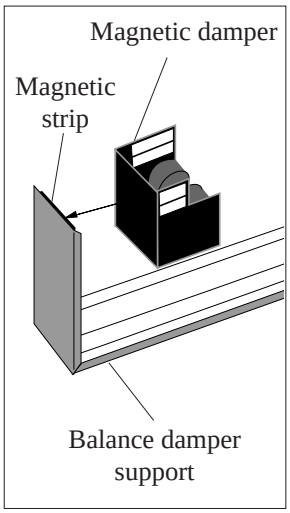



**Figure 7**

③ Place the magnetic damper on the support as shown in Figure 7. Slide the damper bracket from side to side so the vane does not touch the magnets on either side. Also slide the damper bracket in or out so that all three index lines (one on the damper vane and two on the bracket) are all visible at the same time (see Figure 8). Clamp the balance damper support in place with the brass thumb screw located on the base of the Current Balance.

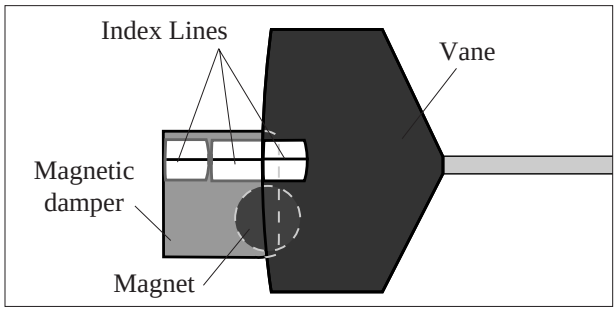



**Figure 8**

## Refilling the Gallium Pots

① Lower each gallium pot by loosening the position screw (see Figure 3) and pushing down on the pot until it reaches the bottom of its travel slot. Then retighten the screw to hold the pot in its lower position.

② Loosen the cover thumb screws and press down and away from the pots to release the covers. Then rotate the covers 90 degrees and clamp them on the side of the pot by tightening the same cover thumb screws.

③ If the gallium is solid, warm the vial of gallium to about 30 degrees Celsius. One method would be to immerse the vial in hot tap water (for 15-30 minutes). Do not use boiling water as this might melt the plastic seal.

> ➤ **CAUTION:** Gallium causes intergranular corrosion of aluminum and can damage aluminum objects.

⑤ Pour about half of the 0.6 ml vial of gallium (see Figure 1) into each pot. Do not overfill.

④ To make the electrical contact, loosen the position screws on each gallium pot and raise each pot so that the pointed contacts extend nearly to the bottom of the liquid gallium. This position is found by raising the pot until the rectangular frame begins to rise, then lowering the pot until the frame ceases to appear to be supported by the gallium. The frame is supposed to be suspended by the suspension wire rather than supported by the gallium which is only there to make the friction-free electrical contact.

⑥ If the contacts do not match the gallium pools, loosen the small allen (hex) set screws on the top of the two small black blocks (see Figure 9) that clamp the wire to the balance frame, then slide the frame as needed. Re-tighten the set screws with caution because excess tightening will cut the wire and too little tightening will allow the wire to slip.

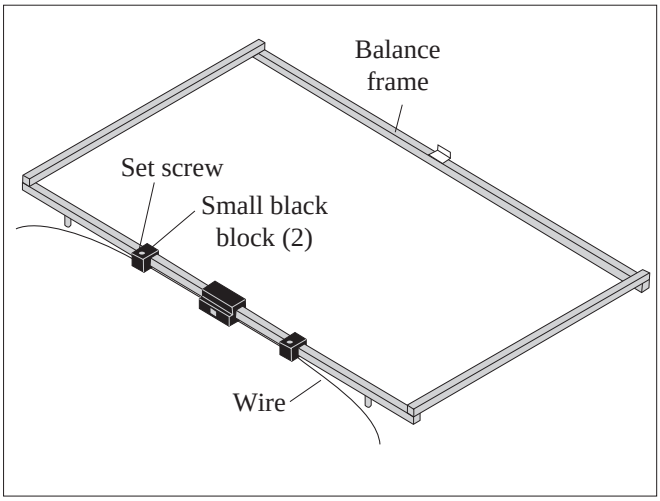



**Figure 9 Torsion Wire Suspension**

# Experiment Setup

The following steps must be performed at the beginning of each experiment:

- wiring
- balancing the rectangular frame so it is not touching the lower conductor and is supported only by the wire suspension, and
- zeroing the balance so the parallel conductors are a known distance apart which then can be used as a reference for all other desired separations.

