It is known that about one electron per atom of copper contributes to the current. The atomic mass of copper is 63.54 g and its density is 8.92 g/cm³. Calculate the average drift speed of electrons traveling through a copper wire with a cross-sectional area of 1 mm² when carrying a current of 1 A (values similar to those for the electric wire to your study lamp).

Correct answer: \(7.38624 \times 10^{-5} \text{ m/s}\).

Explanation:

Given:

- \(N = 1\),
- \(M = 63.54 \text{ g}\),
- \(\rho = 8.92 \text{ g/cm}^3\),
- \(A = 1 \text{ mm}^2 = 1 \times 10^{-6} \text{ m}^2\),
- \(I = 1 \text{ A}\), and
- \(q_e = 1.602 \times 10^{-19} \text{ C/electron}\).

We first calculate \(n\), the number of current-carrying electrons per unit volume in copper. Assuming one free conduction electron per atom, \(n = \frac{N_A \rho}{M}\), where \(N_A\) is Avogadro’s number and \(\rho\) and \(M\) are the density and the atomic weight of copper, respectively

\[n = \left(\frac{\text{1 electron}}{\text{atom}}\right) \frac{N_A \rho}{M} = \frac{6.02 \times 10^{23} \text{ atoms}}{63.54 \text{ g}} \cdot \frac{(8.92 \text{ g/cm}^3)}{\frac{10^6 \text{ cm}^3}{1 \text{ m}^3}} = 8.45112 \times 10^{28} \text{ electrons/m}^3.

The drift speed is \(v_d\),

\[v_d = \frac{I}{n q_e A} = \frac{1 \text{ A}}{8.45112 \times 10^{28} \text{ electrons/m}^3 \cdot \frac{1}{1.602 \times 10^{-19} \text{ C/electron}} \cdot \frac{1}{(1 \times 10^{-6} \text{ m}^2)} = 7.38624 \times 10^{-5} \text{ m/s}}.\]
For the voltage $V$ from Part 1 and the resistance $R_{\text{wet}},$

$$I = \frac{V_{\text{min}}}{R_{\text{wet}}}$$

$$= \frac{100 \text{ V}}{5300 \Omega \left( \frac{1000 \text{ mA}}{1 \text{ A}} \right)}$$

$$= 18.8679 \text{ mA}.$$ 

---

**004 (part 3 of 3) 0 points**

What would be the minimum voltage that would produce a current that could be felt when the skin is wet?

Correct answer: 5.3 V.

**Explanation:**

Given : $I_{\text{min}} = 1 \text{ mA}$, and $R_{\text{wet}} = 5300 \Omega$.

$$V_1 = I_{\text{min}} R_{\text{wet}}$$

$$= (1 \text{ mA}) \left( \frac{1 \text{ A}}{1000 \text{ mA}} \right) (5300 \Omega)$$

$$= 5.3 \text{ V}.$$ 

---

**005 (part 1 of 4) 0 points**

If the current carried by a metallic conductor is doubled,

(a) What happens to the charge carrier density? Assume that the temperature of the metallic conductor remains constant.

1. It quadruples.
2. It is unchanged. **correct**
3. It is quartered.
4. It quadruples.
5. It is halved.

**Explanation:**

Basic Concept:

$$J = \sigma E = n q v_d$$

$$v_d = \frac{q E}{m \tau}.$$ 

---

**006 (part 2 of 4) 0 points**

(b) What happens to the current density?

1. It doubles. **correct**
2. It is unchanged.
3. It is quartered.
4. It quadruples.
5. It is halved.

**Explanation:**

The current density $J = \frac{I}{A}$ only depends on the current $I$ and the cross-sectional area of the conductor $A$, so if $I$ doubles and $A$ remains the same, $J$ must also double:

$$J' = \frac{2I}{A} = 2 \frac{I}{A} = 2J.$$ 

---

**007 (part 3 of 4) 0 points**

(c) What happens to the electron drift velocity?

1. It is unchanged.
2. It is halved.
3. It is quartered.
4. It quadruples.
5. It doubles. **correct**

**Explanation:**

The electron drift velocity $v_d$ is given by

$$v_d = \frac{I}{n q A},$$

where $q$ is the charge of an electron. So if $I$ doubles, $v_d$ must also double:

$$v_{d}' = \frac{2I}{n q A} = 2 \frac{I}{n q A} = 2v_d.$$
008 (part 4 of 4) 0 points
(d) What happens to the average time between collisions?

