Name: ______________________

AP Physics C: E&M

Unit 4 Complete Review

Electric Circuits

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1. In a wire, the charge flowing through a cross-section is given by

$$q = at + bt^2$$

where a and b are constants. What is the current i in the wire at time t?

(A) $a + bt$
(B) $at + 2bt$
(C) $a + 2bt$
(D) $2a + bt$

2. In a wire, the current varies with time according to

$$i = 4t$$

where t is measured in seconds. What is the total number of electrons that pass through a cross-section of the wire from $t = 0$ to $t = t_0$?

(A) $\frac{4t_0^2}{e}$
(B) $\frac{2t_0^2}{e}$
(C) $\frac{t_0^2}{e}$
(D) $\frac{8t_0^2}{e}$

3. An electric heater is rated at 60 W when connected to a 120 V source. What is the resistance of the heating element?

(A) 60 Ω
(B) 120 Ω
(C) 180 Ω
(D) 240 Ω

4. Two cylindrical copper conductors are made from the same material. Conductor 1 has length L and cross-sectional area A. Conductor 2 has length $2L$ and cross-sectional area $4A$. What is the ratio of the resistance of Conductor 2 to the resistance of Conductor 1?

(A) $\frac{1}{4}$
(B) $\frac{1}{2}$
(C) 1
(D) 2

5. In a conducting material, E represents the magnitude of the electric field and J represents the current density. What physical quantity is represented by the ratio $\frac{E}{J}$?

(A) Resistance
(B) Resistivity
(C) Voltage
(D) Current

6. Two copper wires have different cross-sectional areas and carry different currents. Wire I has cross-sectional area A and carries current I. Wire II has cross-sectional area $2A$ and carries current $4I$. What is the ratio of the drift speed in Wire II to the drift speed in Wire I?

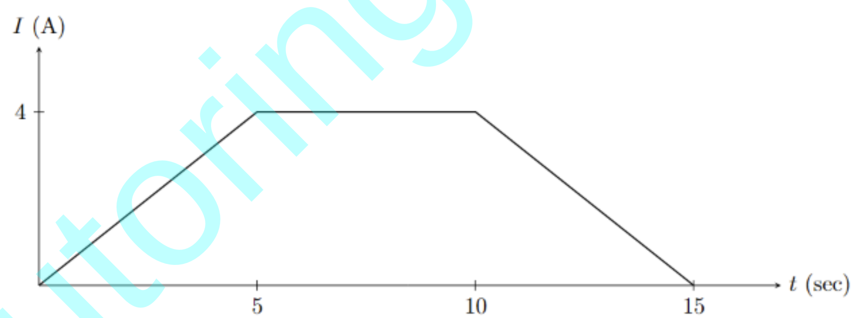
(A) $\frac{2}{1}$

(B) $\frac{1}{2}$

(C) $\frac{4}{1}$

(D) $\frac{1}{4}$

7. The current i through a wire varies with time as shown in the graph below. What is the total number of electrons that pass through a cross-section of the wire during the first 15 s?



(A) $\frac{20}{e}$

(B) $\frac{30}{e}$

(C) $\frac{40}{e}$

(D) $\frac{50}{e}$

8. A cylindrical wire of radius R carries a current density given by

$$J = J_0\left(1 - \frac{r^2}{R^2}\right),$$

where r is the distance from the axis of the wire. What is the total current through the wire?

(A) $\dfrac{\pi J_0 R^2}{4}$

(B) $\dfrac{\pi J_0 R^2}{2}$

(C) $\pi J_0 R^2$

(D) $\dfrac{3\pi J_0 R^2}{4}$

9. A cylindrical resistor of length L and cross-sectional area A has a resistivity that varies with position according to

$$\rho(x) = \rho_0(1 + \alpha x),$$

where x is measured from one end of the resistor ($0 \leq x \leq L$). What is the total resistance of the resistor?