## Wiring

① Connect the balance to a variable DC power supply as shown in Figure 10 using banana plug lead wires. Use long lead wires and keep them as far away from the rectangular frame as possible (minimum distance 25 cm). This is so the magnetic field produced by the current in the lead wires will have a negligible effect on the balance.

② Place the compass on the Current Balance base under the two parallel conductors. To eliminate the effect of the Earth's magnetic field, orient the parallel conductors in the magnetic N-S direction as indicated by the alignment of the compass needle. Remove any ferromagnetic materials from the vicinity of the Current Balance.

➤ **NOTE:** To eliminate the effects of all extraneous magnetic fields, bypass the fixed conductor and complete the current loop with a lead wire. Then orient the Current Balance until there is no deflection of the beam when a large current is turned on and off.

③ A 9V transformer is supplied with the Current Balance to power the gallium heater. To keep the gallium liquid, plug it into the jack (see Figure 10).

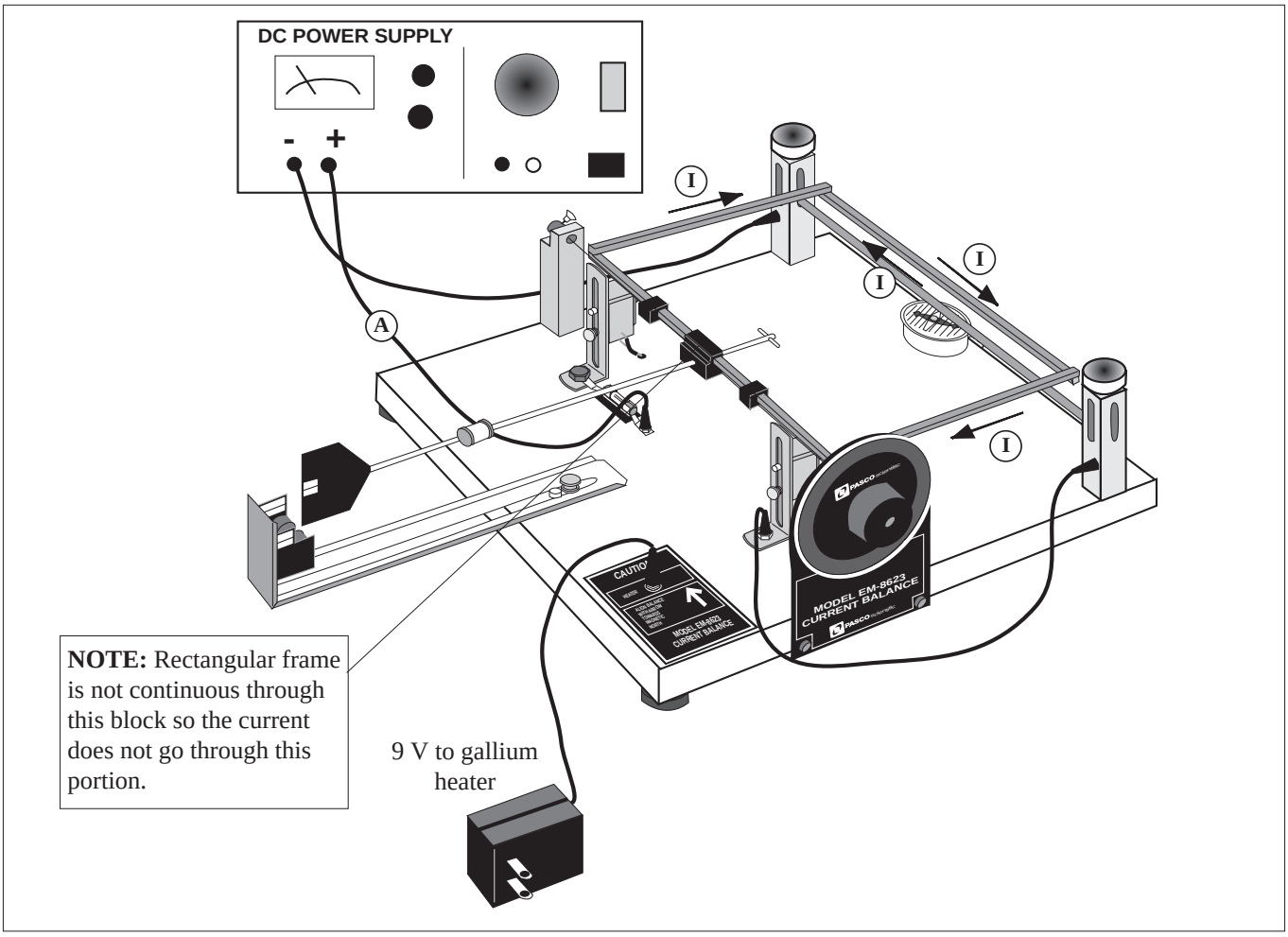



**Figure 10 Wiring Diagram**

## Balancing

① Turn the degree dial to zero degrees, making sure that the dial is in the center of its range by looking in back of the degree dial to see if the peg sticking through the large gear is halfway through the range of the gear slot (see Figure 5). Rotate the rear wire clamping thumb screw so it is vertical (see Figure 4).

② Slide the counterbalance mass (see Figure 2) until the balance beam is horizontal. Fine adjustments in balance can be made by turning the rear wire thumb screw (see Figure 4) slightly, which twists the back portion of the torsion wire. Because there is so little friction in the pivot, air currents may cause the balance to move. Avoid drafts.

③ Position the slidable damping magnets (see Figure 7) so that when the balance beam is horizontal, the index reads zero (all three index lines line up as in Figure 8).

## Zeroing

In the following steps the separation between the parallel conductors is calibrated by first making the two conductors touch each other, at which point the separation is known (the diameter of the conductor = 3.2 mm). Then the additional separation is determined by keeping track of how many revolutions are made on the 1 mm pitch screw as the bottom conductor is lowered away from the top conductor.

> ➤ **NOTE:** To lower the conductor, turn the screws clockwise.

