012-15871A

Hall Effect Experiment

SE-7260

Instruction Manual

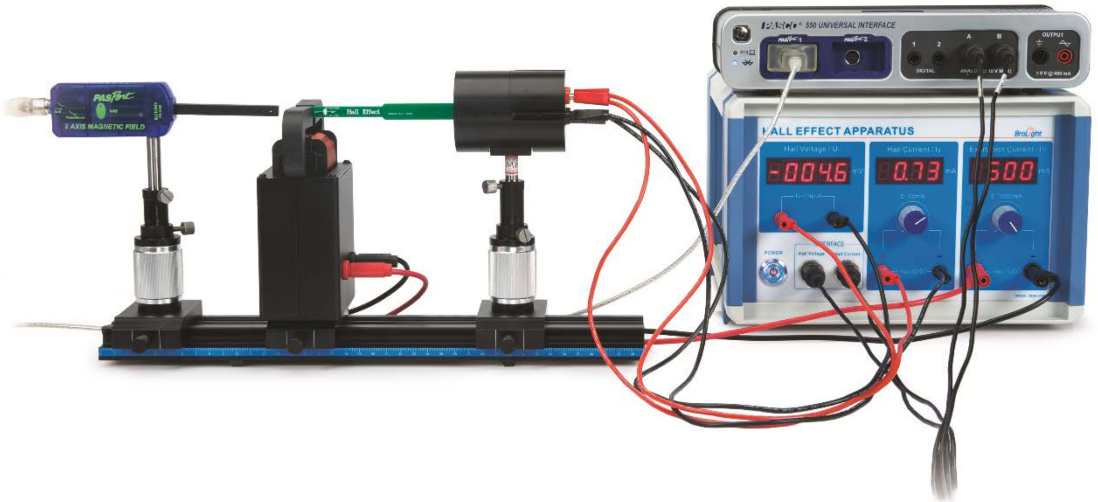
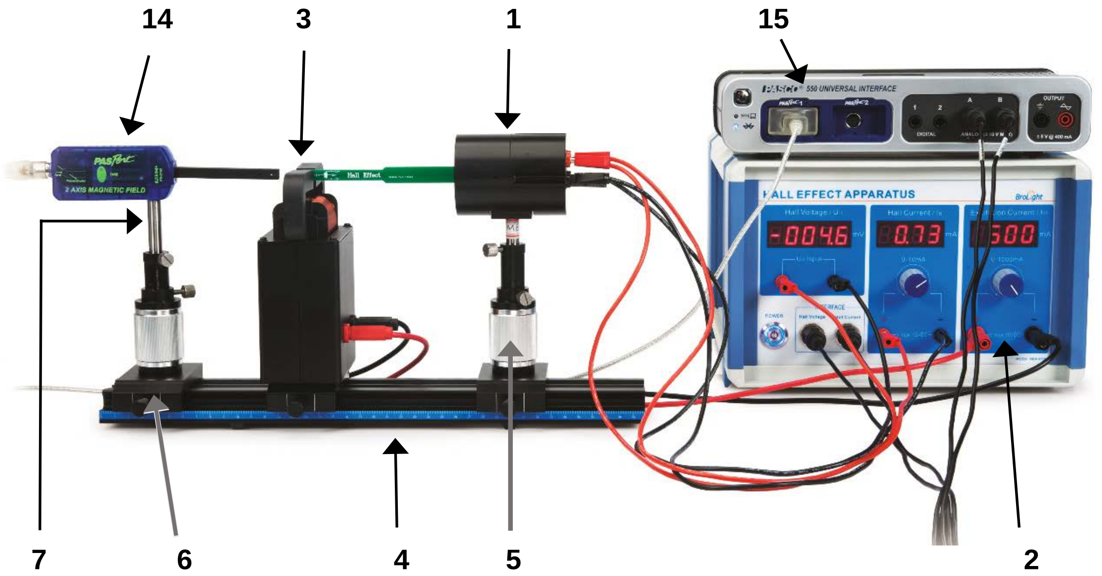


Table of Contents

Hall Effect Experiment
SE-7260

Equipment List



No.	Material list	Quantity
1	Hall probe, n-semiconductor (n-GaAs)	1
2	Hall Effect Apparatus	1
3	U-Core Electromagnetic Coil, 1A, 1000 turns	1
4	Track, 400 mm	1
5	Adjustable Post Holder, 25 mm	2
6	Optical Carrier, 50 mm	2
7	Post, 90 mm	2
8	Power Cord	1
9	Connecting Cable, red, 1 m	1
10	Connecting Cable, black, 1 m	1
11	Connecting Cable, banana plug, red, 0.8 m	2
12	Connecting Cable, banana plug, black, 0.8 m	2
13	User's Manual	1

Required but not included in SE-7260

14	2-Axis Magnetic Field Sensor	PS-2162	1
15	PASCO 850 or 550 Universal Interface	UI-5000/UI-5001	1
	PASCO Capstone software	See www.pasco.com	1

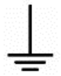
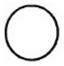
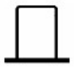
Safety Information

⚠ **Warning:**

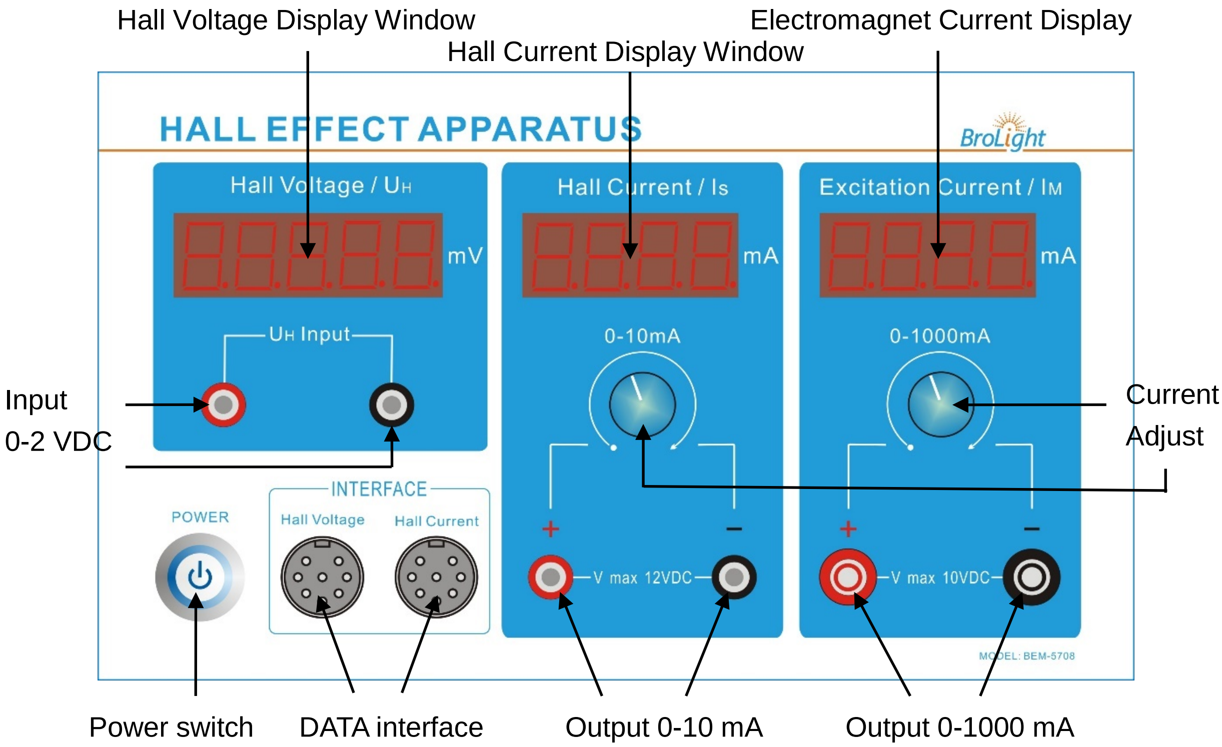
To avoid possible electric shock or personal injury, follow these guidelines:

- Do not clean the equipment with a wet cloth.
- Before use, verify that the apparatus is not damaged.
- Do not defeat power cord safety ground feature.
- Plug in to a grounded (earthed) outlet.
- Do not use product in any manner not specified by the manufacturer.
- Do not install substitute parts or perform any unauthorized modification to the product.
- Line and Current Protection Fuses: For continued protection against fire, replace the line fuse and the current-protection fuse only with fuses of the specified type and rating.
- Main Power and Test Input Disconnect: Unplug instrument from wall outlet, remove power cord, and remove all probes from all terminals before servicing. Only qualified, service-trained personnel should remove the cover from the instrument.
- Do not use the equipment if it is damaged. Before you use the equipment, inspect the case. Pay particular attention to the insulation surrounding the connectors.
- Do not use the equipment if it operates abnormally. Protection may be impaired. When in doubt, have the equipment serviced.
- Do not operate the equipment where explosive gas, vapor, or dust is present. Do not use it in wet conditions.
- Do not apply more than the rated voltage, as marked on the apparatus, between terminals or between any terminal and earth ground.
- When servicing the equipment, use only specified replacement parts.
- Use caution when working with voltage above 30V AC rms, 42V peak, or 60V DC. Such voltages pose a shock hazard.
- To avoid electric shock, do not touch any bare conductor with hand or skin.
- Adhere to local and national safety codes. Individual protective equipment must be used to prevent shock and arc blast injury where hazardous live conductors are exposed.
- Remaining endangerment: When an input terminal is connected to dangerous live potential it is to be noted that this potential at all other terminals can occur!

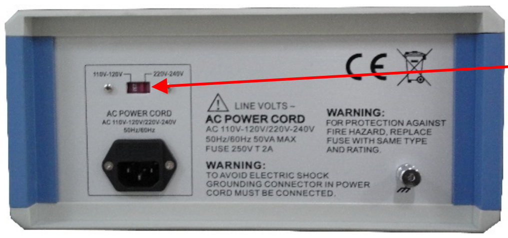
Electrical Symbols

	Alternating Current
	Direct Current
	Caution, risk of danger, refer to the operating manual before use.
	Caution, possibility of electric shock
	Earth (ground) Terminal
	Protective Conductor Terminal
	Chassis Ground
	Conforms to European Union directives.
	WEEE, Waste Electric and Electronic Equipment
	Fuse
	On (Power)
	Off (Power)
	In position of a bi-stable push control
	Out position of a bi-stable push control

Hall Effect Apparatus



- Power switch: Turns the power to the instrument ON or OFF.
- Current Adjust: Adjust the current supplied to the electromagnet.
- Input: Connected to the Hall Probe to read the Hall voltage (0 to 2 V DC)
- Hall Current Output: Adjust the current flowing through the semi-conductor.
- Excitation Current Output: Adjust the current through the electromagnet to change the magnetic field strength.
- Display Window: Displays the current or voltage value.
- Interface: Connect to a PASCO 550 or 850 Universal Interface to collect data.



110-120V~/220-240~ Please make sure you select the right setting according to your AC voltage level.

Note: Before connecting any cords or cables, be sure that both switches on the Power Supply are in the OFF position.

Note: The input power connector can be operated at 115VAC or 230VAC. Please select the right setting according to your AC voltage level.

Maintenance

Fuse Replacement

Open cover to remove fuse.

WARNING:

To reduce the risk of electric shock or damage to the instrument, turn the power switch off and disconnect the power cord before replacing a fuse.

1. Disconnect the power cord from the instrument.
2. Open the fuse cover and remove the fuse.
3. Replace the fuse(s). Use the same type fuses.
4. Reconnect the power cord and turn on the instrument.
5. If the problem persists, contact PASCO for service.

Note: Replace the burned fuses with new fuses of the same type, or buy them from the manufacturer.

Experiment

Using a PASCO 550 or 850 Universal Interface and Capstone Software

Introduction

The Hall Effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. It was discovered by Edwin Hall (1855-1938) in 1879. The Hall effect was discovered in 1879 by Edwin Herbert Hall while he was working on his doctoral degree (research on current-carrying metal forced in magnetic field) at Johns Hopkins University in Baltimore, Maryland. His measurements of the tiny effect produced in the apparatus he used were an experimental tour de force, accomplished 18 years before the electron was discovered.

Since the magnitude of the Hall voltage depends on the charge density, the voltage is grater in a semi-conductor than in a pure metal conductor. This version of the experiment uses and n-doped germanium semi-conductor. The magnitude of the Hall voltage is also dependent on the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.