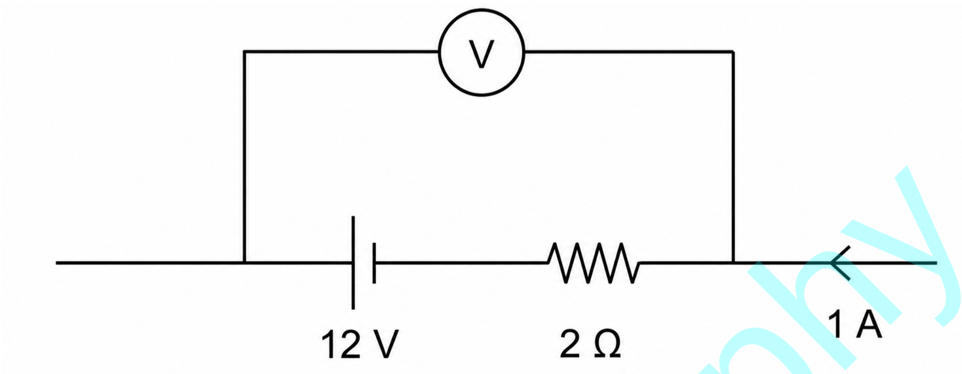
(A) $\dfrac{\rho_0}{A}\left(L + \alpha L^2\right)$

(B) $\dfrac{\rho_0}{A}\left(L + \dfrac{\alpha L^2}{2}\right)$

(C) $\dfrac{\rho_0 L}{A}(1 + \alpha L)$

(D) $\dfrac{\rho_0}{A}\left(\dfrac{L}{2} + \alpha L^2\right)$

10. A rechargeable battery has an emf of 12 V and an internal resistance of 2 Ω. A current of 1 A flows through the battery in the direction shown. An ideal voltmeter is connected across the battery terminals. What is the reading of the voltmeter?



(A) 4 V

(B) 8 V

(C) 10 V

(D) 12 V

11. A portable device is connected to an ideal 9 V battery. The total resistance of the circuit is 40.5 Ω. How much electrical energy is converted into other forms during a time interval of 60 s?

(A) 120 J

(B) 240 J

(C) 360 J

(D) 60 J

12. The current through a resistor of resistance R varies with time according to

$$I(t) = kt,$$

where k is a positive constant. How much energy is dissipated by the resistor during the time interval $0 \leq t \leq t_f$?

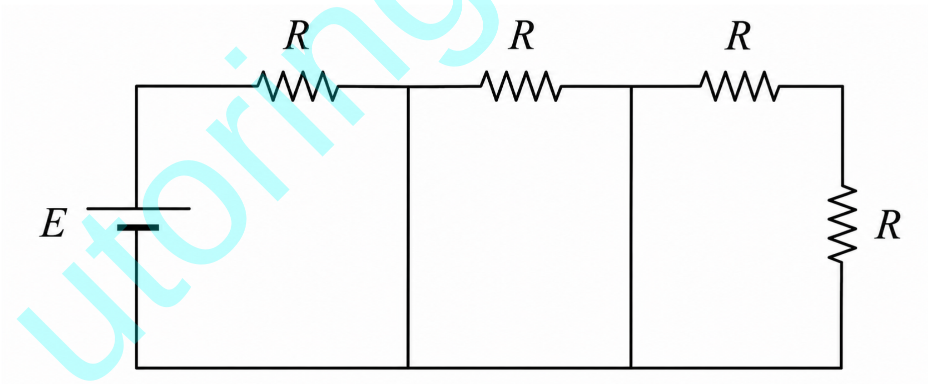
(A) kRt_f

(B) $k^2Rt_f^2$

(C) $2k^2Rt_f$

(D) $\frac{1}{3}k^2Rt_f^3$

13. The circuit shown consists of five identical resistors, each of resistance R, connected to an ideal battery of emf E. The vertical wires are ideal conductors. What is the current supplied by the battery?