① To make the bottom conductor parallel (level) with the top conductor, place a mass (200 mg) on the mass pan (see Figure 2) and/or twist the degree dial maximum clockwise to force the conductors together. Rotate the two separation adjustment screws alternately until there is no gap between the conductors on either end of the conductors.

> ➤ **NOTE:** Although the conductors are carefully selected to be straight, there may still be a slight bend in them. To minimize this error, insert a bent paper clip or needle in the small hole at the end of the bottom conductor and carefully rotate the conductor until the gap is eliminated or minimized.

② Remove the mass from the pan and/or return the degree dial to the center zero position. Now the bottom conductor is parallel to the top conductor and the zero position can be determined by moving the bottom conductor up so it just barely touches the top conductor. Raise the bottom conductor by rotating the separation adjustment screws counterclockwise alternately one turn at a time until the bottom conductor just barely touches the top conductor. This should keep the conductors parallel as the bottom conductor is raised. When the conductors are just touching, the balance beam should still read zero. When this is complete, the separation between the two conductors is equal to one rod diameter (3.2 mm).

> ➤ **NOTE:** If the bottom conductor cannot be raised enough by turning the separation screws, rebalance the top conductor so that it is slightly lower. This may require moving the counterbalance mass and the damping magnets.

③ Now whenever the balance is in the zero position, the center-to-center separation of the conductors is known to be 3.2 mm. Then any other desired separation can be known by keeping track of the number of rotations of the separation adjustment screws which move the bottom conductor one millimeter for each complete rotation.

There is a circular scale on the top of each screw marked off in divisions of 1/20 of a complete rotation. To keep track of the rotation of the screw, line up a corner of the square post (below the screw) with the scale. For example (see Figure 11), the number 4 is lined up with the outer corner of the square post, so one total rotation is complete when the 4 is once again lined up with the same corner and then the conductor has been raised or lowered 1 mm. Or, if it is desired to move the conductor only 0.5 mm, the screw can be rotated until the 9 is in the position formally occupied by the 4. Rotate both screws the same amount to maintain a parallel separation of the conductors.

