

Supplemental Notes: Thermionic Emission Experiment

Experiments in Modern Physics (P451)

The goal of this lab is to study thermionic emission from a Tungsten filament. The procedure and analysis is outlined in detail in Ref. [1]. The purpose of these notes is to provide supplemental information that primarily deals with the utilization of the laboratory vacuum system.

Setup and Equipment

Pumping station (see Fig. 1) with various types of vacuum pumps, gauges, and valves. Look over the station carefully, and be sure you can identify all the indicated components before you start. The filament will be inserted into a port on the front of the pumping station. Be sure to carefully study the pins on the filament and draw a connection diagram. After inserting the filament, use a meter to check for shorts from any of the pins to the vacuum vessel *before* beginning the pump down procedure.

Pumps

- Mechanical fore pump (FP1).
- Oil diffusion pump (DP).

Gauges

- Ionization gauge (GI).
- Thermocouple gauges (GTC1,2).

In addition to understanding the physics principles behind these pumps and gauges, make sure you understand the pressure ranges over which each operates. *Because some pumps and gauges—like a diffusion pump and an ionization gauge—can be damaged if operated at the “wrong” pressure, it is very important that you check with the instructor before turning on pumps or gauges, or opening or closing valves. You also should check before turning these devices off! Shutting down the pumping devices must occur in a certain prescribed order!*

Startup Procedure

Check and leave the gate valve, VG, open throughout the experiment. There is no need to ever isolate volume 1 from the diffusion pump.

1. Close all valves *except* the gate valve.
2. Turn on gauges GTC1,2 and pump FP1 using the power strip on the back of the vacuum station.
3. Open V7 and V2 to begin evacuating volume 1. Opening the valves after starting up the pump ensures that any oil ejected from the pump into the lines during pump startup will not go into the vacuum chamber.
4. You may find it interesting to monitor GTC1, GTC2, and GCV as a function of time during the pump-down period. *Do NOT turn on the ion gauge GI!*
5. Wait until GTC1 is stable. It should be below 100 mTorr.
6. Turn on the diffusion pump cooling water (under sink).
7. Close valve V2 to isolate volume 1 from the fore pump. V7 should remain open as the fore pump will serve as a backing pump for the diffusion pump.

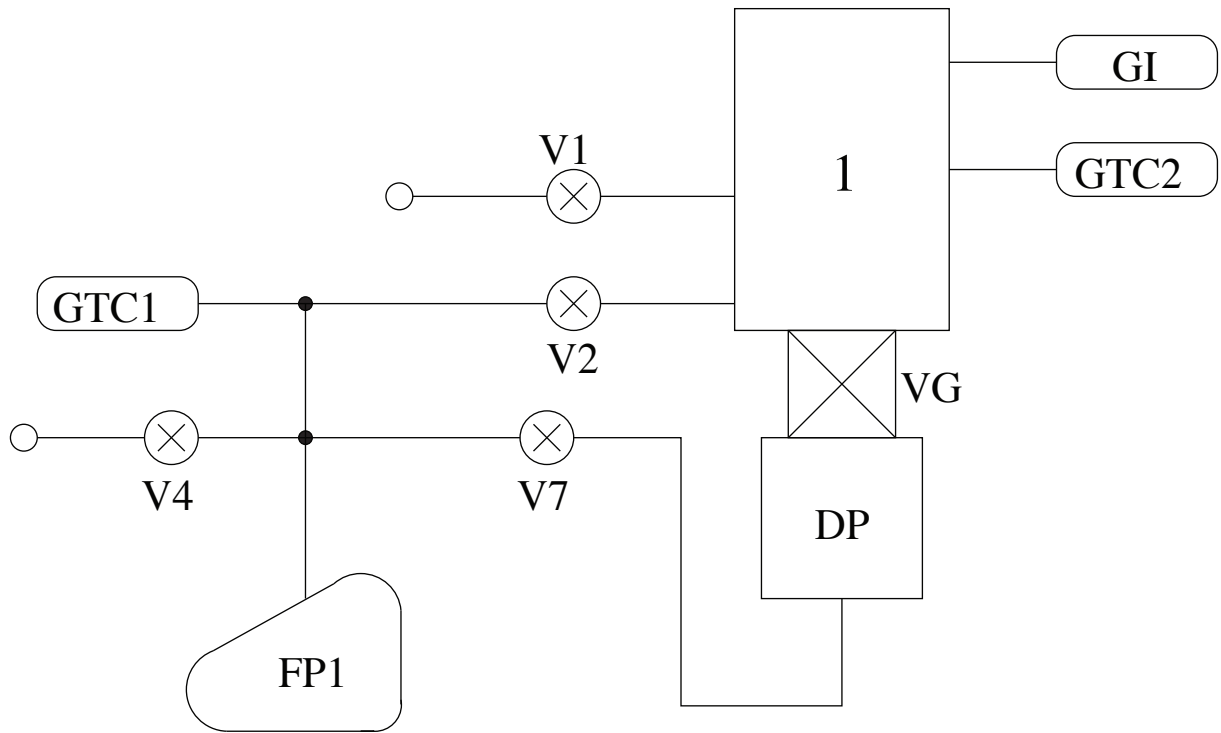


Figure 1: A diagram of the lab vacuum system. The filament for thermionic emission studies is inserted into a port in volume 1.

8. Engage the heater for the diffusion pump. If it does not stay on, get the instructor!
9. Wait about 1/2 hour, at which time GTC2 should now read near zero and not be visibly decreasing.
10. Turn on the ion gauge GI to check pressure in volume 1. Anything at 10^{-5} Torr or below should be sufficient for the thermionic emission experiment.

Shutdown Procedure

Note that the shutdown procedure for the diffusion pump takes about 30 minutes – plan your time accordingly!

1. V2 should already be closed and V7 should be open.
2. Turn off the diffusion pump heater. *Leave the cooling water on and FP1 running – the diffusion pump doesn't stop pumping until it cools down.*
3. Wait 30 minutes.
4. Close V7.
5. Turn off FP1.
6. Turn off cooling water.

Additional Hints

- Reference [1], Experiment 7 provides both theoretical and experimental details of how to make measurements. You should attempt to verify Child's Law and measure the work function of tungsten. If you have time for additional measurements, you may choose to use the solenoid at the experiment station to measure the charge to mass ratio of the electron.
- Reference [1] contains a typo in the definition for γ on page 145. The correct definition may be obtained by comparing Eqs. (17) and (18).
- The electrical circuit used to make the measurements (Fig. 7.7 of Ref. [1]) needs to be constructed carefully to avoid shorts to ground. Discuss the wiring of the circuit with your instructor before starting.
- Plot the thermionic emission current as a function of the accelerating voltage on a log-log plot. Identify the space charge limited and temperature limited regimes. These are difficult to identify without plotting – it is advisable to plot the data as they are being taken to identify regions where additional data should be recorded.
- At high currents, the filament is very fragile. Jarring the apparatus or simply running at very high current for prolonged periods of time may break the filament. If this happens you will need to shutdown the vacuum system and repair the filament.

References

- [1] D. Preston and E. Dietz, *The Art of Experimental Physics*, Wiley (1991).