(A) $\frac{E}{2R}$

(B) $\frac{E}{R}$

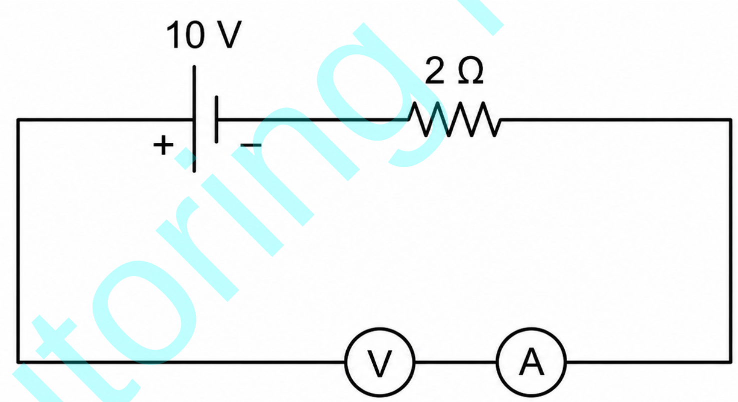
(C) $\frac{4E}{R}$

(D) $\frac{E}{4R}$

14. To measure the current through a circuit element and the potential difference across it, how should an ideal ammeter and an ideal voltmeter be connected?

	Ammeter	Voltmeter
(A)	In parallel	In series
(B)	In parallel	In parallel
(C)	In series	In series
(D)	In series	In parallel

15. The circuit shown contains a 10 V ideal battery, a 2 Ω resistor, an ideal voltmeter, and an ideal ammeter. What is the reading of the voltmeter?



(A) 0 V
(B) 5 V
(C) 1 V
(D) 10 V

16. An ammeter has an internal resistance of $3.6 \times 10^{-3}\ \Omega$ and gives full-scale deflection when the current through it reaches 0.2 A. A circuit is expected to carry a maximum current of 2 A. Which of the following modifications would allow the meter to measure the current without exceeding full-scale deflection?

(A) Connect a $3.6 \times 10^{-3}\ \Omega$ resistor in parallel with the ammeter.

(B) Connect a $3.6 \times 10^{-3}\ \Omega$ resistor in series with the ammeter.

(C) Connect a $4 \times 10^{-4}\ \Omega$ resistor in parallel with the ammeter.

(D) Connect a $4 \times 10^{-4}\ \Omega$ resistor in series with the ammeter.

17. A voltmeter has an internal resistance of $20\ \Omega$ and gives full-scale deflection when the voltage across it reaches 2 V. A circuit is expected to contain voltages as large as 120 V. Which of the following modifications would allow the meter to measure the voltage without exceeding full-scale deflection?

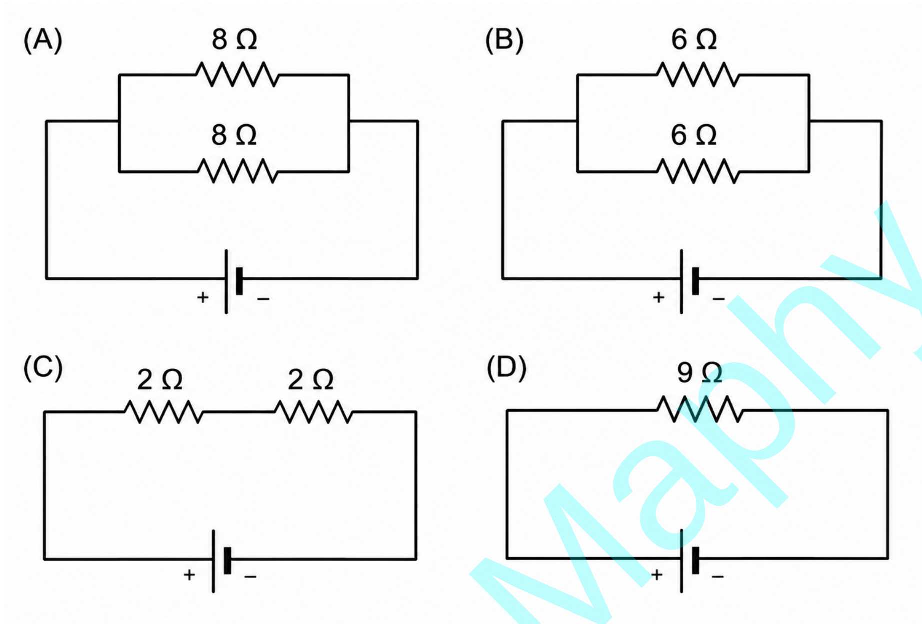
(A) Connect an 11,800 Ω resistor in series with the voltmeter.

