THERMAL & CHEMICAL EFFECT OF CURRENT

1. A room heater is rated 500 W, 220 V.
a) find the electric resistance of the room heater.
b) if the line voltage drops to 200 V, find the wattage of the heater.
c) if an electric bulb rated 100 W, 220 V is connected in series with the heater find the power delivered by heater and bulb at rated supply voltage.

Answer: a) 96.8 Ω, b) 413 W, c) 13.9 W and 69.7 W

2. Two bulbs rated as 250 V, 100 W and 250 V, 40 W are connected in series. The combination is connected across the 250 V supply. Find
a) powers produced by them individually,
b) maximum supply voltage the series combination can safely withstand,
c) powers produced by both the bulbs individually at this potential.

Answer: a) 20.41 W, 8.16; b) 350 V; c) 16 W, 40 W

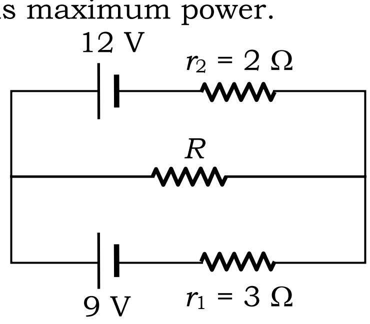
3. A supply line connects a source maintained at constant voltage of 250 V to an electric heater rated as 250 V, 1000 W at a distance of 500 m from the source. If the heater produces 810 W, find the resistance per unit length of the wire of the supply line.

Answer: 6.94 mΩ m^{-1}

4. A 250 V, 100 W bulb can produce 121 W safely. What voltage fluctuation it can withstand in terms of % change in applied voltage.

Answer: 10%

5. For what value of resistance R in the following circuit, the power produced in it will be maximum. Also find this maximum power.



Answer: 1.2 Ω, 24.3 W

6. When a battery is shorted by the resistance wires of resistances R_1 and R_2 turn by turn, it produces same thermal power in them. Find the internal resistance of the battery.

Answer: $r = \sqrt{R_1 R_2}$

7. Find the amount of heat generated in the coil of resistance R due to a charge Q flowing through it, if the current in the coil decreases continuously down to zero halving its value in every τ seconds.

{ **Hint :** Current as a function of time is $\left(i = i_0 2^{-t/\tau}\right)$ and $\int_0^\infty i\,dt = Q$}

Answer: $\dfrac{Q^2 R \ln 2}{2\tau}$

8. If the diameter of a cylindrical filament decreases by 2% due to evaporation. By what % the potential across it should be changed to maintain same temperature. The amount of heat radiated to environment is directly proportional to curved surface area of the filament.

Answer: increase by 1%

9. A silver and a copper voltammeter are connected in series with a 12.0 V battery of negligible internal resistance. It is found that 0.806 g of silver is deposited in half an hour. Find
a) the mass of the copper deposited and
b) the energy supplied by the battery.
ECE of silver = 1.12×10^{-6} kg/C, and that of copper = 6.6×10^{-7} kg/C.

Answer: a) 0.475 gm; b) 8.64×10^{3} J

10. Potential difference across the terminals of a battery of emf 12 V and internal resistance 2 Ω drops to 10 V when it is connected to a silver voltammeter. Find the silver deposited at the cathode in half an hour. Atomic weight of silver is 107.9 g/mole.

Answer: 2 g

11. A brass plate having surface area 200 cm^2 on one side is electroplated with 0.10 mm thick silver layers on both sides using a 15 A current. Find the time taken to complete the job. The density of silver is 10.5×10^{3} kg/m^3 and the atomic weight is 107.9 g/mole.

Answer: 42 minutes approximately.

12. An emersion heater rated as 225 V, 1000 W is connect to 200 V supply and immersed in a water jug containing 2 liters of water at 20°C. If on an average 90% of the heat produced by heater goes to water, find the time it takes for the water to start boiling. Given, mechanical equivalent of heat J = 4.2 Jouls/call.

Answer: 15 min. 45 sec.

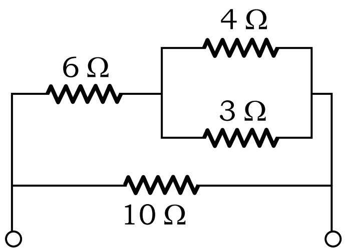
13. When a battery is connected across an external resistance the potential difference across its terminals drops from 12 V to 11.2 V. Find the efficiency of at which battery is operating.