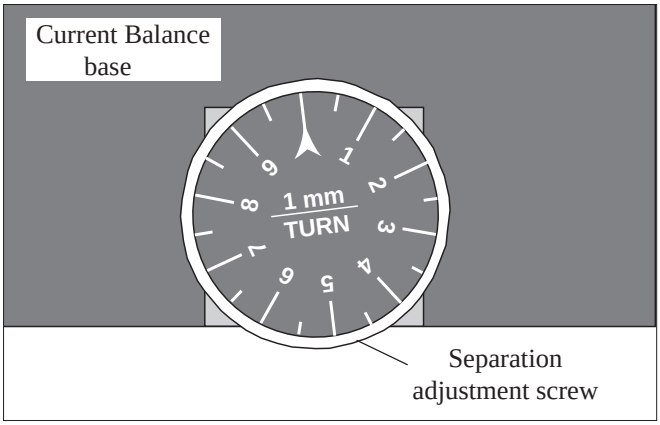



**Figure 11 Top View of Separation Adjustment Screw**

# Notes

# Experiment 1: Force vs. Current

## Introduction

The magnetic force of one current-carrying conductor on another parallel current-carrying conductor depends on the current in the conductors, the length of the conductor, and the separation between the centers of the conductors. In this experiment the separation and the length of the conductor are held constant while the current is varied to find how the force depends on the current.

## Procedure

Prepare the apparatus as described in the Experiment Setup section.

① Set the separation of the parallel conductors to 8 mm, or more, by following the instructions in the previous section titled "Zeroing".

② Apply a known downward force by placing a mass between 5 mg and 50 mg on the center of the mass pan.

③ Adjust the current until the balance returns to zero. Record the current. Now the magnetic force lifting the top conductor is equal to the weight of the known mass pushing it down.

④ Holding the separation constant, repeat steps 2 and 3, measuring the force for several different currents over as wide a range as the power supply will allow, up to a maximum current of about 15 Amps. Fill out Table 1.1.

| mass (m) | Current (I) | Force (mg) |
|---|---|---|
| | | |

**Table 1.1 Data and Calculations**

Constant Separation = (Number of Turns x 1 mm) + 3.2 mm = ____

Length of conductor = _____

## Data and Analysis

① Derive an expression for the force between two parallel current-carrying conductors in terms of the current and the separation.

② Plot F vs. $I^2$ to show that the result is a straight-line graph as predicted by the theory.

③ Calculate the slope of the best-fit line from the graph. By looking at the expression derived in Part 1, determine the theoretical expression for the slope. Using this expression for the slope, solve for the magnetic permeability constant, $m_0$ in terms of the slope. Calculate $m_0$ by plugging into this equation. It will be necessary to measure the length of the parallel conductors.

# Notes

# Experiment 2: Force vs. Separation

## Introduction

The magnetic force of one current-carrying conductor on another parallel current-carrying conductor depends on the current in the conductors, the length of the conductor, and the separation between the centers of the conductors. In this experiment the current and the length of the conductor are held constant while the separation is varied to find how the force depends on the separation.

## Procedure

Prepare the apparatus as described in the Experiment Setup section.

① Since the current will be held constant in this experiment, the force will be determined using the continuous degree dial rather than the discrete masses. To calibrate the degree dial, first make sure the balance beam is at the zero-balance position when the degree scale is at the center zero and there is no current flowing through the balance and then perform the following steps:

a. Place a 20 mg mass on the mass pan, making certain it is centered over the conductor. Turn the degree dial counterclockwise to bring the beam back to the zero-balance position and record the degrees of rotation.

b. Repeat Step (a) for 50, 100, and 150 mg loads, filling in Table 2.1.

c. Plot the force versus the angle (ß) and draw the best-fit straight line through the data points. Calculate the slope, k, to determine the force for any rotation of the degree dial using the equation $F = k\beta$.

② Choose a current in the 5 to 10 Amp range and keep it constant for all measurements.

③ Measure the force required to return the balance to zero for several separations from 4 to 15 mm, filling in Table 2.2. The force is calculated from the angle reading on the degree dial and the separation is determined by knowing how many rotations down from the minimum separation the conductor has been lowered.

**Table 2.1 Calibration Data**

| mass (m) | Angle (ß) | Force (mg) |
|---|---|---|
| | | |

Table 2.2 Data and Calculations

Constant Current = _____

Length of conductor = _____

Degree Scale Calibration (k) = _____

| Separation Number of turns (N) | Angle (ß) | Force (kß) | Separation (N x 1 mm + 3.1 mm) |
|---|---|---|---|
| | | | |

## Data and Analysis

① Derive an expression for the force between two parallel current-carrying conductors in terms of the current and the separation.