(B) Connect an 11,800 Ω resistor in parallel with the voltmeter.

(C) Connect a 1,180 Ω resistor in series with the voltmeter.

(D) Connect a 1,180 Ω resistor in parallel with the voltmeter.

18. Five different circuits are connected to identical batteries with negligible internal resistance, as shown below.



(i) Which circuit draws the smallest current from the battery?

(A) Circuit A
(B) Circuit B
(C) Circuit C
(D) Circuit D

(ii) Which circuit dissipates the greatest electrical power?

(A) Circuit A
(B) Circuit B
(C) Circuit C
(D) Circuit D

19. A battery has an emf of 6 V. When it supplies a current of 0.5 A to an external circuit, the terminal voltage is measured to be 5.8 V. What is the internal resistance of the battery?

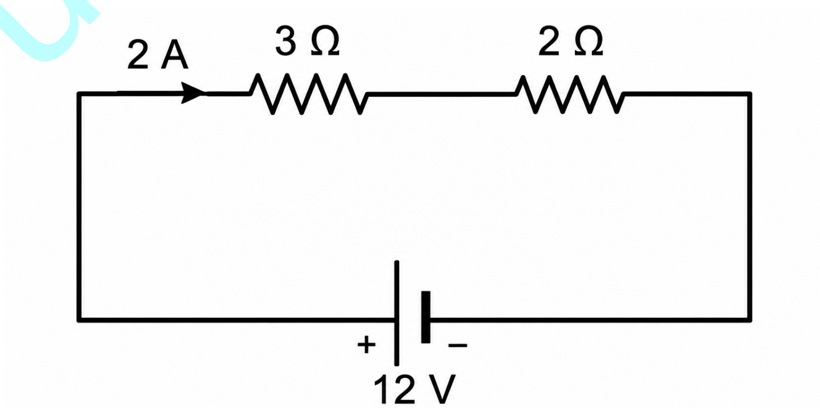
(A) 0.4 Ω
(B) 4 Ω
(C) 0.6 Ω
(D) 6 Ω

20. A cylindrical wire is connected to an ideal battery that maintains a constant voltage across the wire. The wire has length L, diameter d, and resistivity ρ. By decreasing which of the following quantities can the power dissipated by the wire be increased?

(A) L only
(B) d only
(C) L and ρ only
(D) d and ρ only

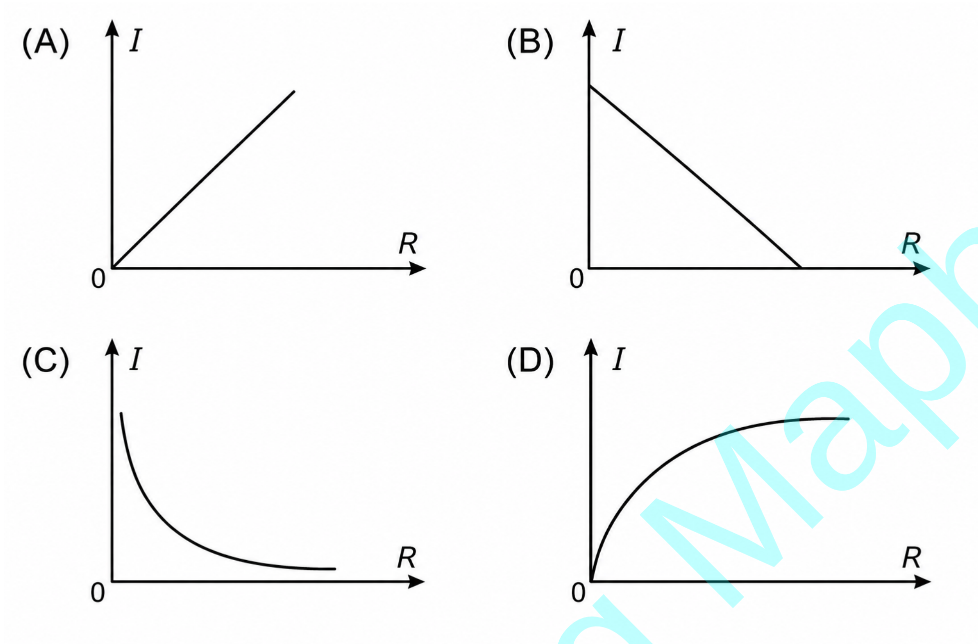
21. A circuit contains two resistors of 3 Ω and 2 Ω connected in series to a 12 V battery. The current in the circuit is 2 A.