Answer: 93.3%

14. If an electric heater operates at an average efficiency of 60%, find the cost of boiling 900 ml of water from 20°C. Electricity rates are Rs. 4.50 per unit, specific heat of water is 1 call/gm-°C and mechanical equivalent of heat J = 4.2 Jouls/call.

Answer: 63 paisa.

15. If power generated in 3Ω resistance is 12 W Find the power generated in 10 Ω Resistance in the following circuit.



Answer: 72.9 W

16. A bulb rated as *W* watt, *V* volt is supplied with current from *n* cells in series each of emf *E*, volt and internal resistance *r*. Find the number *n* to run the bulb at rated power *W*.

Answer: $\dfrac{RW}{(EV - rW)}$

17. An emersion heater produces 950 W in boiling water. If it is kept outside the water, in equilibrium the filament temperature becomes 200°C. What power will it produce if the temperature coefficient of the resistance of filament is $\alpha_R = 4.5 \times 10^{-3}$ per °C.

Answer: 725 W

18. Find the % change in power produced by a resistance wire if due to stretching its length increases by 2%. Assume uniform stretching and volume of wire remaining constant during stretching.

Answer: 4% decrease.

19. Find the armature resistance of an electric motor connected across a dc source of 200 V. The motor draws 10 amp and runs at 40% efficiency.

Answer: 12 Ω

20. Find the neutral, and inversion temperature of copper-iron thermocouple if the cold junction temperature is 0°C. (α_{Cu} = 2.76 μV °C^{-1}, β_{Cu} = 0.012 μV °C^{-2}, α_{Fe} = 16.6 μV °C^{-1}, β_{Fe} = –0.03 μV °C^{-2}).

Answer: 329.5°C, 659°C

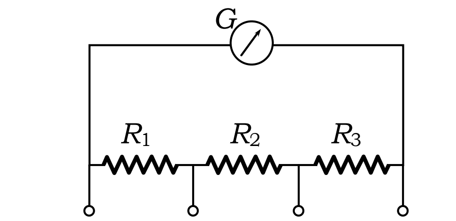
21. A moving coil galvanometer of resistance 20 Ω gives full scale deflection for the current of 1 mA. It is to be converted into an ammeter of range 20 A. The shunt of 0.005 Ω is available. What resistance should be connected in series with the galvanometer coil.

Answer: 30Ω

22. A fuse made of lead wire has an area of cross-section 0.2 mm^2. On short-circuiting, the current in the fuse wire reaches 30 A. How long after the short–circuiting, will the fuse begin to melt? For lead, the specific heat = 0.032 cal g^{-1} °C^{-1}, melting point = 327 °C, density = 11.34 g cm^{-3} and the resistivity = 22 × 10^{-6} Ω cm. The initial temperature of the wire is 20°C. Neglect heat losses due to radiation.

Answer: 0.945 ms

23. The galvanometer shown in figure has a resistance of 50 Ω and current required for full scale deflection is 1 mA. Find the resistance R_1, R_2 and R_3 required to convert it into ammeter having ranges as indicated

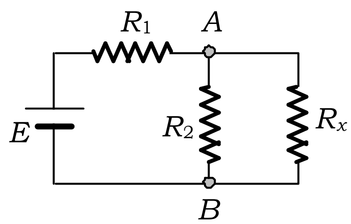


Answer: $\frac{1}{198}\Omega, \frac{1}{22}\Omega, \frac{5}{11}\Omega$

24. A galvanometer has a current sensitivity of 1 mA per division. A variable shunt is connected across the galvanometer and the combination is put in series with a resistance of 500 Ω and cell of internal resistance 0.5 Ω. It gives a deflection of 5 division for shunt of 5 Ω and 20 division for shunt of 25 Ω. Find the emf of cell and resistance of galvanometer.

Answer: 47.1 V, 88.2 Ω

25. In the figure the voltage source of emf E provides a constant voltage and has negligible internal resistance. Then if R_1 = 20 Ω and R_2 = 30 Ω, the value of resistance R_x is such that the power generated in it is practically independent of small variations of its value. Then R_x is



Answer: $R_x = 12\Omega$

26. A capacitor of capacitance 8 μF is joined to a battery of emf 6.0 V through a resistance of 24 Ω. Find the current in the circuit

a) just after the connections are made,

b) one time constant after the connections are made.

Answer: a) 0.25 A, b) 0.09 A

27. How many time constants will elapse before the
a) current in a charging RC circuit drops to half of its initial value?
b) current in a discharging RC circuit drops to half of its initial value?
c) energy stored in capacitor reaches half of its steady state value in a charging RC circuit?
d) power delivered by battery drops to half of its maximum value in RC circuit? drops to half of its initial value?

