

# Experiment 4

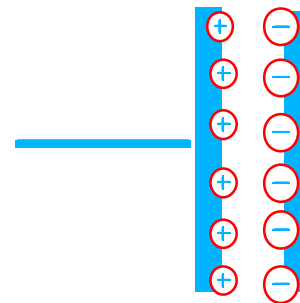
In this experiment you will construct a device to measure the absolute value of a voltage through the measurement of a force. The actual measurements that you will make will be of mass, distance and time but the result will be a measurement of an electrical potential in Volts.

$$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2} \quad \text{two point charges}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{\text{F}}{\text{m}} \quad \text{fudge factor for unphysical units}$$

$$V = \frac{\text{P.E.}}{Q} \quad \text{electric potential like potential energy}$$

## Parallel Plate Capacitor



### From Gauss's Law

$$E = \frac{Q}{A\epsilon_0}$$

### Potential Difference

$$V = Ed = \frac{Qd}{A\epsilon_0}$$

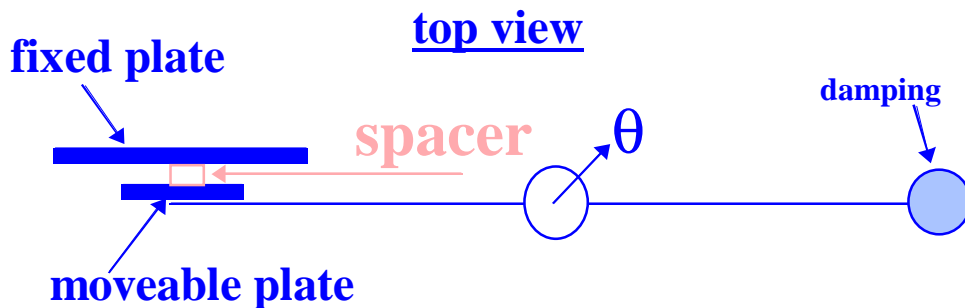
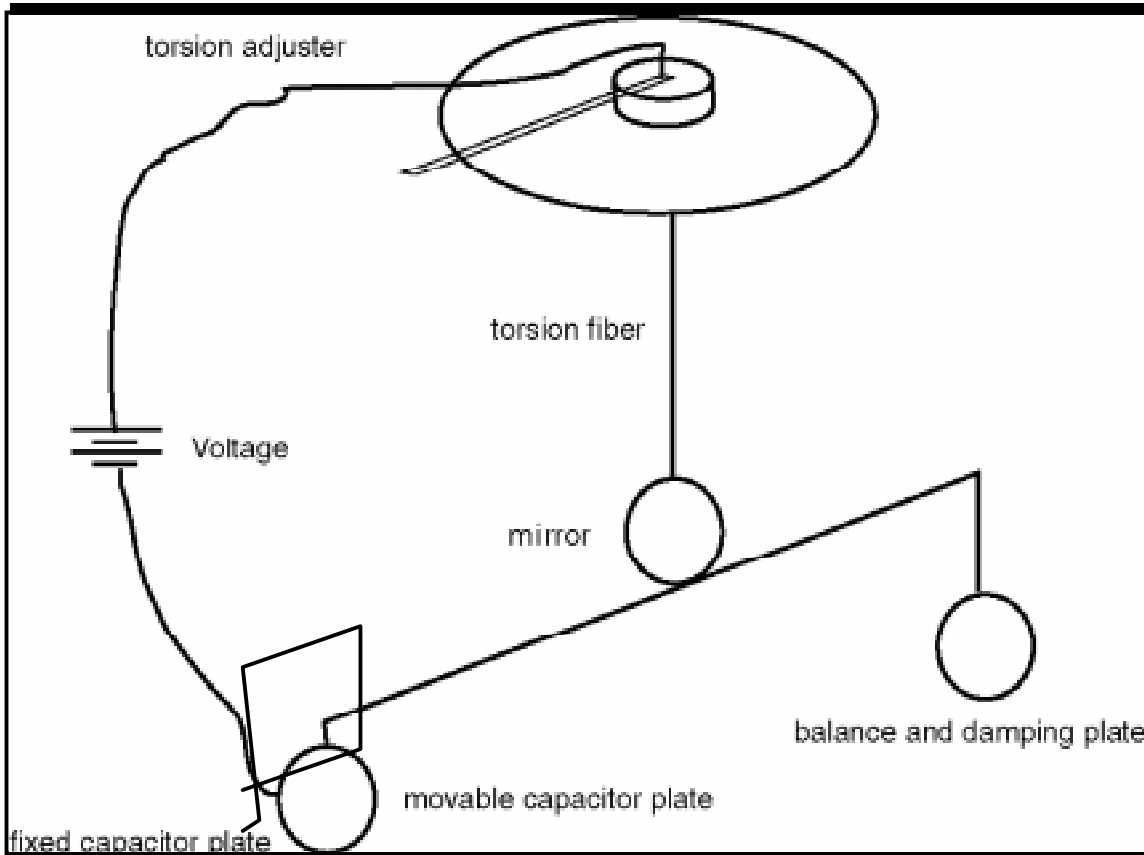
### Force between plates

$$F = \frac{1}{2} \frac{A\epsilon_0}{d^2} V^2$$

### Estimate force to be measured

$$F = \frac{1}{2} \frac{(A = 3\text{cm}^2)(8.8 \times 10^{-12}\text{F/m})}{(d = 0.1\text{cm})^2} (V = 1000\text{V})^2 = 1.2 \times 10^{-3}\text{N}$$

# Calibrate a Voltmeter



- Set up the apparatus.
- Keep table dry.
- Strip wire well.
- Measure the spacer.
- Measure  $\kappa$ .
- Make the plates parallel for spacer in contact.
- Find Voltage that just causes plates to move apart.
- Try calibration at about 1000 Volts.
- Now get several measurements at lower voltage.
- Water must be stable.
- Move slowly.
- Protect your apparatus from air currents.
- Now use laser-mirror system to try to find stable equilibrium.
- How well could you check systematic differences in voltmeters this way?

# Equilibrium Positions

$$F = -\frac{1}{2}A\epsilon_0 V^2 \frac{1}{d^2} \quad \text{electrostatic attraction}$$

$$F = \frac{\kappa\theta}{l} = \frac{\kappa}{l} \left( \theta_{\text{scale}} - \frac{d}{l} \right) \quad \text{force applied by torsion ballance}$$

spacer can ballance negative force when in contact. unstable