Theory

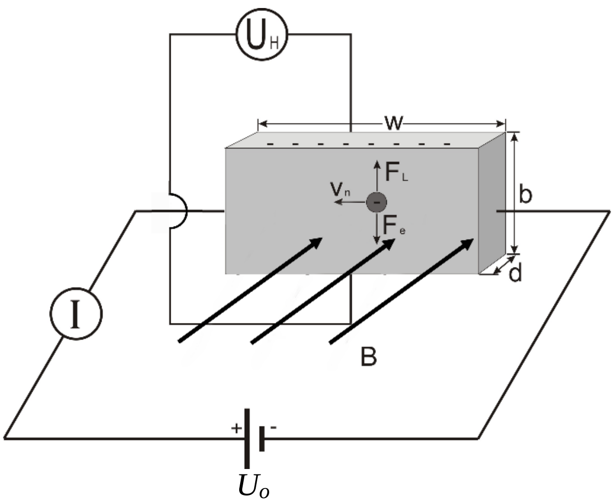


Fig. 1a

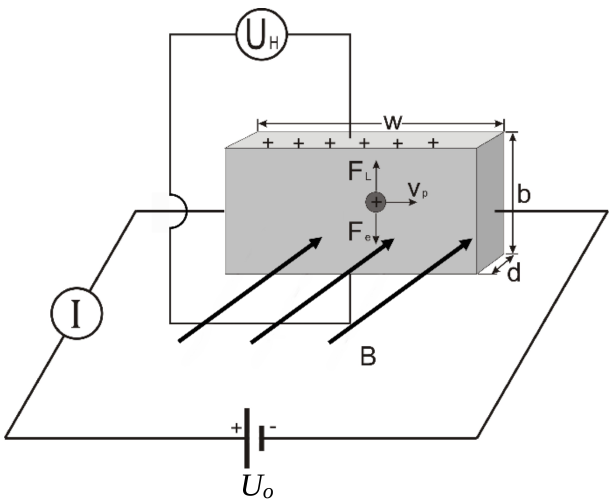


Fig. 1b

Fig. 1: Hall Effect in a rectangular sample of thickness d, height b and length w. At equilibrium conditions the Lorentz force F_L acting on the moving charge carriers is balanced by the electrical force F_e which is due to the electric field of the Hall Effect.

The Hall Effect is an important experimental method of investigation to determine the microscopic parameters of the charge transport in metals or doped semiconductors.

To investigate the Hall Effect in this experiment a rectangular strip of n-doped semiconductor is placed in a uniform magnetic field B as shown in Fig. 1. When a current I flows through the rectangular shaped sample an electrical voltage (Hall voltage) is set up perpendicular to the magnetic field B and the current I due to the Hall Effect.

The Hall Effect experiment determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction (Fig. 1a) or as a positive charge moving in the opposite direction (Fig. 1b). To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of flow of current. The moving charge experiences a Lorentz force:

$$\overrightarrow{F_L} = q\vec{v} \times \vec{B}$$

causing a charge build-up on one side of the semiconductor (creating an electric field), which in turn leads to a Coulomb force

$$\overrightarrow{F_e} = q\vec{E}.$$

The direction of the electric field will depend on the sign of the charge carriers and the polarity of the Hall voltage across the semiconductor reveals this sign. At equilibrium, the Lorentz force equals the Coulomb force:

$$qvB = qE \qquad (1)$$

where *q* is the magnitude of the charge of the charge carrier, *v* is the drift speed of the charge carrier, *B* is the magnitude of the magnetic field, and *E* is the magnitude of the induced electric field.

The drift speed of the charge carrier is related to the current flowing through the semiconductor.

$$I = \frac{charge}{\Delta t} = \frac{(volume\ charge\ density)(volume)e}{\Delta t} = \frac{n(bdw)e}{\Delta t} = nbdve$$

since the drift speed is w/Δt and n is the charge per unit volume. Therefore, the drift speed is given by

$$v = \frac{I}{nbde} \qquad (2)$$

Substituting for the drift speed into equation (1) gives

$$\frac{IB}{ndbe} = E \qquad (3)$$

But *E* is related to the Hall voltage, U_H,

$$E = \frac{U_H}{b} \qquad (4)$$

Substituting for *E* into equation (3) gives

$$U_H = \frac{IB}{nde} \qquad (5)$$

$$U_H = \frac{R_H IB}{d} \qquad (6)$$

Where R_H is the Hall coefficient (*=1/ne*) which depends on the material and the temperature. At equilibrium conditions (Fig. 1) for weak magnetic fields, the Hall coefficient R_H can be expressed as function of the charge density (carrier concentration) and the mobility of electrons and holes:

$$R_H = \frac{p\mu_p^2 - n\mu_n^2}{e(p\mu_p + n\mu_n)^2} \qquad (7)$$

$e = 1.602 \cdot 10^{-19}\ C$ (elementary charge)

n: density of electrons

p: density of holes

μ_p: mobility of holes

μ_n: mobility of electrons

The mobility is a measure of the interaction between the charge carriers and the crystal lattice. The mobility is defined as:

$$\mu_n = \frac{v}{E_o} \qquad (8)$$

v: drift velocity.

E_o: electric field due to the voltage drop.

The electric field E_o can be determined by the voltage drop U_o and the length *w* of the n-semiconductor strip:

$$E_o = \frac{U_o}{w} \qquad (9)$$

The drift velocity *v* can be determined from the equilibrium condition, where the Lorentz force compensates the electrical force which is due to the Hall field (Fig. 1). From Equation (1):

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

Which can be expressed using the relation $E_H = U_H / b$ as:

$$v = \frac{U_H}{bB} \qquad (10)$$

Substituting equation (9) and (10) in equation (8), the mobility μ_n of holes can be estimated at room temperatures as follows:

$$\mu_n = \frac{U_H w}{b B U_o} \qquad (11)$$

Equipment

Qty	Part #	Item
1	SE-7260	Hall Effect Apparatus
1	UI-5000 or UI-5001	850 or 550 Universal Interface
1	UI-5401	PASCO Capstone Software
2	UI-5218	8-pin DIN Extension Cable
1	PS-2162	2-Axis Magnetic Field Sensor with PASPORT Extension Cable