② Plot F vs. 1/r to show that the result is a straight-line graph as predicted by the theory.

③ Calculate the slope of the best-fit line from the graph. By looking at the expression derived in Part 1, determine the theoretical expression for the slope. Using this expression for the slope, solve for the magnetic permeability constant, $\mu_o$, in terms of the slope. Calculate $\mu_o$ by plugging into this equation. It will be necessary to measure the length of the parallel conductors.

# Experiment 3: Horizontal Component of the Earth's Magnetic Field

## Introduction

In this experiment no current flows through the bottom conductor of the Current Balance so the only magnetic field lifting the top conductor is the Earth's horizontal field.

## Procedure

Prepare the apparatus as described in the Experiment Setup section.

① Orient the balance so that the parallel conductors are perpendicular to the N-S magnetic field (i.e., aligned with East-West).

② Unplug the leads to the bottom conductor and connect them directly together if they are long enough or use a third lead wire if necessary. Make sure these wires are kept away from the balance.

③ Now that the lower conductor has been bypassed, only the Earth's magnetic field will act on the current flowing in the upper conductor. Use as large a current as possible, up to 15 Amps, for best results. Measure the force required to balance the apparatus.

④ Measure the length of the top conductor that is perpendicular to the Earth's magnetic field.

## Data and Analysis

Calculate the horizontal component of the magnetic field using the equation $B = \frac{F}{IL}$.

## Questions

① Why does this experiment only measure the horizontal component of the Earth's magnetic field? How is the effect of the vertical component eliminated?

② In the other experiments using the Current Balance, why doesn't the Earth's magnetic field cause an error?

③ Where on the Earth would the Current Balance indicate the horizontal component of the Earth's magnetic field is zero?

# Appendix

## Wire Replacement

In the event that the wire is broken, extra wire and an allen (hex) wrench are provided to facilitate the repair. While performing the following steps, handle the balance frame carefully to avoid bending the conductors and do not over-tighten the set screws that hold the wire because this will cut the wire.

① Raise the gallium pots so they support one side of the rectangular frame while the other side of the frame is resting on the lower fixed conductor.

② Loosen the two thumb screws and the six small set screws (located in the black blocks and at the ends of the wire) about two turns each and remove the old wire (see Figure 9).

③ Cut a piece of wire about 50-55 cm long.

④ First thread it through the two black plastic blocks on the rectangular frame. A little patience may be required. You may be able to straighten the first couple of centimeters of the wire by pulling it between your thumb-nail and fore-finger, with the thumb-nail pressing against the outside of the curve. This may require several tries but it will greatly simplify threading the wire.

⑤ Carefully tighten the bottom set screw on each of the black blocks until there is a slight drag on the wire. Excess tightening may damage the wire.

⑥ Thread the end of the wire furthest from the degree dial through the rear support and then through the plastic wire clamp. The wire should extend through the plastic about 2 cm. Tighten the allen (hex) set screw on the plastic wire clamp until there is a slight drag on the wire.

⑦ Tighten the thumb screw on the plastic wire clamp so the wire is held in place but do not over-tighten.

⑧ Thread the other end of the wire through the wire clamp on the degree dial (see Figure 5). If the wire catches on the threads in the shaft, inserting a small smooth tube into the shaft may help (a plastic coffee-stirrer tube works well). Tighten the allen (hex) set screw on the degree dial until there is a slight drag on the wire

⑨ A spring scale is provided to fasten onto the end of the wire. After attaching the scale, pull on the scale so it reads about 18 N (4 lbs) tension. While holding the tension, tighten the thumb screw on the wire clamp on the back-side of the degree dial. The wire is now secured on both ends.

⑩ Slide the balance beam as needed to put the contact posts near the center of the gallium pots and gently tighten the two remaining allen (hex) set screws located in the tops of the two black plastic blocks (see Figure 9). This locks the rectangular frame into place and completes the replacement of the wire.

## Storage

To store the Current Balance, put the covers back on the gallium pots. Leave the gallium in the pots.

① Lower the gallium pots by loosening the position thumb screws (see Figure 3) and pushing the pot down.

② Loosen the cover thumb screw.