What is the internal resistance of the battery?

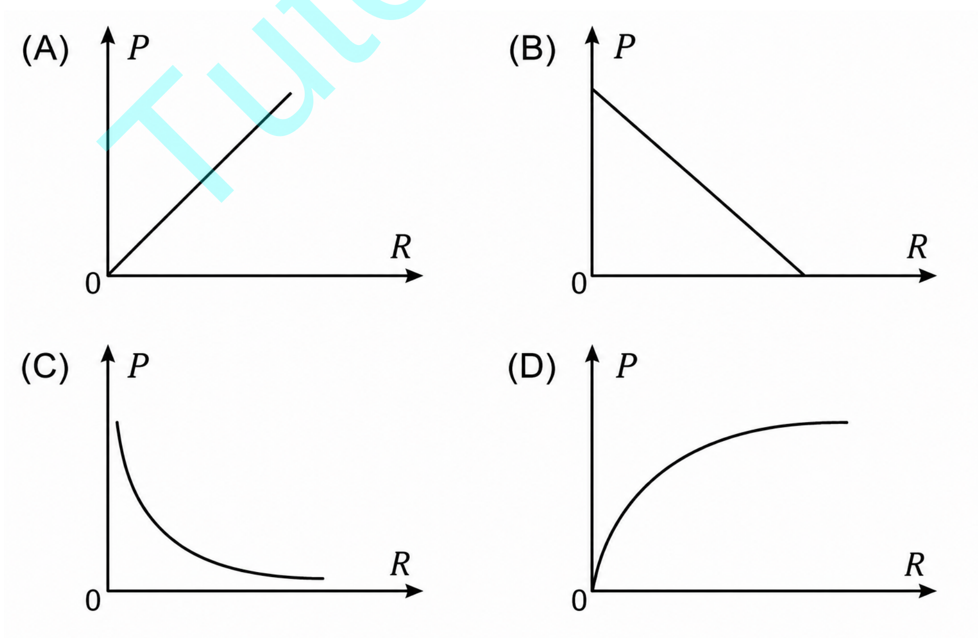


(A) 1 Ω
(B) 2 Ω
(C) 3 Ω
(D) 0.5 Ω

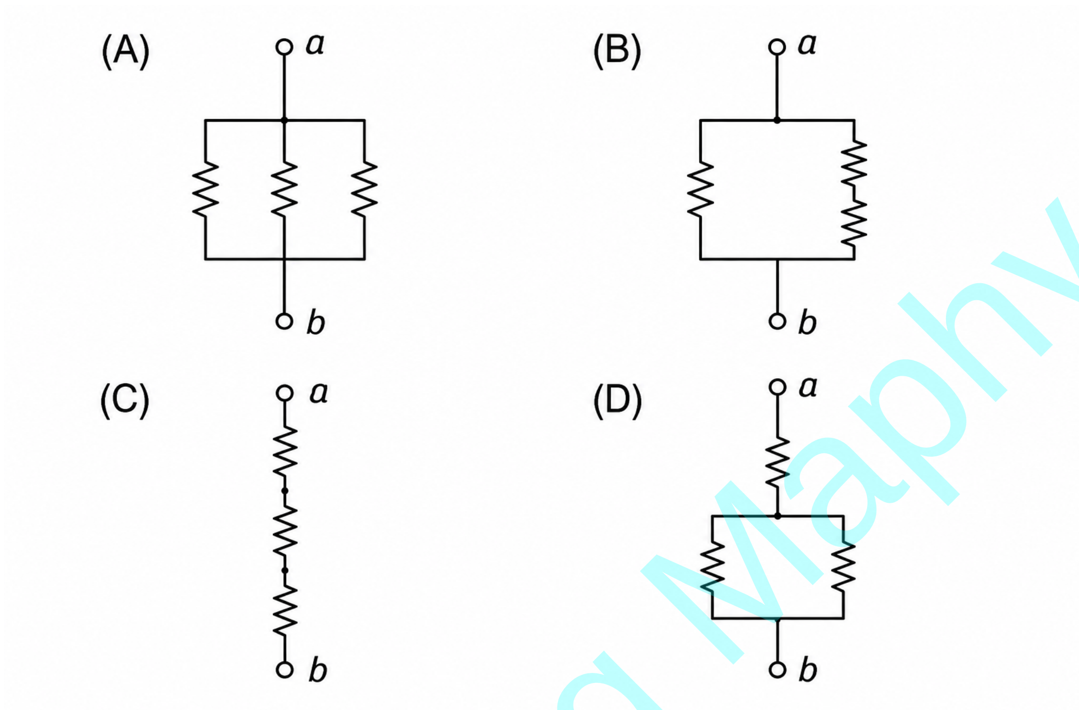
22. An ohmic conductor is connected across a source that maintains a constant potential difference V. Which of the following graphs best represents the current I in the conductor as a function of its resistance R?