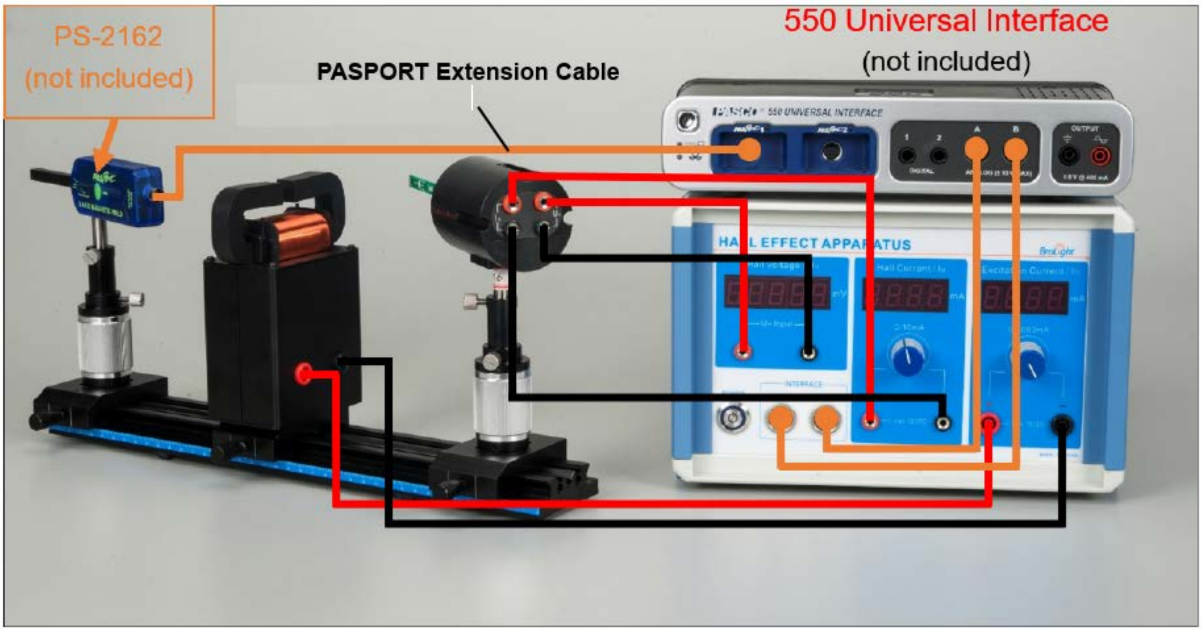
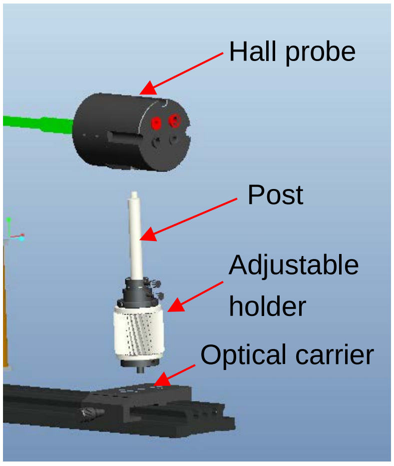


Fig. 2: Electrical setup of the Hall Effect experiment, schematically.

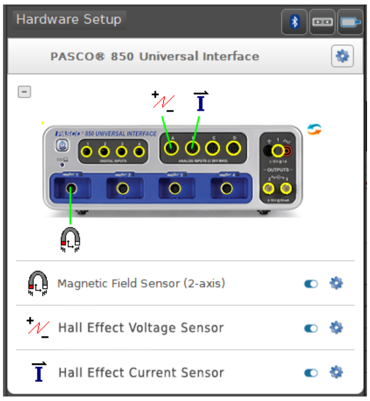
Hardware Setup

Note: Before connecting any cords or cables, be sure that all power switches on the interface and power supplies are in the OFF position and all current controls are turned fully counterclockwise.



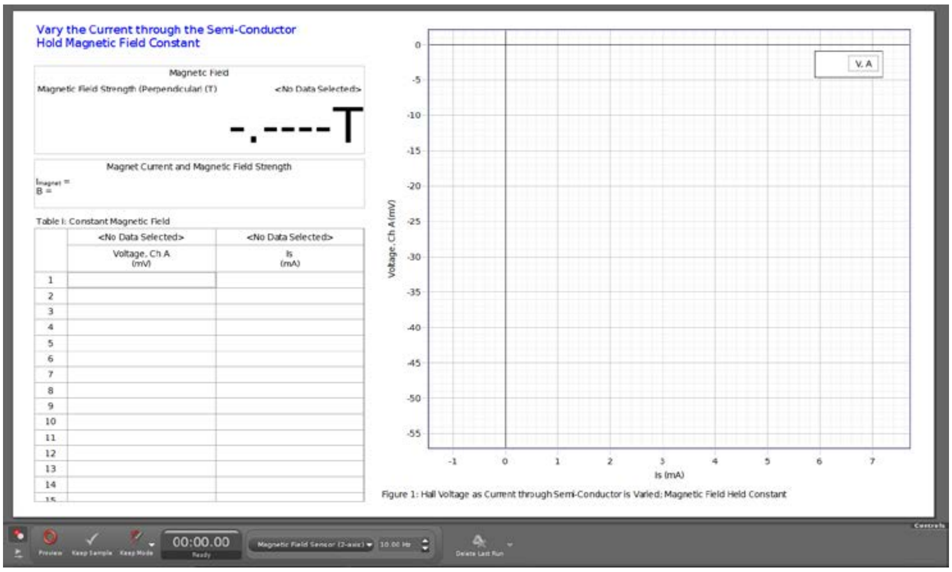
1. Screw the steel rod into the Hall probe unit. Fix the adjustable holder on the optical carrier. Put the post into the adjustable holder.
2. Connect the electromagnet to the banana jacks labeled Excitation Current (I_m) on the Hall Effect Apparatus.
3. On the back of the Hall Effect Probe, connect the ports labeled I_s to the banana jacks labeled Hall Current (I_s) on the Hall Effect Apparatus.
4. On the back of the Hall Effect Probe, connect the ports labeled U_H to the banana jacks labeled Hall Voltage (U_H) on the Hall Effect Apparatus.

5. Connect the steel rod to the 2-Axis Magnetic Field Sensor and install it on the optical carrier on the track.
6. Connect a PASPORT Extension Cable (PS-2500) between the 2-Axis Magnetic Field Sensor (PS-2162) and a PASPORT port on the 550 or 850 Universal Interface. Keep the default sample rate.
7. Connect the 8-pin DIN Extension Cable (UI-5218) between the port marked ‘Interface-Hall Voltage’ on the Hall Effect Apparatus and the Analog Input A on the 550 or 850 Universal Interface. (Note: The Hall Voltage U_H is proportional to the output voltage of the 8-pin DIN connector, 0 to 2000 mV vs. 0 to 2 V. When using a 550 or 850 Universal Interface, the Hall Voltage is automatically calibrated in the software.)
8. Connect the 8-pin DIN Extension Cable (UI-5218) between the port marked “Interface-Hall Current” on the Hall Effect Apparatus and the Analog Input B on the 550 or 850 Universal Interface. (Note: The Hall Current is proportional to the output voltage of the 8-pin DIN connector, 0 to10 mA vs. 0 to 1 V. When using a 550 or 850 Universal Interface, the Hall Current is automatically calibrated in the software.)
9. Push the optical carrier slowly, and adjust the adjustable holder until the end of Hall probe is centered in the magnetic field.
10. Turn ON the power for the Universal Interface and Hall Effect Apparatus.
11. Rotate the Excitation Current (I_M) 0–1000mA adjust knob until the ammeter reads zero.
12. Rotate the Hall current (I_S) 0–10mA adjust knob until the ammeter reads zero.