1. It doubles.
2. It is halved.
3. It is quartered.
4. It is unchanged. **correct**
5. It quadruples.

**Explanation:**
The average time \( \tau \) between collisions is given by
\[
\tau = \frac{v d m}{q E},
\]
where \( m \) is the mass of an electron and \( E \) is the applied electric field (determined by Ohm’s Law: \( J = \sigma E \)).
Substituting for \( E \),
\[
\tau = \frac{v d m \sigma}{q J}.
\]
Since \( v_d \) and \( J \) are each multiplied by a factor of two, the factors of two cancel (as long as \( \sigma \) does not change due to heating). All the other variables remain the same (as long as \( \sigma \) does not change due to heating). Therefore \( \tau \) remains unchanged.

009 (part 1 of 2) 0 points
The circuit below shows four identical bulbs connected to an ideal battery, which has negligible internal resistance. Rank the bulbs in order from brightest to dimmest.

![Circuit Diagram]

1. \( D > C > B > A \)
2. \( B = C > A = D \)
3. \( D > B = C > A \)
4. \( A = C > D > B \)
5. \( A = D > B = C \) **correct**
6. \( A = B = C = D \)
7. \( A = B > D = C \)
8. \( A > B = C > D \)
9. \( A > B > C > D \)
10. \( A = B = C > D \)

**Explanation:**
From the figure, the total resistance of the circuit is \( 2R + \frac{R}{2} = \frac{5R}{2} \). Then
\[
I_A = I_D = \frac{V}{5R} = \frac{2V}{5} = 0.4 \frac{V}{R}
\]
\[
I_B = I_C = \frac{1}{2}I_A = \frac{1}{2} \frac{V}{5R} = 0.2 \frac{V}{R}
\]
The rankings of the currents are also the corresponding rankings of the brightness.

010 (part 2 of 2) 0 points
Suppose a switch has been added to the circuit as shown. The switch is initially closed.

When the switch is opened, what happens to the currents through bulbs A, B, and D?

1. \( I_A \) decreases, \( I_B \) remains the same, \( I_D \) decreases.
2. \( I_A \) remains the same, \( I_B \) decreases, \( I_D \) remains the same
3. \( I_A \) increases, \( I_B \) increases, \( I_D \) increases.
4. $I_A$ remains the same, $I_B$ increases, $I_D$ remains the same.

5. $I_A$ decreases, $I_B$ increases, $I_D$ decreases. correct

6. $I_A$ remains the same, $I_B$ remains the same, $I_D$ remains the same.

7. $I_A$ increases, $I_B$ remains the same, $I_D$ decreases.

8. $I_A$ increases, $I_B$ remains the same, $I_D$ increases.

9. $I_A$ increases, $I_B$ decreases, $I_D$ increases.

10. $I_A$ decreases, $I_B$ decreases, $I_D$ decreases.

Explanation:
With the switch open, the total resistance of the circuit is $3R$, so
$$I_A = I_B = I_D = \frac{V}{3R} = 0.33 \frac{V}{R}$$

This is to be compared with the case that the switch is closed, where from previous part, $I_A = I_D = 0.4 \frac{V}{R}$ and $I_B = 0.2 \frac{V}{R}$. So for the present case, $I_A$ and $I_D$ decrease and $I_B$ increases.

011 (part 1 of 4) 0 points
A battery has an emf of 12 V and an internal resistance of 0.13 Ω. Its terminals are connected to a load resistance of 2 Ω.

Find the current in the circuit. correct

Correct answer: 5.6338 A.

Explanation:
Given: $\mathcal{E} = 12$ V,
$R = 2$ Ω, and
$r = 0.13$ Ω.

The total resistance is $R + r$, so
$$I = \frac{\mathcal{E}}{R + r} = \frac{12 \text{ V}}{2 \Omega + 0.13 \Omega} = 5.6338 \text{ A}.$$

012 (part 2 of 4) 0 points
Calculate the terminal voltage of the battery. Correct answer: 11.2676 V.