23. A variable resistor is connected across an ideal battery that maintains a constant voltage. Which of the following graphs best represents the power dissipated by the resistor as a function of its resistance R?



24. Four circuits are constructed using three identical resistors. Which circuit has the greatest equivalent resistance?

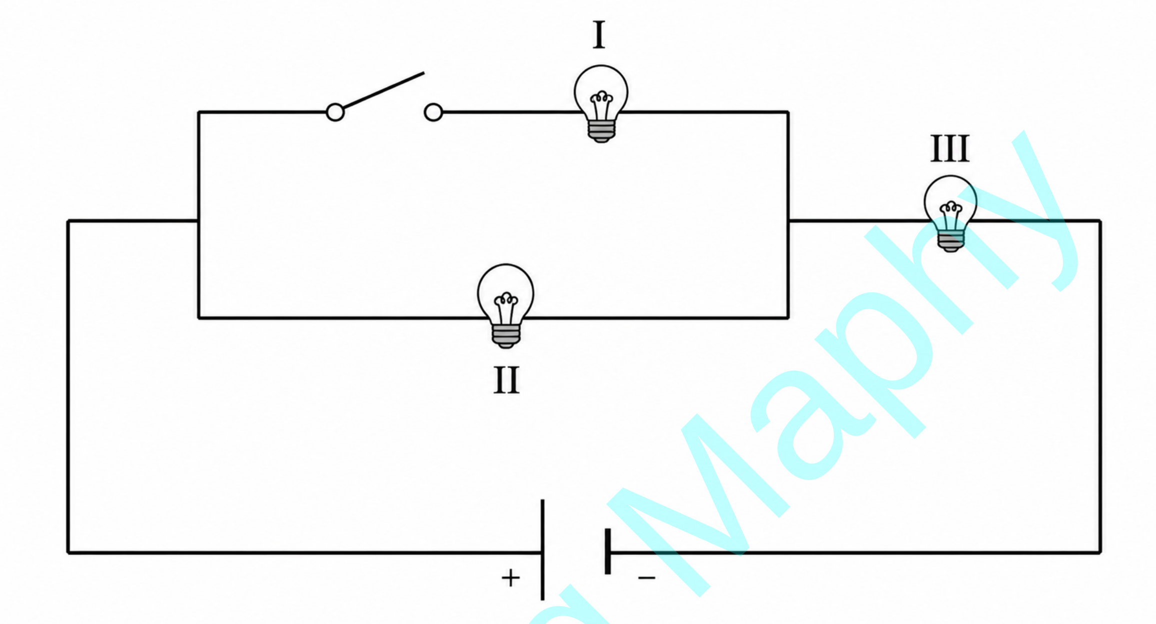


25. A resistor of resistance R dissipates power P when a current I flows through it. The resistor is replaced by another resistor with resistance $3R$, while the current remains the same. What is the power dissipated by the new resistor?