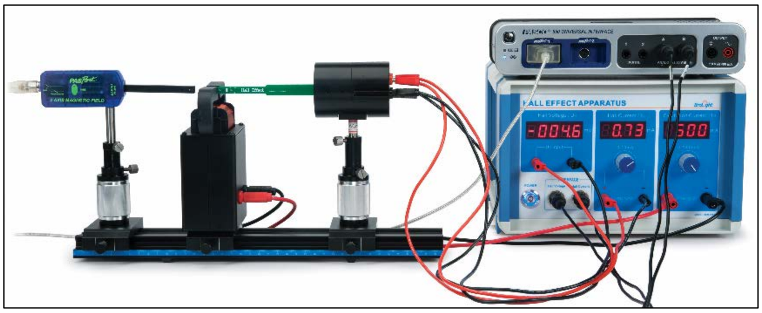
Software Setup

1. Open the PASCO Capstone program and in the Hardware Setup, the Hall Current, Hall Voltage, and Magnetic Field sensors should be auto-recognized.
2. Create a graph of Hall Voltage “U_H” vs. Hall Current “I_S”. Choose units of mV for the voltage and mA for the current. In the graph properties, turn off connected lines.
3. Create a Digits display of the Magnetic Field Strength (Perpendicular).
4. Create a table with the Hall Voltage (mV) and the Hall Current (mA).
5. Change the sampling mode to Keep.

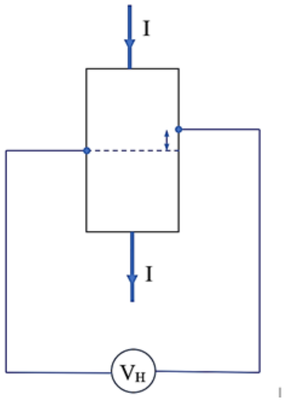


Procedure I: Constant Magnetic Field

In this part of the experiment, the magnetic field will be held constant and the current through the semi-conductor will be varied.



1. Set the Excitation Current (I_M) 0-1000mA to a desired value (e.g., 500 mA) so the magnetic field strength will be constant.
2. Make sure the Hall Current "I_S" 0-10mA is zero.
3. Click Preview and adjust the Hall Current to 0.5 mA. Press Keep to record the voltage and current. Then increase the Hall Current by increments of 0.5 mA, pressing Keep for each, until the Hall Current is 5.5 mA. Then press Stop. Return the Hall Current to zero.
4. Move the Hall Probe out of the magnet. Press the tare button on the side of the Magnetic Field Sensor. Move the end of the Magnetic Field Sensor into the center of the magnet. Click Preview and Keep to record the magnetic field strength. Then press Stop.
5. Set the current 0-1000mA to another value (e.g., 800 mA), and then record data again, repeating Steps 2 through 4.
6. On the graph, apply a linear fit to the V vs. I data.
7. Hall Voltage Compensation: Because the leads that measure the Hall Voltage may not be exactly opposite each other across the semi-conductor, a voltage may appear that is due to the potential difference along the direction of the current. To measure this and compensate for it, slide the Hall Probe completely out of the magnet, set the magnet current to zero, and perform Step 3 to record the Hall Voltage without any magnetic field. Apply a linear fit to the V vs. I data. The slope of this line will be subtracted from the slopes of the other lines to compensate for the offset of the Hall Voltage due to misalignment of the leads.



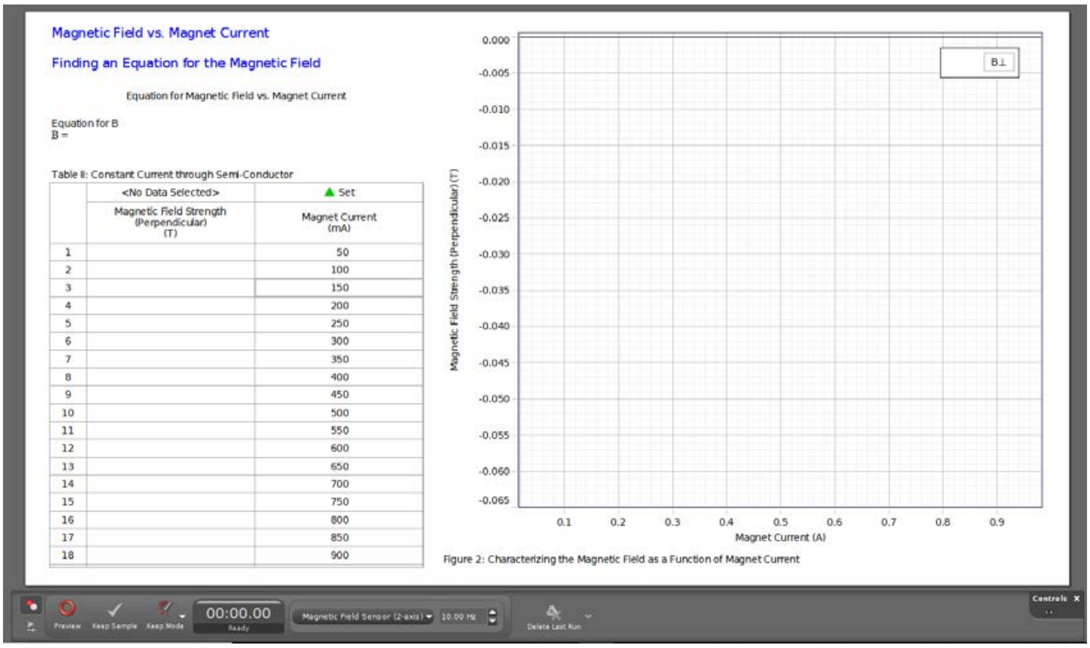
Misalignment of Hall Voltage Leads

Procedure II: Constant Current through the Semi-Conductor

In this part of the experiment, the magnetic field will be varied by varying the current through the electromagnet while the current through the semi-conductor will be held constant. Rather than measuring the magnetic field for each data point, we will first characterize the magnetic field as a function of the current.