Explanation:
The terminal voltage $V$ of the battery is equal to
$$V_r = \mathcal{E} - Ir = 12 \text{ V} - (5.6338 \text{ A})(0.13 \Omega) = 11.2676 \text{ V}.$$

013 (part 3 of 4) 0 points
Find the power dissipated in the load resistor. Correct answer: 63.4795 W.

Explanation:
The power dissipated in the load resistor is
$$P_R = I^2R = (5.6338 \text{ A})^2(2 \Omega) = 63.4795 \text{ W}.$$

014 (part 4 of 4) 0 points
Find the power dissipated in the battery. Correct answer: 4.12617 W.

Explanation:
The power dissipated in the battery is
$$P_t = I^2r = (5.6338 \text{ A})^2(0.13 \Omega) = 4.12617 \text{ W}.$$

015 (part 1 of 2) 0 points
In the figure below the switch $S$ is initially in position “1”. Given, $R_1 = R_2 = R_3$. Neglect the internal resistance of the battery.
What happens to the current through $R_3$ when the switch is moved to the open position “2”.

1. The current through $R_3$ decreases to two-thirds its original value.

2. The current through $R_3$ increases to twice its original value.

3. The current through $R_3$ increases to three-halves its original value.

4. The current through $R_3$ is reduced to one-half its original value.

5. The current through $R_3$ remains the same. correct

Explanation:
The voltage across $R_3$ is the $E$ of the battery, and is unchanged. The current through $R_3$ remains the same, $\frac{E}{R_3}$.

016 (part 2 of 2) 0 points
What happens when switch $S$ is moved to position “3”, leaving $R_2$ and $R_3$ parallel?

1. The current through $R_2$ is half what it was with $R_1$ in the circuit.

2. The current through $R_2$ and $R_3$ are now the same. correct

3. The current through $R_3$ increases.

4. The current through $R_3$ decreases.

5. The current through $R_2$ remains the same as when $R_1$ was in the circuit.

Explanation:
Since $R_2$ and $R_3$ have the same terminal voltage and resistance, the current through $R_2$ and $R_3$ must now be the same.

017 (part 1 of 1) 0 points
Consider the following circuit containing identical bulbs.

1. $A = B = C = D = E$

2. $A = D = E > B = C$

3. $B = C > A = D = E$

4. $A = B = C > D = E$ correct

5. $A = B = C > D > E$

6. $A = B > A = D = E$

7. $A = C > B > D = E$

8. $A = D = E > B > C$

9. $C > B > A > D > E$

10. $E = D > A > B = C$

Explanation:
The potential across bulbs $A$, $B$ and $C$ is $V$. The potential across bulbs $D$ and $E$ is $\frac{V}{2}$. Thus

$$i_A = i_B = i_C = \frac{V}{R}$$

$$i_D = i_E = \frac{V}{2R}.$$

018 (part 1 of 2) 0 points
Four identical light bulbs are connected either in series (circuit 1) or parallel (circuit 2)
to a constant voltage battery with negligible internal resistance, as shown.

We can see that the bulbs in circuit 2 are more than 4 times brighter than the bulbs in circuit 1.

019 (part 2 of 2) 0 points
If one of the bulbs in circuit 2 is unscrewed and removed from its socket, the remaining 3 bulbs

1. go out.
2. are unaffected. correct
3. become brighter.
4. become dimmer.

Explanation:
Since the bulbs are parallel, after one of the bulbs is unscrewed, the voltage across each remaining bulb is unchanged, and the brightness is unaffected.

020 (part 1 of 3) 0 points
Hint: Apply the Kirchhoff’s law to the loop ACDA.

Given: $2R_1 = 2R_4 = R_2 = R_3$, $R_1 = r$. $I$ is the current entering and leaving the circuit.

Each current shown in the figure is denoted by the same subscript as the resistor through which it flows (e.g., $i_1$ is the current flowing through $R_1$).

Find the ratio $\frac{i_1}{i_2}$.

1. $\frac{i_1}{i_2} = 2$ correct
2. $\frac{i_1}{i_2} = \frac{1}{3}$
3. $\frac{i_1}{i_2} = 3$
4. $\frac{i_1}{i_2} = 1$
5. $\frac{i_1}{i_2} = \frac{1}{2}$
6. $\frac{i_1}{i_2} = \frac{1}{4}$
7. $\frac{i_1}{i_2} = 4$

**Explanation:**

Given:

- $R_1 = r$
- $R_2 = 2r$
- $R_3 = 2r$, and
- $R_4 = r$.

