ELEC 435
Problem Set 2
Due: September 12, 2014

Homework Problems.

H2.1 The *electrosphere* is the dc conducting region of the upper atmosphere with conductivity provided by molecules ionized by cosmic rays. It has a height of approximately 25km and in fair weather is positively charged with a potential difference of about 300,000V with respect to the earth's surface. In the vicintity of a thunderstorm, the potential is nearly 100 times greater, and of opposite sign.

A large white bird is flying through a thunderstorm when it is hit by lightning. The bolt knocks loose a 1 gram feather, electrically charges it, and blasts it out of the thunderstorm zone. The feather is held suspended for several days until it floats over a radium mine and is discharged, whereupon it slowly sinks to the ground and lands at the feet of Forrest Gump.

What was the charge on the feather as it floated in the air?

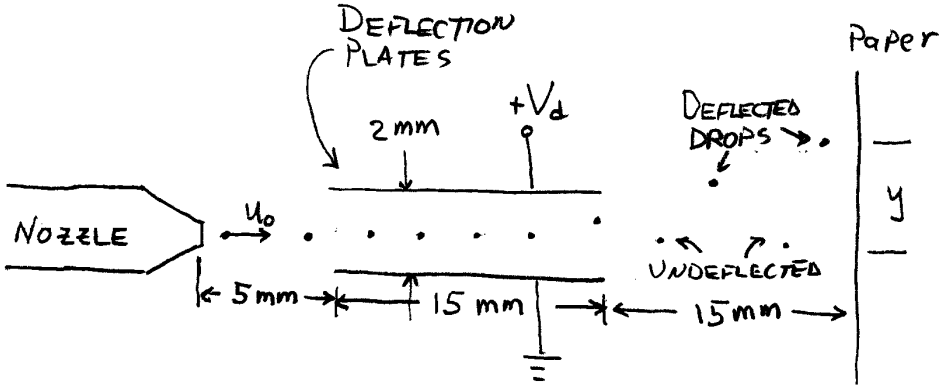
H2.2 The figure below is a diagram of an electrostatic ink-jet printer (for printing on paper rather than Coke cans). The nozzle produces a stream of spherical droplets having a diameter of 30 μm and an initial velocity (u_0) of 25 m/s. The ink has a density of $10^3 \mathrm{kg/m}^3$. Each droplet carries an electric charge q whose value depends on the desired deflection. The range of q is from 0 to -60 fC (femtocoulombs). The deflection potential V_d is 2 kV.

(a) Ignoring the effects of air drag and gravity, what is the maximum possible vertical deflection y?

(b) What is the maximum vertical deflection if the effects of drag and gravity are taken into account. For simplicity, assume that the conditions are such that Stokes' Law gives a sufficiently accurate value for the drag force. According to Stokes' Law, the drag force on a sphere of radius r traveling at velocity u through a fluid (in this case air) of viscosity η is given by

$$F_D = 6\pi\eta r u$$

The viscosity of air at room temperature and 1 atm is $\eta = 1.81 \times 10^{-5} \mathrm{Ns/m}^2$.



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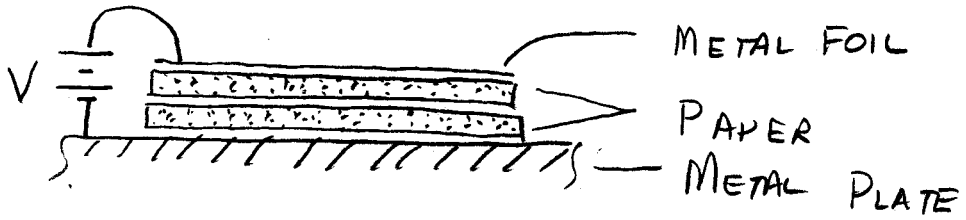
H2.3 The apparatus below is intended to be used as a replacement for a vacuum clamp for laminating two sheets of paper together, holding them flat and clamped together while the glue dries. The paper being used has a thickness of 0.002 in.

(a) For $V = 100$ V, what is the pressure holding the sheets together?

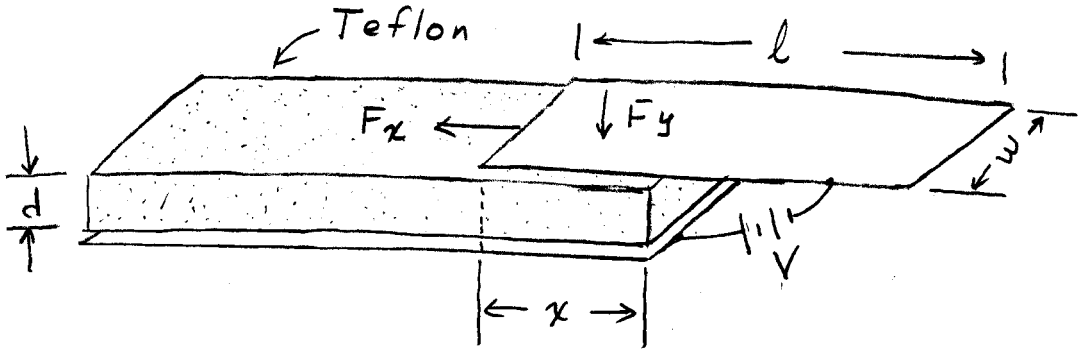
(b) What voltage would be required to equal the clamping force of a vacuum clamp?



H2.4 The device below consists of two steel plates, each 5 cm wide and 10 cm long, separated by a piece of teflon 1 mm thick. A voltage of 100 V is applied between the plates.

(a) If the amount of overlap (x) is 5 mm, what are the normal and tangential forces (F_y and F_x) on the top plate? (Neglect the weight of the plates.)

(b) If the top plate is released from the configuration in part (a), at what value of x will it come to rest?



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Quiz Problems.

Q2.1 The shaft, wheel, and block of the following system are made of cast iron. Assume that the shaft is free to rotate, supported by magic, frictionless bearings. Also assume that the cord supporting the weight is made of magic, massless rope. The total length of the rope is 4 feet, and it is firmly attached to the shaft on one end and to the block on the other. (The specific gravity of cast iron is 7.1.)

(a) What is the angular velocity of the wheel at the time the weight touches the ground?

(b) Sketch the velocity of the wheel as a function of time.