1. To discover the relationship between the magnetic field strength and the current through the magnet coils, create a table of Magnetic Field Strength (Perpendicular). In the second column, create a User-Entered data set called Magnet Current (with units of mA). Pre-fill the column with values from 50 to 900 mA in steps of 50 mA. Create a graph of

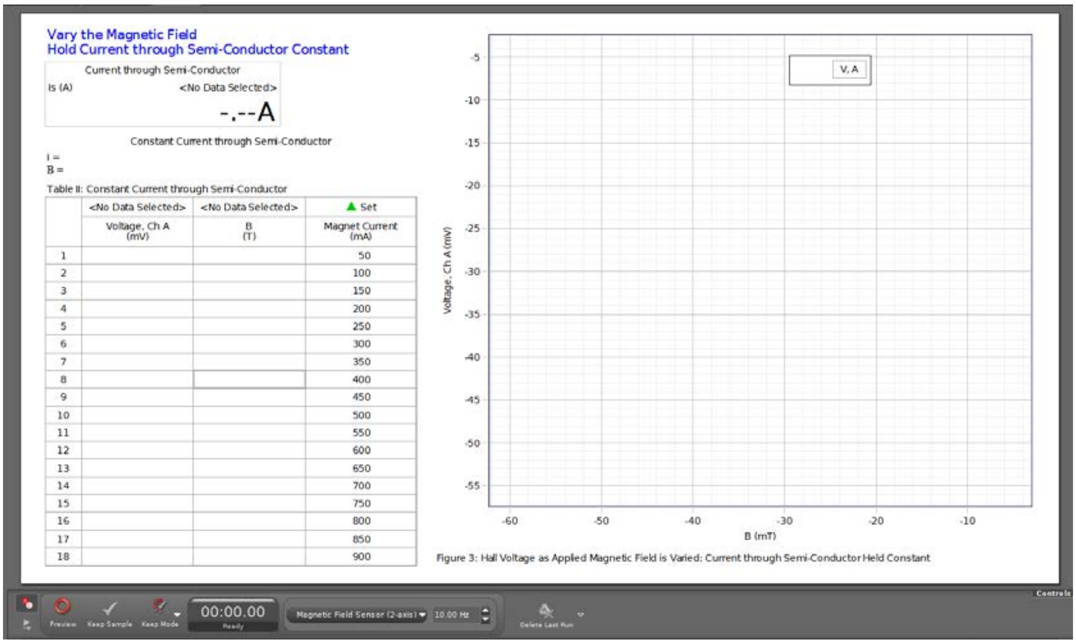
Magnetic Field Strength (Perpendicular) vs. Magnet Current (A).



2. With the Hall Current set to zero, press the tare button on the side of the Magnetic Field Sensor. Move the Magnetic Field Sensor into the center of the magnet.
3. Click Preview and adjust the “Excitation Current” (the current through the electromagnet) to 50 mA as read on the digital readout on the Hall Effect Apparatus. Then click Keep.
4. Adjust the “Excitation Current” to each value in the table and click Keep for each value. Then click Stop. Return the “Excitation Current” to zero to prevent the magnet from getting too hot.
5. On the graph, apply a cubic curve fit. In the Capstone calculator, create an equation for the magnetic field, B:

   $B = a + b*I + c*I^2 + d*I^3$ in units of T

   where I = [Magnet Current (A)] and a, b, c, and d are the cubic fit coefficients.
6. Create a graph of Hall Voltage (mV) vs. B (mT). In the graph properties, turn off connected lines.



6. Create a Digits display of the Hall current I_s.
7. Create a table of the Hall Voltage (mV), the calculation B, and the User-Entered set Magnet Current (mA).
8. Set the Hall current I_s (0-10mA) to a desired value (e.g., 5 mA).
9. Make sure the Excitation Current (I_M) 0-1000mA is zero.
10. Set the sampling rate to 10 Hz.
11. Move the Magnetic Field Sensor out of the magnet and move the Hall Effect Probe into the center of the magnet.
12. Click Preview and increase the Excitation Current to 50 mA and click Keep. Continue to increase the Excitation Current by steps of 50 mA up to 900 mA, clicking Keep for each current setting. Then click Stop.
13. Set the Hall Current 0-10mA to another value (e.g., 8 mA), then record data again, repeating Steps 10 through 13.
14. On the graph, apply a linear fit to the V vs. B data.

Analysis

The dimensions of the n-semiconductor strip: w = 3.9mm, b = 2.3mm, d = 1.2mm

1. For the constant magnetic field data, use the slope of the graph and equation (5) to determine the density of charge carriers (n). Remember to compensate by subtracting the slope of the graph for zero magnetic field from the slope of the run with the magnetic field.

   $$U_H = \left(\frac{B}{nde}\right) I \qquad (5)$$

2. Determine the sign of the charge carriers by using the sign of the Hall voltage and making a diagram showing the direction of the magnetic field, drift velocity, and the Lorentz force.
3. For the constant current data, use the slope of the graph and equation (5) to determine the density of charge carriers (n)

   $$U_H = \left(\frac{I}{nde}\right) B \qquad (5)$$

4. For the constant current data, calculate the drift speed from equation (10) using the slope of the Hall Voltage vs. B graph:

   $$v = \frac{U_H}{bB} \qquad (10)$$

   $$U_H = (vb)B$$

Appendix A: General Specifications

Dimensions of the n-semiconductor strip: w = 3.9mm, b = 2.3mm, d = 1.2mm
Supply voltage: 110-120V~/220-240V~
Mains supply voltage fluctuations: ±10%
Frequency: 50/60Hz
Fuse Protection for inputs: 250 V T2A
Display: 3-1/2 Digit Display and 4-1/2 Digit Display
Temperature: Operating: 0°C to 40 °C, Storage: -20 °C to 50 °C
Operating Altitude: 0 to 2000 meters
Relative Humidity: Noncondensing < 10 °C, 90% from 10 °C to 30 °C; 75% from 30 °C to 40 °C
Certifications: CE
Safety Compliance: IEC/EN 61010-1
Overvoltage category: II
Degree of protection: IP20
Normal energy protection: 5J

Item	**Description**
Hall probe, n-semiconductor	Control current: <10mA Semiconductor material: GaAs (gallium arsenic) Hall sensitivity: ≥150mV/(mA·T)
Hall Effect Apparatus	0~1000mA dc, V ≤ 20V (ripple < 1%); 3.5 Digit Display; 0-10mA dc, V ≤ 12V (ripple < 1%), 3.5 Digit Display Hall voltage: 4-1/2 Digit Display
Electromagnetic coil	Number of turns: 1000 Current to the coils: ≤ 1A