(A) $\frac{P}{9}$
(B) $\frac{P}{3}$
(C) P
(D) $3P$

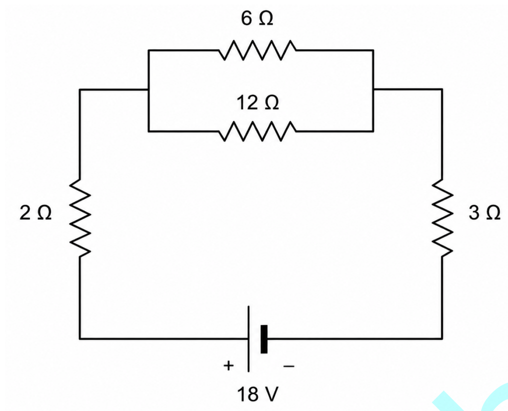
26. The circuit shown contains three identical light bulbs. Initially, the switch in the branch containing bulb I is closed. The switch is then opened.

How does the brightness of bulb II and bulb III change?



	Bulb II	Bulb III
(A)	Gets brighter	Gets dimmer
(B)	Gets dimmer	Gets brighter
(C)	Gets brighter	Gets brighter
(D)	Gets dimmer	Gets dimmer

27. For the circuit shown,



(i) What is the current supplied by the battery?

(A) 4 A
(B) 2 A
(C) 1 A
(D) 0.5 A

(ii) What is the potential difference across the 2 Ω resistor?

(A) 1 V
(B) 2 V
(C) 4 V
(D) 6 V

(iii) What is the power dissipated by the 6 Ω resistor?

(A) 10.7 W
(B) 5.3 W
(C) 24.5 W
(D) 37.2 W

28. A battery with emf ε and internal resistance R supplies current to a light bulb of resistance r. What is the total power dissipated in the circuit?

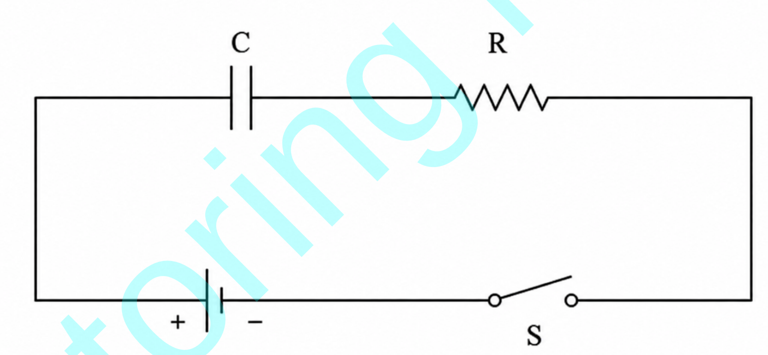
(A) $\dfrac{\varepsilon^2}{R+r}$

(B) $\dfrac{(\varepsilon - IR)^2}{R}$

(C) $\dfrac{(\varepsilon - IR)^2}{R+r}$

(D) $\dfrac{\varepsilon^2}{R}$

29. Consider the circuit below



(i) Immediately after the switch is closed, which of the following best describes the current through resistor R and the charge on the capacitor?

	Current I	Charge Q
(A)	Zero	Maximum
(B)	Maximum	Zero
(C)	Zero	Zero
(D)	Maximum	Maximum

(ii) After the switch has been closed for a long time, which of the following best describes the current through resistor R and the charge on the capacitor?

	Current I	Charge Q
(A)	Zero	Maximum
(B)	Maximum	Zero
(C)	Zero	Zero
(D)	Maximum	Maximum

(iii) The resistor has resistance $R = 1 \times 10^6\ \Omega$ and the capacitor has capacitance $C = 1$ nF. What is the time constant of the circuit?