Answer: a) 0.69, b) 0.69, c) 1.23, d) 0.69

28. In a charging RC circuit with emf of battery E, find the maximum rate at which energy is being stored in the capacitor and the time at which this rate is maximum.

Answer: $\frac{E^2}{4R}$, $RC\ln 2$

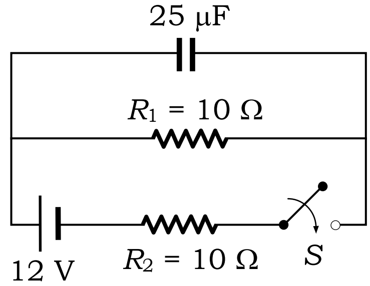
29. A capacitor C, charged to a potential V is discharged through a resistance R by connecting it across the resistance at t = 0. Find the heat dissipated in one time constant after the connections are made
a) using change in energy stored in capacitor
b) using $\int i^2 R dt$

Answer: $\frac{CV^2}{2}\left(1-\frac{1}{e^2}\right)$

30. A parallel plate capacitor is filled completely with a dielectric material having resistivity ρ and dielectric constant k. The capacitor is charged and disconnected. Now the capacitor starts discharging through the dielectric present between the plates. Find the time constant of discharging of the capacitor, notice that this time constant is independent of all geometrical parameters of the capacitor.

Answer: $k \in_0 \rho$

31. The switch S shown in figure is kept closed for a long time so that the capacitor attains steady state. At t = 0 the switch is opened. Find the current in resistance R_1 as function of time.



Answer: 11 mA

32. A capacitor of capacitance 100 μF is connected across a battery of emf 6.0 V through a resistance of 20 kΩ for 4.0 s. The battery is then replaced by a conductor. Find the charge on the capacitor 4.0 s after the replacement of battery.

Answer: 70 μC

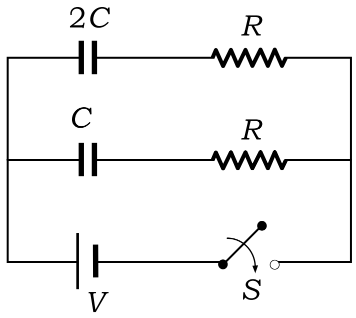
33. A capacitor of capacitance C is given a charge Q. At t = 0, it is connected to an uncharged capacitor of same capacitance C through a resistance R. Find the charge on the capacitor which was initially uncharged, as a function of time.

Answer: $\frac{Q}{2}\left(1-e^{-\frac{2t}{RC}}\right)$

34. A capacitor of capacitance C is given a charge Q. At t = 0, it is connected to a battery of emf E and internal resistance r. Find the charge on the capacitor as a function of time.

Answer: $CE\left(1-e^{-\frac{t}{rC}}\right)+Qe^{-\frac{t}{rC}}$

35. In the circuit shown in figure switch S is closed at time $t = 0$. Find the ratio i_1/i_2 as a function of time.



Answer: $e^{\frac{t}{2RC}}$

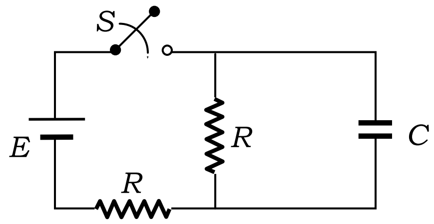
36. The electric field between the plates of a parallel plate capacitor of capacitance 2.0 μF drops to one third of its initial value in 4.4 μs when the plates are connected by a thin wire. Find the resistance of the wire.

Answer: 2.0 Ω

37. A capacitor is connected to a 12 V battery through a resistance of 10 Ω. It is found that the potential difference across the capacitor rises to 4.0 V in 1 μs. Find the capacitance of the capacitor.

Answer: 0.25 μF

38. At $t = 0$ the switch S is closed. Find the voltage across the capacitor as a function of time in the following circuit.



Answer: $\frac{E}{2}\left(1-e^{-\frac{2t}{RC}}\right)$

39. A circuit consists of a cell of emf E with negligible internal resistance, a resistance R and a capacitor of capacitance C connected in series in a single loop. With capacitor fully charged, at $t = 0$ the capacitance of capacitor is abruptly changed to C/η. Find the current flowing through the circuit as function of time.

Answer: $i=\frac{(\eta-1)E}{R}e^{-\frac{\eta t}{RC}}$

40. A 5.0 μF capacitor having charge of 20 μC is discharged through a wire of resistance 5.0 Ω. Find the heat dissipated in the wire between 25 to 50 μs after the connections are made.

Answer: 4.7 μJ