Appendix B: Teacher's Notes

Sample Data

Procedure I: Constant Magnetic Field

Dimensions of the n-semiconductor strip: w = 3.9 mm, b = 2.3 mm, d = 1.2mm

Table I: Constant Magnetic Field

Run #2		Run #3		No B-field	
I_{mag} = 500 mA; B = -0.0361 T		I_{mag} = 750 mA; B = -0.0532 T		I_{mag} = 0; B = 0	
Hall Voltage (mV)	Current I_s (mA)	Hall Voltage (mV)	Current I_s (mA)	Hall Voltage (mV)	Current I_s (mA)
-5.6	0.51	-7.7	0.51	-3.0	1.02
-11.1	1.02	-15.0	1.02	-6.0	2.02
-16.5	1.52	-22.2	1.52	-8.9	3.02
-21.7	2.02	-29.4	2.02	-11.9	4.02
-27.1	2.52	-36.6	2.51	-14.8	5.02
-32.3	3.02	-44.1	3.02	-17.6	6.01
-37.6	3.52	-51.2	3.51	-20.5	7.02
-43.0	4.02	-58.5	4.02	-23.4	8.02
-48.4	4.52	-65.7	4.51	-26.3	9.01
-53.6	5.02	-73.1	5.02	-29.2	10.01
-58.8	5.51	-80.2	5.51		
-64.2	6.01	-87.3	6.01		
-69.5	6.51	-94.4	6.51		
-74.8	7.01	-101.6	7.01		
-79.8	7.51	-108.6	7.51		
-85.1	8.01	-115.7	8.01		
-90.3	8.51	-122.7	8.51		
-95.4	9.01	-129.8	9.01		
-100.6	9.51	-136.9	9.51		
-105.7	10.00	-143.9	10.01		

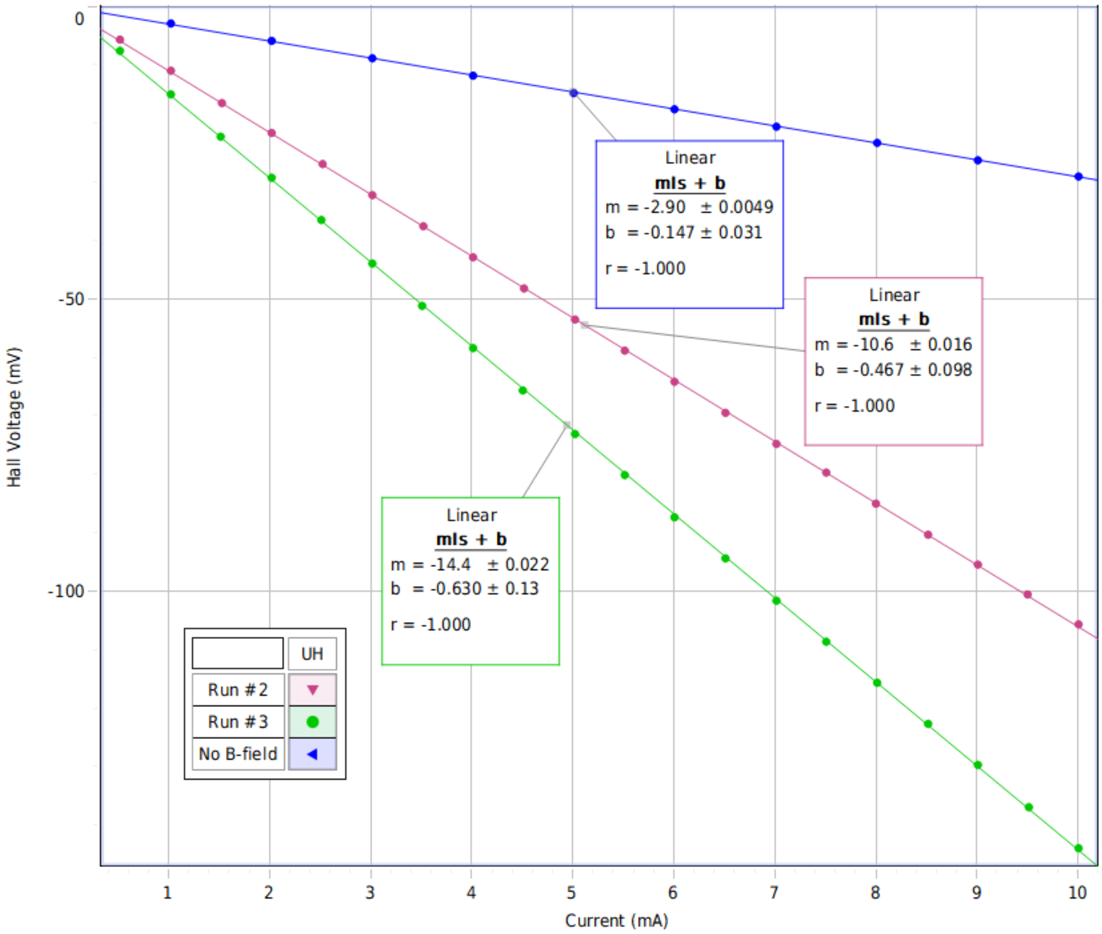


Figure 1: Hall Voltage as Current is Varied

$$U_H = \frac{IB}{nde} \qquad (5)$$

$$[Slope\ of\ U_H\ vs.I] = \frac{B}{nde}$$

For Run #2:

$$n = \frac{B}{[slope]de} = \frac{0.0361T}{(10.6 - 2.9V/A)(0.0012m)(1.60 \times 10^{-19}C)} = 2.44 \times 10^{19}/m^3$$

For Run #3:

$$n = \frac{B}{[slope]de} = \frac{0.0361T}{(14.4 - 2.9V/A)(0.0012m)(1.60 \times 10^{-19}C)} = 2.41 \times 10^{19}/m^3$$

Determining the Sign of the Charge Carriers:

For the experimental setup, the direction of B and *v* relative to the Hall Probe are shown in Figure 2. If the charge carriers were positive, the Lorentz Force would force them to the left in Figure 2 and the Hall Voltage would read positive. However, in this experiment, the Hall Voltage is negative, thus the charge carriers must be negative and the velocity is in the opposite direction as shown in Figure 3.

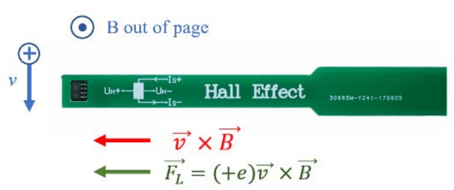


Figure 2: Negative Hall Voltage

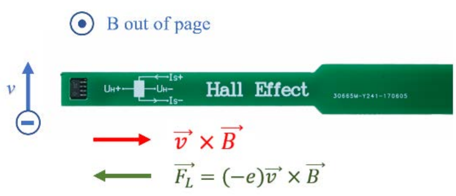


Figure 3: Positive Hall Voltage

Procedure II: Constant Current through Semi-Conductor

Table II: Magnetic Field vs. Magnet Current

Magnetic Field Strength (Perpendicular) (T)	Magnet Current (mA)
-0.0035	50
-0.0071	100
-0.0106	150
-0.0142	200
-0.0177	250
-0.0213	300
-0.0248	350
-0.0283	400
-0.0319	450
-0.0354	500
-0.0389	550
-0.0424	600
-0.0459	650
-0.0494	700
-0.0529	750
-0.0564	800
-0.0598	850
-0.0632	900

