1. The immediate cause of many deaths is ventricular fibrillation, an uncoordinated quivering of the heart as opposed to proper beating. An electric shock to the chest can cause momentary paralysis of the heart muscle, after which the heart will sometimes start organized beating again. A *defibrillator* is a device that applies a strong electric shock to the chest over a time interval of a few milliseconds. The device contains a capacitor of several microfarads, charged to several thousand volts. Electrodes called paddles, about 8 cm across and coated with conducting paste, are held against the chest on both sides of the heart. Their handles are insulated to prevent injury to the operator, who calls "Clear!" and pushes a button on one paddle to discharge the capacitor through the patient's chest. Assume that an energy of 300 J is to be delivered from a 30.0-μF capacitor.

a. To what potential difference must it be charged?

Consider the following, a *defibrillator* connected to a 32 μF capacitor and a 47 kΩ resistor in a RC circuit. The circuitry in this system applies 5000 V to the RC circuit to charge it.

b. What is the time constant of this circuit?

c. What is the maximum charge on the capacitor?

d. What is the maximum current in the circuit during the charging process?

e. What are the charge and current as functions of time?

f. How much energy is stored in the capacitor when it is fully charged?

2. A 100 μF capacitor wired in a simple series *RC* circuit is initially charged to 10 μC and then discharged through a 10 kΩ resistor.

- What is the time constant of the circuit?
- What is the initial current that flows?
- How much charge is left on the capacitor after 1 time constant?
- What is the current after 1 time constant?
- How much charge is left on the capacitor after 3 time constants have elapsed and what current is flowing then?

3. The Earth's atmosphere is able to act as a capacitor, with one plate the ground and the other the clouds and in between the plates an air gap. Air, however, is not a perfect insulator and can be made to conduct, so that the separation of charges from the cloud to ground can be bridged. Such an event is called a lightning strike. For this question, we'll model the atmosphere as a spherical capacitor and try to calculate the number of lightning strikes that happen every day. First, let's assume that the clouds are distributed around the entire Earth at a distance of 5000 m above the ground of area $4\pi R^2_{Earth}$, where R_{Earth} = 6400km.

- What is the resistance of the air gap?

Next we need to calculate the capacitance of the Earth-cloud capacitor. Here we will use the fact that the capacitance and we'll calculate ΔV. Assuming that we have a spherical charge distribution, so that ΔV is the difference in potential between the lower plate (the Earth's surface) and the upper plate (the clouds) and that in a typical day, 5×10^5 C of charge is spread over the surface of the Earth.

- What is ΔV?
- What is the capacitance of the Earth-cloud capacitor?

Since the accumulated charge will dissipate through the air, we have a simple RC circuit.

- What is the time constant for this discharge that is spread over the whole surface of the earth?

Experimentally it is found that for each lightning strike about 25 C of negative charge is delivered to the ground.

- What is the number of lightning for this amount of charge?
- Approximately how long would it take the Earth-cloud capacitor to discharge to 0.3% of its initial amount?
- How many lightning strokes per day?

Of NASCAR, airplanes and dryer sheets: **When a car travels down the road it interacts with the air it's passing through. Frictional forces between the car and the surrounding air rip electrons from the air and deposit them on the car. This creates a separation of and thus the car can become highly charged.**

When the car stops moving, the accumulated charge discharges through the tires as a capacitor can discharge through a resistor. If a person outside the car attempts to touch the car before it is discharged, a painful spark could occur. Worse yet, if fuel vapors are present, the spark could cause a fire or explosion. This is especially dangerous in the sport of *NASCAR*. Consider the just stopped *NASCAR* above, with an effective capacitance (the car being one plate and the ground the other) of 500×10^{-12} F and an initial electric potential of -30 kV relative to the ground.

a. If the charge discharges through the 4 tires (which can be considered 4 resistors in parallel), what is the time constant for this discharge of the car if R_{tire} = 500 MW?
b. What is the initial stored energy associated with the charge on the car?
c. How long would it take for the energy stored to dissipate to 50mJ (which is probably less energy than is needed to cause an explosion) as the car discharges through the tires?
d. During pit-stops the crew runs to the car to refuel it or make any necessary changes. Given the haste of the crew, should the tires be of high or low resistance? Explain your reasoning.
e. Friction is responsible for charging the car and the frictional force due to air can be modeled by $F = \frac{1}{2}C_D A\rho v^2$. What is the magnitude of the frictional force if a NASCAR were traveling 190 mi/hr (~84 m/s?)
f. If the car body acts as the upper plate and is taken to be roughly 1m above the ground, how much charge is transferred to the car due to friction?
g. How long would it take to dissipate this stored energy to 50mJ?


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