③ Rotate the cover 90 degrees, push the cover down and toward the pot, and tighten the cover thumb screw.

If storage space is limited, remove the damping vane by following the instructions in Part II of the Assembly section in reverse.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44-R1387

# MATERIAL SAFETY DATA SHEET

[redacted]

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

## SECTION I

| | |
|---|---|
| MANUFACTURER'S NAME: ATLANTIC METALS & ALLOYS, INC. | EMERGENCY TELEPHONE NO.: (203) 359-8881 |
| ADDRESS (Number, Street, City, State, and ZIP Code): P.O. BOX 386 OLD GREENWICH, CT 06870 | |
| CHEMICAL NAME AND SYNONYMS: GALLIUM METAL | TRADE NAME AND SYNONYMS: NONE |
| CHEMICAL FAMILY: ELEMENT | FORMULA: GA |

## SECTION II - HAZARDOUS INGREDIENTS

| PAINTS, PRESERVATIVES, & SOLVENTS | % | TLV (Units) | ALLOYS AND METALLIC COATINGS | % | TLV (Units) |
|---|---|---|---|---|---|
| PIGMENTS | N/A | | BASE METAL | 100 | not known |
| CATALYST | N/A | | ALLOYS | N/A | |
| VEHICLE | N/A | | METALLIC COATINGS | N/A | |
| SOLVENTS | N/A | | FILLER METAL PLUS COATING OR CORE FLUX | N/A | |
| ADDITIVES | N/A | | OTHERS | N/A | |
| OTHERS | N/A | | | | |

| HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES | % | TLV (Units) |
|---|---|---|
| | | |
| None Known | | |
| | | |
| | | |

## SECTION III - PHYSICAL DATA

| | | | |
|---|---|---|---|
| BOILING POINT (°F.) | 4357°F | SPECIFIC GRAVITY ($H_2O$=1) | 5.90 |
| VAPOR PRESSURE (mm Hg.) | | PERCENT, VOLATILE BY VOLUME (%) | Nil |
| VAPOR DENSITY (AIR=1) | N/A | EVAPORATION RATE (_____ =1) | Nil |
| SOLUBILITY IN WATER | Nil | Melting Point | 85°F |
| APPEARANCE AND ODOR | Bright Silvery; Odorless | | |

## SECTION IV - FIRE AND EXPLOSION HAZARD DATA

| | | | | |
|---|---|---|---|---|
| FLASH POINT (Method used) | None | FLAMMABLE LIMITS N/A | Lel | Uel |
| EXTINGUISHING MEDIA | Sand | | | |
| SPECIAL FIRE FIGHTING PROCEDURES | None. Gallium Metal does not have an explosion or flame point in solid or molten form. | | | |
| NUSUAL FIRE AND EXPLOSION HAZARDS | None Known | | | |

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## SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE: Not Known

EFFECTS OF OVEREXPOSURE: May cause Dermatitis and depression of bone marrow function.

EMERGENCY AND FIRST AID PROCEDURES: Remove subject from source of contamination; seek immediate medical aid.

## SECTION VI - REACTIVITY DATA

| | | | |
|---|---|---|---|
| STABILITY | UNSTABLE | | CONDITIONS TO AVOID |
| | STABLE | X | |

INCOMPATABILITY *(Materials to avoid)*: No known incompatable materials.

HAZARDOUS DECOMPOSITION PRODUCTS: When very highly heated will emit fumes that may be toxic. May react at high temperatures with oxidizing materials.

| | | | |
|---|---|---|---|
| HAZARDOUS POLYMERIZATION | MAY OCCUR | | CONDITIONS TO AVOID |
| | WILL NOT OCCUR | X | N/A |

## SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Sweep up and pack in heavy gauge polyethylene bag. Pack bag into sturdy outer container.

WASTE DISPOSAL METHOD: Return to supplier

## SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION *(Specify type)*: Provide adequate ventilation to minimize air contamination.

| | | |
|---|---|---|
| VENTILATION | LOCAL EXHAUST: Fume Removal | SPECIAL |
| | MECHANICAL *(General)*: N/A | OTHER |

PROTECTIVE GLOVES: Rubber or plastic gloves.

EYE PROTECTION: Approved safety glasses

OTHER PROTECTIVE EQUIPMENT:

## SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Liquid Gallium may cause intermetallic corrosion of other metals. Do not allow Liquid Ga to contact structural members.