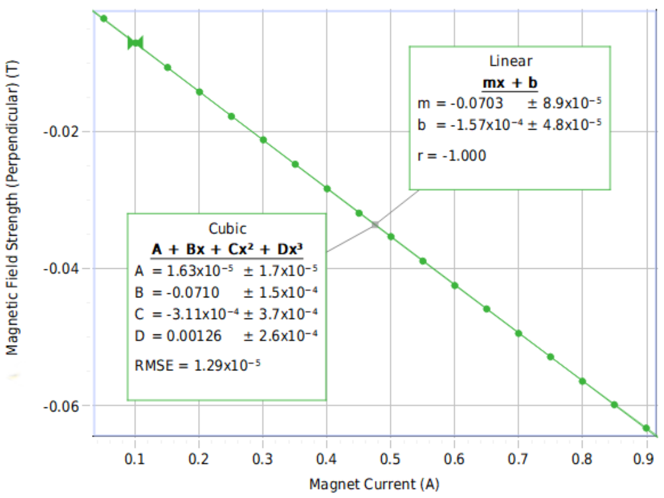


Figure 4: Magnetic Field as a Function of Coil Current

Equation for B

$B = -0.0000163 - 0.0710\ I - 0.000311\ I^2 + 0.00126\ I^3$

Table III: Constant Current through Semi-Conductor

Run #7: I = 5.06 mA; Run #9: I = 7.52 mA

Run #7	Run #9	Set	Set
Hall Voltage (mV)	Hall Voltage (mV)	B (T)	Magnet Current (mA)
-19.0	-28.3	0.00	50
-22.8	-34.0	-0.01	100
-26.7	-39.6	-0.01	150
-30.4	-45.3	-0.01	200
-34.2	-51.0	-0.02	250
-38.0	-56.7	-0.02	300
-42.0	-62.5	-0.02	350
-45.7	-68.2	-0.03	400
-49.6	-73.9	-0.03	450
-53.4	-79.6	-0.04	500
-57.3	-85.4	-0.04	550
-61.1	-91.0	-0.04	600
-65.0	-96.9	-0.05	650
-68.9	-102.7	-0.05	700
-72.8	-108.4	-0.05	750
-76.6	-114.1	-0.06	800
-80.6	-119.9	-0.06	850
-84.4	-125.7	-0.06	900

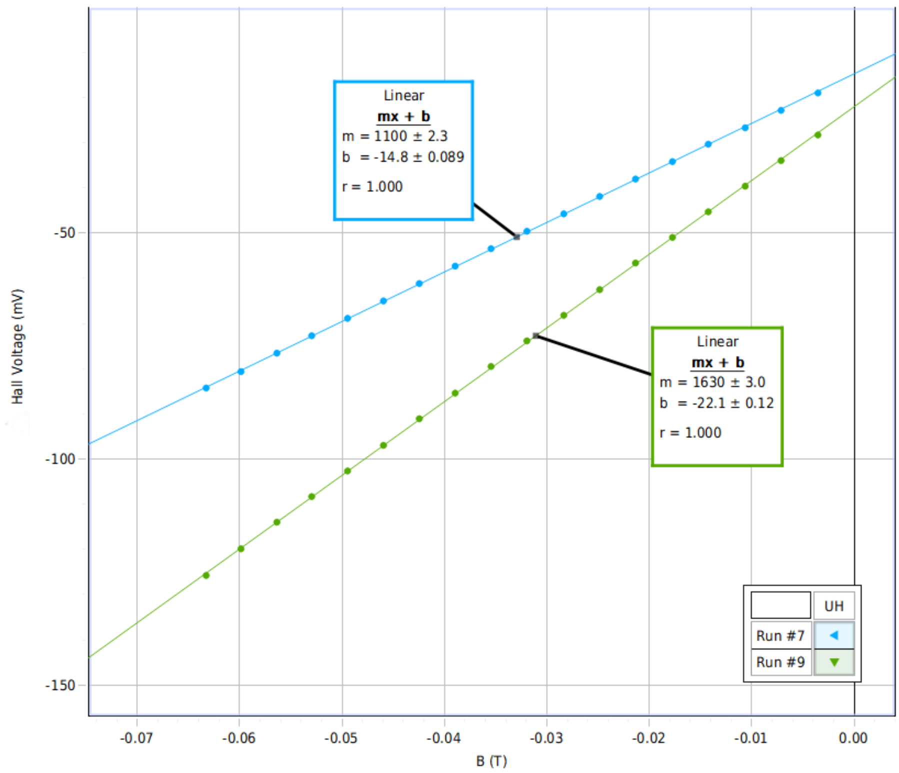


Figure 5: Hall Voltage as Magnetic Field Varies

$$U_H = \frac{IB}{nde} \qquad (5)$$

$$[Slope\ of\ U_H\ vs.B] = \frac{I}{nde}$$

For Run #7:

$$n = \frac{I}{[slope]de} = \frac{0.00506A}{(1.1V/A)(0.0012m)(1.60 \times 10^{-19}C)} = 2.40 \times 10^{19}/m^3$$

For Run #9:

$$n = \frac{I}{[slope]de} = \frac{0.00752A}{(1.62V/A)(0.0012m)(1.60 \times 10^{-19}C)} = 2.42 \times 10^{19}/m^3$$

According to equation (10):

$$U_H = (vb)B$$

$$[slope\ of\ U_H vs.B] = vb$$

For Run #7:

$$v = \frac{slope}{b} = \frac{1.1V/T}{0.0023m} = 480m/s$$

For Run #9:

$$v = \frac{slope}{b} = \frac{1.62V/T}{0.0023m} = 704m/s$$

Appendix C: Product End of Life Disposal Instructions

This electronic product is subject to disposal and recycling regulations that vary by country and region. It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment. To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle/disposal service, or the place where you purchased the product.

The European Union WEEE (Waste Electronic and Electrical Equipment) symbol (above) and on the product or on its packaging indicates that this product must not be disposed of in a standard waste container.

Appendix D: Technical Support

For assistance with any PASCO product, contact PASCO at:

Address:	PASCO scientific 10101 Foothills Blvd. Roseville, CA 95747-7100	Web:	www.pasco.com
Phone:	916-462-8384 (worldwide) 800-772-8700 (U.S.)	Email:	support@pasco.com

Limited Warranty: For a description of the product warranty, see the PASCO web site.

Instruction Manual: To download a PDF file of the *Instruction Manual*, go to www.pasco.com/manuals. Enter the product number (SE-7260) and select “Submit”.