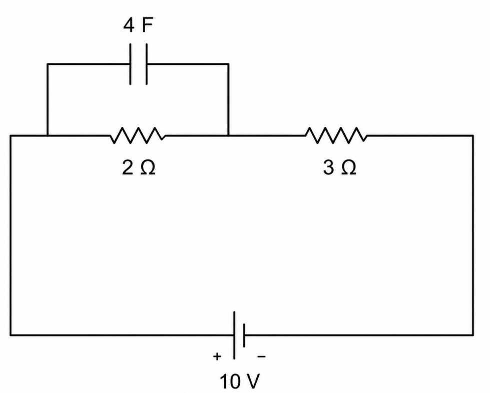
(A) 10^{-6} s

(B) 10^{-3} s

(C) 10^{-9} s

(D) 10^{6} s

30. The circuit shown contains a 10 V battery, a 4 F capacitor, and resistors of 2 Ω and 3 Ω. The circuit has reached steady state.



(i) What is the current supplied by the battery?

(A) 1 A

(B) 2 A

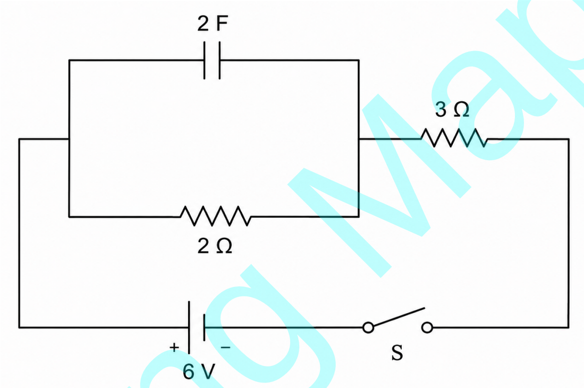
(C) 4 A

(D) 5 A

(ii) What is the charge stored on the capacitor?

(A) 8 C
(B) 16 C
(C) 20 C
(D) 40 C

31. In the circuit shown, the capacitor is initially uncharged. The switch S is closed at $t = 0$.



(i) What is the current through the branch containing the 2 F capacitor immediately after the switch is closed?

(A) 0 A
(B) 1.2 A
(C) 2.0 A
(D) 2.4 A

(ii) What is the current through the branch containing the 2 Ω resistor immediately after the switch is closed?

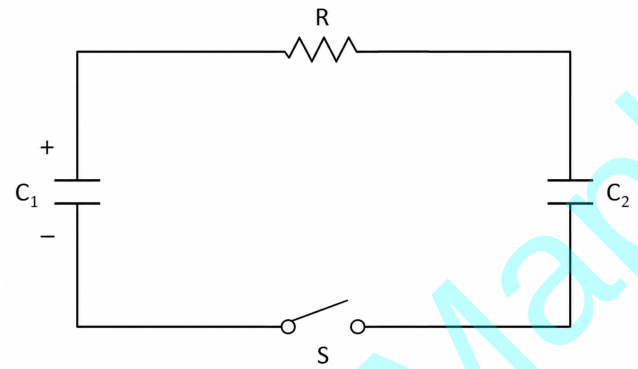
(A) 0 A
(B) 1.2 A
(C) 2.0 A
(D) 2.4 A

FRQ

32. Part I

Two capacitors, $C_1 = 6\ \mu$F and $C_2 = 18\ \mu$F, are connected in series with a resistor $R = 120\ \Omega$ and a switch S, as shown below. Initially, capacitor C_1 is charged to 120 V and capacitor C_2 is uncharged.

At time $t = 0$, the switch is closed.



(a) Determine the final voltage across each capacitor after equilibrium is reached.

(b) Determine the charge on each capacitor after the system reaches equilibrium.

(c) Calculate the difference between the initial energy stored in the capacitor system and the final energy stored in the capacitor system.

(d) The current in the resistor is modeled by

$$I(t) = I_0 e^{-t/\tau}$$

where I_0 is the initial current immediately after the switch is closed and τ is the time constant of the circuit.

Determine I_0 and τ values.

(e) Using integral calculus, determine the total energy dissipated in the resistor from $t = 0$ until equilibrium is reached.

Is the result obtained consistent with your answer to part (c)? Justify your answer using a conservation principle.

Part II

A second trial is performed. Immediately after the switch is closed, the plate separation of capacitor C_2 is reduced to one-half its original value and then held fixed.

(f) Without performing any numerical calculations, determine whether the time constant τ of the circuit is greater than, less than, or equal to the time constant in the original experiment.