OTHER PRECAUTIONS: Store Gallium in a refrigerator. Maintain good housekeeping procedures: wash thoroughly before smoking or eating, collect all Gallium spills. Wear protective gloves.

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PASCO® scientific

[redacted]

# GALLIUM

*Dangerous Properties of Industrial Materials.*

*Fourth Edition, N. Irving Sax*
*Van Nostrand Reinhold Company, Publisher*

## Gallium

### General Information

A beautiful, lustrous, silvery liquid metal or gray solid.
Formula: Ga
At wt:69.72, mp: 29.78°C, bp: 2403°C, d(solid): 5.904 at 29.6°C,
d (liquid): 6.095 at 29.8°C.

### Hazard Analysis

**Toxicity:** It has a metallic taste, causes dermatitis and depression of bone marrow function. See Ga compounds.

## Gallium Compounds

### Hazard Analysis

Toxic Hazard Rating:
- Acute Local: U
- Acute Systemic: Ingestion 1.
- Chronic Local: U
- Chronic Systemic: Ingestion 1.

**Toxicology:** Preliminary investigations show a low order of toxicity. Work has been done with the oxide, tartrate, benzoate, and anthranilate, which were used by some investigators in the treatment of experimental syphilis. Amounts up to 15 mg/kg of body weight were injected intravenously and were tolerated without harm by laboratory animals. Larger doses produce hemorrhagic nephritis. In the case of gallium lactate, work done at the Naval Medical Research Institute showed that intravenous injections of about 40 mg of gallium per kg of body weight in rats or rabbits was lethal. Metallic gallium as well as the nitrate produced no skin injury and subcutaneous injection of relatively large amounts could be tolerated both by rabbits and rats without evidence of injury. It has, however, been demonstrated that gallium remains in the tissues for long periods of time following intramuscular injection of soluble gallium salts. Tissue distribution experiments indicate that it behaves like bismuth and mercury in that one respect.

[redacted]

*Toxic Hazard Rating Code*

*0 None:* (a) *No harm under any conditions.*
(b) *Harmful only under unusual conditions or overwhelming dosage.*

*1 Slight:* *Causes readily reversible changes which disappear after end of exposure.*

*2 Moderate:* *May involve both irreversible and reversable changes not severe enough to cause death or permanent injury.*

*3 High:* *May cause death or permanent injury after very short exposure to small quantities.*

*U Unknown:* *No information on humans considered valid by authors.*

# Teacher's Guide

## Experiment 1: Force vs. Current

### Notes on Procedure

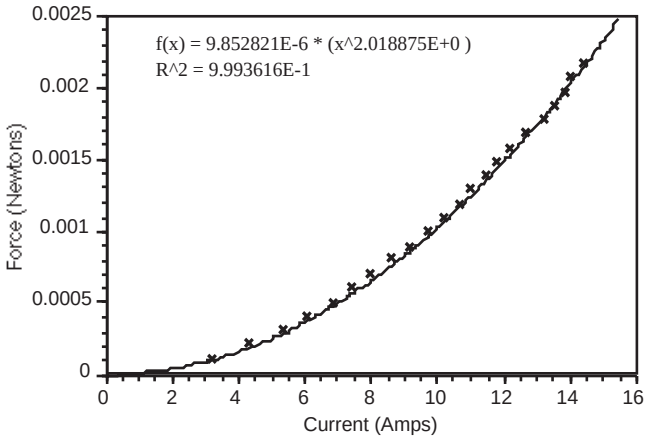
① For best results in calculating the value of $\mu_o$, keep the distance between the conductors as large as possible.

② The masses used will depend on the separation and the current. Using larger masses and currents does not necessarily give better results: our best results were obtained with the smallest masses.

③ This is the most critical measurement in the experiment. Make sure that the balance is exactly zeroed, and measure the current carefully.

④ Using larger currents will not necessarily give better results. Our best results were with currents ranging from 3 to 8 amps.