![Diagram](image)

**Basic Concept:** DC Circuit.

**Solution:** Based on Kirchhoff’s law, the equation for the loop ACDA is given by

\[-i_1 R_1 + i_2 R_2 = 0\]

\[\Rightarrow \frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{2r}{r} = 2.\]

4. $i_5 = \frac{I}{3}$ correct
5. $i_5 = \frac{I}{2}$
6. $i_5 = \frac{I}{5}$
7. $i_5 = \frac{I}{7}$
8. $i_5 = \frac{I}{4}$

**Explanation:**

\[i_1 = 2i_2\]

\[I = i_1 + i_2 = 2i_2 + i_2 = 3i_2\]

\[\Rightarrow i_2 = \frac{I}{3}\]

\[\Rightarrow i_1 = \frac{2I}{3}.\]

Following a similar analysis, one finds that $\frac{i_4}{i_3} = 2$, so that $i_3 = \frac{I}{3}$ and $i_4 = \frac{2I}{3}$.

**Note:** The junction equation at D is

\[i_2 + i_5 = i_4\]

\[\Rightarrow i_5 = i_4 - i_2, \quad \text{or}\]

\[= i_3 - i_1\]

\[= \frac{I}{3} - \frac{2I}{3} = -\frac{I}{3}\]

\[|i_5| = \frac{I}{3}.\]

**022** (part 3 of 3) 0 points

Find the resistance $R_{AB}$.

1. $R_{AB} = 3r$
2. $R_{AB} = 0$
3. $R_{AB} = r$
4. $R_{AB} = 2r$
5. $R_{AB} = \frac{4}{3}r$ correct
6. \( R_{AB} = \frac{1}{3} r \)
7. \( R_{AB} = \frac{2}{3} r \)
8. \( R_{AB} = \frac{3}{2} r \)
9. \( R_{AB} = \frac{5}{3} r \)

Explaination:
By inspection, the following circuit is equivalent to the original circuit.

\[ R_{AB} = 2 \frac{R_1 R_2}{R_1 + R_2} = 2 \frac{2 r^2}{r + 2r} = \frac{4}{3} r \]

023 (part 1 of 3) 0 points
Consider a cubic resistor network shown, where all the resistors are the same. Each resistor has a resistance \( r \). A current \( I \) comes into the network at A. The same current leaves the network at B. Determine \( I_{AC} \), i.e. the current between points A and C.

1. \( \frac{I}{3} \) correct
2. \( \frac{I}{4} \)
3. \( \frac{I}{9} \)
4. \( \frac{I}{5} \)
5. \( I \)
6. \( \frac{I}{6} \)
7. \( \frac{I}{2} \)

Explaination:
Basic Concept: Symmetry in circuits.
Solution:
Go through the network systematically from A to B. The current enters at A. Since the network is completely symmetric, there can be no difference in resistance for the three possible paths the current can split into at A. Thus, each of the three must carry identical current, and they must add up to \( I \) (since no current is lost at the junction):

\[ I_{AC} = \frac{I}{3} \]

024 (part 2 of 3) 0 points
Determine \( I_{CD} \), i.e. the current between points C and D.

1. \( \frac{I}{9} \)
2. \( \frac{I}{4} \)
3. \( \frac{I}{2} \)
4. \( I \)
5. \( \frac{I}{5} \)
6. $I_C = \frac{I}{6}$ correct

7. $I_A = \frac{I}{3}$

Explanation:
Now we are at C. The current coming in from A has two possible choices of path, and again there is complete symmetry between the two. Thus the current going through C splits in half:

$$I_{CD} = \frac{I_{AC}}{2} = \frac{I}{6}$$

---

025 (part 3 of 3) 0 points

Determine $R_{AB}$; i.e. the effective resistance between points A and B.

