11 **Coulombmeter**, with shielded Faraday cup, ISU brand (we have 11, #2794-2804)
- a. **should have extension tube for shield** (painted 3 lb. coffee can, open at each end) held in place with duct tape;
- b. contains digital multimeter (Soar model ME-540);
- c. has switch-selectable capacitors (10, 1.0, 0.1 μF);

11 x 2 Braun-type electroscope (Klinger KE5235) modified to have a Teflon insulator
- a. use two black 24" banana wires to ground the outer structure of the electroscopes.

11 x 2 metal can, for use with the electroscope
- a. ordinary "tin" food cans are satisfactory; all sharp edges should be removed (3-1/8" diameter x 4-1/4" high is a nice size)
- b. each can should have conducting metal surfaces, with no insulating coatings or coverings.

11 x 2 friction rod set, ISU brand, including holder and two rods as follows:
- a. **rod, PVC, gray**, 11.75" x 5/8" diameter (negative when rubbed with tissue.)
- b. **rod, acrylic, clear**, 11.75" x 5/8" diameter (positive when rubbed with tissue.)
- c. **rod holder, oak**, 4" x 4" x 1.5", with two holes, each 1" deep and 11/16" diameter, with label

11 **electrophorus**, ISU brand, including metal disk and two plates as follows:
- a. disk, aluminum, 8" diameter x 1/4" thick, with white Teflon handle, 3/4" diameter x 10" long
- b. plate, PVC, gray, 10.5" x 10.5" x 1/4"
- c. plate, acrylic, clear, 10.5" x 10.5" x 1/4"

11 **neon bulb**, mounted in black plastic light shield with banana jacks (bulb type A1A, 0.6 mA, Digikey A1A)

11 **rotating stand for rods**
- a. includes an oak base approx. 4" x 4" x 1-5/8", with 2-3/8" diameter recess to accept the stand;
- b. Pasco model SE-8605 ($9.50 ea.)

11 **set of low mass plastic rods** in a coffee can (2 lb. size) with a plastic base
- a. these are used on rotating holder;
- b. set should include an aluminum rod, 12" long, 3/8" diameter (preferably hollow, but solid is O.K.);
- c. set should include a "dumb-bell", made of two ping pong balls on either end of a 1/4" Teflon rod, overall length of 8", with balls coated with conductive coating.

11 **insulated ball and disk set**, including:
- a. 2 - ping pong ball, with conductive coating, mounted on a Teflon rod (1/4" diameter), 16.5" overall length.
- b. set of 2 disks (1.25" diameter) with dissimilar plastic pads on aluminum rods (1/4" diameter, approx. 12" long), Pasco-9057.
- c. mounting board with 6 holes (to hold the disks and balls on rods)

11 **squeeze bottle**, with methanol
- a. bottle should be labeled with proper warning label for methanol

11 **box of ordinary tissues**

11 **grounded wrist strap assembly, consisting of:**
   a. an aluminum box connected to two grounded wrist straps;
   b. plug the attached banana wire into the special AC plug with banana jack (see next item)
   c. each of the wrist straps has an internal 1 megaohm resistor; for additional safety, the aluminum box has an additional 1 megaohm resistor in series to ground. These resistors protect the user from harm if they should accidentally come in contact with 120 VAC.

11 **special AC plug with banana jack** for connecting a banana wire to the third-wire ground.

11 **set of banana wires** including 2 BK-36", 4 BK-24", 2 BK-12"; 4 RD-24", 2 RD-12")

11 x 2 Teflon insulated wire, 30" long, red, with banana plug at each end, labeled as Teflon insulated wire

11 **lab wire holder assembly**, consisting of:
   a. slotted wire holder, Pomona #508 [orange/beige];
   b. vertical stand, about 1 meter tall, with a tee-base;
   c. C-clamp, 4", to hold the tee-base of the stand on the table;
   d. clamp to hold wire holder to vertical rod.
   e. wire holder should be mounted 30" above the table on the vertical stand, and the tee-base of the stand should be clamped at the center of the table edge opposite from the students.