### Notes on Data and Analysis



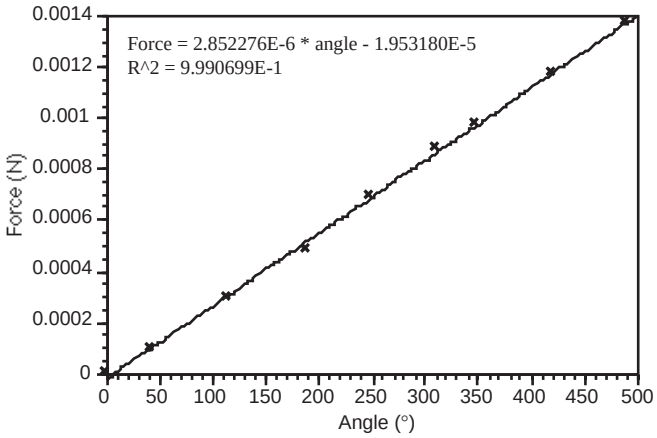

① $F = \frac{\mu_o L I^2}{2\pi r}$

② Alternately, one can plot F vs. I then use power regression or a log-log plot to show the squared dependence of F on I. The power regression method will also give a multiplicative constant which corresponds to the slope described in step 3. (see graph above)

③ $\mu_o = \frac{2\pi r\,(slope)}{L}$

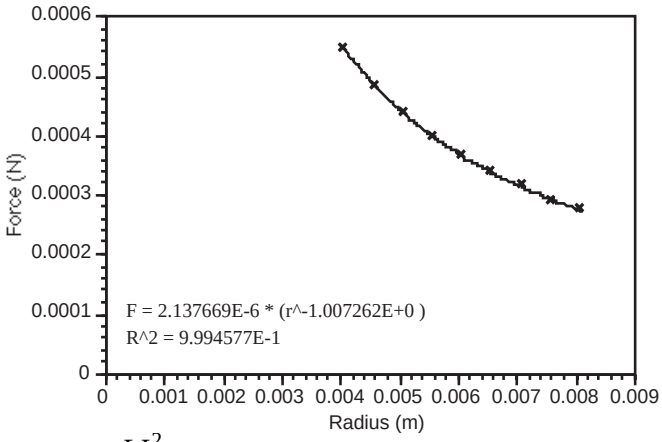
# Experiment 2: Force vs. Separation

## Notes on Procedure




➤ **NOTE:** The torsion constant (slope) will vary slightly with wire tension. You will have to recalculate the slope each time the apparatus is set up.

## Notes on Data and Analysis




① $F = \dfrac{\mu_o L I^2}{2\pi r}$

② Alternately, one can plot force vs. radius then use power regression or a log-log plot to verify the inverse dependence of F on R. The power regression method will also give a multiplicative constant which corresponds to the slope described in step 3. (See graph above)

③ $\mu_o = \dfrac{2\pi\,(slope)}{I^2 L}$

Values of $\mu_o$ determined by this method are generally less accurate than values determined by the method of experiment 1, with errors in the range of 10%.

# Experiment 3: Horizontal Component of the Earth's Magnetic Field

## Notes on Procedure

③ Use as large a current as possible, but for as brief a time as possible. Note that standard test leads become noticeably warm with a current of 15A, so be careful.

## Notes on Questions

① The vertical component of the earth's field tends to produce a horizontal force on the apparatus. The balance is constructed to measure vertical displacement only, not horizontal displacement.

② In other experiments, the parallel conductors are parallel to the horizontal component of the earth's field. The side rails of the balance are of course perpendicular to this field, but since the current is moving east in one rail and west in the other, there is no net effect.

③ The horizontal components of the earth's field are zero at the magnetic north and south poles.

# Notes

# Technical Support

## Feed-Back

If you have any comments about this product or this manual please let us know. If you have any suggestions on alternate experiments or find a problem in the manual please tell us. PASCO appreciates any customer feed-back. Your input helps us evaluate and improve our product.

## To Reach PASCO

For Technical Support call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

email: techsupp@PASCO.com

Tech support fax: (916) 786-3292

## Contacting Technical Support

Before you call the PASCO Technical Support staff it would be helpful to prepare the following information:

- If your problem is with the PASCO apparatus, note:

  Title and Model number (usually listed on the label).

  Approximate age of apparatus.

  A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.)

  If possible, have the apparatus within reach when calling. This makes descriptions of individual parts much easier.

- If your problem relates to the instruction manual, note:

  Part number and Revision (listed by month and year on the front cover).

  Have the manual at hand to discuss your questions.