Available in room:

* **One table with High Voltage apparatus** (see the separate equipment list for this table):
   a. for charging a ping pong ball to a known potential;
   b. for calibrating a Braun electroscope as a voltmeter.

Supplies (on supply table or cart):

* **roll of gray duct tape** (for attaching extension tube to coulombmeter)
* extra boxes of tissue;
* a few extra squeeze bottles with methanol;
* extra ping pong balls mounted on Teflon rods.

Other notes:

* **There is a slide show** (revised spring, 2000)

CHECKS:

1. **Check that (conducting) ping pong balls are in good condition.** These require occasional replacement and/or re-coating of the balls.
2. **Braun electroscopes:**
   a. Each semester, the cylindrical sides of the white Teflon insulator should be wiped quickly with tissue soaked in alcohol. This takes only a few seconds and removes any conducting material that may have accumulated on the surface.
3. **Electrophorus:**
   a. Each semester, the white Teflon handle of the electrophorus disk should be wiped quickly with tissue soaked in alcohol. This only takes a few seconds.

High Voltage Table (only one table needed)
(most or all of this apparatus should be stored together)

This table should have:

1. **Braun electroscope calibration setup:** Using this setup, students can observe the P.D. required to cause various deflections of an electroscope, thereby obtaining a rough calibration of the electroscope when used as a (high voltage) DC voltmeter.

2. **Ping pong ball charging enclosure setup:** This setup is intended for charging objects to a known (high) potential.

These two setups are interconnected because they use a single high voltage power supply. The apparatus list that follows is for a joint setup that includes both these setups.

WARNING: THERE SHOULD NOT BE ANY APPARATUS ON THIS TABLE THAT IS ELECTRICALLY DELICATE OR EXPENSIVE; ITS LIFE MAY BE BRIEF IN THE REGION OF THIS TABLE!

Braun electroscope calibration setup:

1 **Braun-type electroscope** (Klinger KE5235) modified to have a Teflon insulator
   a. **Should have a stack-up banana plug (cut from an old banana wire) between the disk and electroscope body** (to provide a horizontal hole for the banana plug of the HV wire (red) from the HV DC power supply).

1 **high voltage probe**, B & K Precision model PR-26
   a. specifications: 40 kV, 600 megaohm input resistance, attenuation factor of 1000, calibrated to be used with a voltmeter with a 10 megaohm input resistance

2 **digital voltmeter**, with a 10 megaohm input resistance on DC voltage scales
   a. prefer an inexpensive meter, such as the Metex 3800; only the meter is needed, no ordinary probes or carrying case.
   b. one of these meters is used with the high voltage probe (listed above)
   c. and one of these is used with the high voltage power supply (listed below)

1 **high voltage, DC power supply**, ISU brand, Physics #2806
   a. a digital voltmeter should be placed on top of this supply, and connected to the **low voltage output monitoring jacks on the back of the supply. UNDER NO CIRCUMSTANCES, SHOULD ANY METER BE CONNECTED TO THE HIGH VOLTAGE OUTPUT WIRES OF THE POWER SUPPLY!!!!! Doing so will instantly destroy the meter.**
   b. This unit is designed to have a current- and energy-limited output for safety (less than 1 mA, and low capacitance output);
   c. this supply has a maximum output current of 75 uA, and is modified to have a 4 KV maximum output voltage.

1 **AC plug with banana jack for ground connections** (plug into outlet strip)

Additional items needed for the Ping pong ball charging enclosure setup:

1 **metal enclosure** (connected to electrical ground)
   a. Currently we use a cylindrical wire mesh enclosure, 24" high x 18" diameter. This is open at the top, and has a 3/4" plywood base covered with mesh on the inside. The mesh is galvanized steel hardware cloth, with 1/4" openings.
   b. Currently we connect this enclosure to ground with an alligator clip (on the end of a banana wire). The clip is used to grasp the mesh wire.

1 **thin vertical wire mounted on an insulating stand**
   a. A length of piano wire (#), 10" long, stuck into a #13 rubber stopper is satisfactory;
   b. The top end of the wire should be rounded, or at least ground flat (to reduce electrical discharge from sharp points).
   c. This vertical wire should be centered on the bottom of the metal enclosure.

These two setups together on a single table require:

1 **set of banana wires:**
   * 1 - 18"R, 2 - 18"B,
   * 1 - 24"B
   * 1 - 36"R

CHECKS:

1. **Check that the electroscope deflects when the power supply output is increased to a few kilovolts.**
2. **Check that the reading of the digital voltmeter connected to the special X 1/1000 monitoring terminals reads sensibly, i.e., that its reading corresponds appropriately to the analog meter on the face of the power supply.**
3. **Touch the High Voltage Probe to the electroscope disk and check that the meter to which the probe is connects gives a sensible reading (that agrees within 1% or so with the reading of the meter which is connected to the low-voltage monitoring terminals for the high voltage supply.'**

Repair and adjustment notes:

1. **Braun electroscopes:** The vanes of the electroscopes should:
   a. rotate freely;
   b. be properly balanced.
      * the vane should return to the vertical orientation when the electroscope is discharged;
      * the vane should not lean against the vertical support when the electroscope is discharged. If it does, the vane will not deflect for small amounts of charge!
      * a vane can be balanced by the addition of a small piece of transparent tape near one end of the vane.
2. **Our "tin" can collection:** Once we found that one of the "tin" cans had an insulating coating on its inside surface! We should be sure that all of our collection has a bare metallic surface. Cans that have been checked should be marked in some small appropriate way.
3. **Conducting ping pong balls:** These are coated with a carbon spray, same as is used for the carbon sheets used for the collision tables. This is called EMI-RFI Shield, manufactured by GC Electronics (or GC Thorsen or GC Waldom), product #10-4807.
4. **The Coulombmeters.** The important components of these lovely instruments are:
   a. A selected multimeter that autoranges and has exceeedingly high resistance on its lowest, DC voltage scale. These are either the Soar model ME-540 (preferred) or the Soar model ME-530 (has slightly lower accuracy). A supply of these is kept in A105.
   b. A selected set of very low leakage capacitors. Spares are kept in A105
   c. teflon insulated wire and low-leakage switch.

Peterson's notes: Separate electricity notebooks

Signs for use on the High Voltage table

Sign to be hung on the outside of the grounded shield. Use a copy of this, or use a colored marking pen to make a sign of similar size.

Ping Pong Ball
Capacitance
$C \approx 2\ pF = 2\ (\ nC / kV\ )$

Sign to be attached to top of digital that is connected to the **LOW VOLTAGE** monitoring terminals of the High Voltage power supply: Use a copy of this, or use a colored marking pen to make a sign of similar size; it may need to be taped on an index card to provide sufficient stiffness.

Multiply this reading
by 1000 for the actual
High Voltage output
of the supply.

Sign to be attached to top of digital meter to which the **High Voltage probe** is connected. Use a copy of this, or use a colored marking pen to make a sign of similar size; it may need to be taped on an index card to provide sufficient stiffness.

Multiply this reading
by 1000 to determine the
Electrical Potential of the tip
of the high voltage probe.

Not currently used:

11 **auto-ranging digital multimeter**, Soar model ME-540, (meter has > 1 G-ohm resistance on 200 mV DC scale.)

11 **capacitor, 10.0 μF**, non-polarized, low leakage type, on mounting board with label (polyester film with metal coating, Panasonic ECQ-E1106KZ, 100 Volts.)

label describing various rods.

7/10/2000: I used Physics 111, #6, The real experiment, as a format for these setup notes.