1. $\frac{r}{3}$
2. $\frac{r}{6}$
3. $\frac{5r}{6}$ correct
4. $\frac{r}{2}$
5. $r$
6. $\frac{4r}{3}$
7. $\frac{2r}{3}$
8. $\frac{3r}{2}$
9. $\frac{7r}{6}$

Explanation:
Finally, we calculate the equivalent resistance. We can step through the path ACDB to find the potential $V_{AB}$ between A and B. Kirchhoff’s Laws tell us that each time we cross a resistor (moving with the current) we drop a potential $V = RI$. Therefore

$$V_A - V_B = rI_{AC} + rI_{CD} + rI_{DB}$$

Now note that $I_{AC} = I_{DB}$ by symmetry, so

$$V_A - V_B = |V_{AB}| = r \left( \frac{I}{3} + \frac{I}{6} + \frac{I}{3} \right) = \frac{5}{6}rI$$

Now $|V_{AB}| = R_{AB}I$, so

$$R_{AB} = \frac{5}{6}r$$

---

026 (part 1 of 2) 0 points

Two identical light bulbs A and B are connected in series to a constant voltage source. Suppose a wire is connected across bulb B as shown.

Bulb A

1. will burn half as brightly as before.
2. will burn as brightly as before.
3. will burn nearly four times as brightly as before. correct
4. will burn twice as brightly as before.
5. will go out.

Explanation:
The electric power is given by

$$P = I^2R = \frac{V^2}{R}.$$ Before the wire is connected, $I_A = I_B = \frac{V}{2R}$ so that

$$P_A = \frac{V^2}{4R}.$$ After the wire is connected, $I'_A = \frac{V}{R}$ and $I'_A = 0$, so

$$I'_B = 0$$

$$P'_A = \frac{V^2}{R} = 4P_A.$$
027 (part 2 of 2) 0 points

and bulb B

1. will burn nearly four times as brightly as before.
2. will burn half as brightly as before.
3. will go out. correct
4. will burn as brightly as before.
5. will burn twice as brightly as before.

Explanation:
Since there is no potential difference between the two ends of bulb B, it goes off.

028 (part 1 of 3) 0 points

Consider the circuit shown below.

Apply Kirchhoff’s rules. What equation does the loop ABCDA yield?

1. \(-\mathcal{E}_1 - \mathcal{E}_2 - i_2 r_2 + i_1 r_1 = 0\)
2. \(-\mathcal{E}_1 - \mathcal{E}_2 + i_2 r_2 - i_1 r_1 = 0\)
3. \(\mathcal{E}_1 - \mathcal{E}_2 - i_2 r_2 - i_1 r_1 = 0\)
4. \(-\mathcal{E}_1 + \mathcal{E}_2 + i_2 r_2 + i_1 r_1 = 0\)
5. \(\mathcal{E}_1 + \mathcal{E}_2 - i_2 r_2 + i_1 r_1 = 0\)
6. \(\mathcal{E}_1 - \mathcal{E}_2 + i_2 r_2 - i_1 r_1 = 0\) correct
7. \(\mathcal{E}_1 + \mathcal{E}_2 + i_2 r_2 - i_1 r_1 = 0\)

Explanation:

DCFED : \(\mathcal{E}_2 - i R - i_2 r_2 = 0\).

029 (part 2 of 3) 0 points

What equation does the loop DCFED yield?

1. \(-\mathcal{E}_2 - i_2 r_2 + i R = 0\)
2. \(-\mathcal{E}_2 + i_2 r_2 - i R = 0\)
3. \(-\mathcal{E}_2 - i_2 r_2 - i R = 0\)
4. \(\mathcal{E}_2 - i_2 r_2 - i R = 0\) correct
5. \(\mathcal{E}_2 + i_2 r_2 - i R = 0\)
6. \(\mathcal{E}_2 + i_2 r_2 + i R = 0\)
7. \(\mathcal{E}_2 - i_2 r_2 + i R = 0\)

Explanation:

030 (part 3 of 3) 0 points

Let: \(\mathcal{E}_1 = \mathcal{E}_2 = \mathcal{E}\), and \(r_1 = r_2 = r\), where \(\mathcal{E} = 9\) V and \(r = 2.4\) Ω. Also \(R = 4.1\) Ω.

Hint: From symmetry, one expects \(i_1 = i_2\).

Find the current \(i\).

Correct answer: 1.69811 A.

Explanation:

Given : \(\mathcal{E}_1 = \mathcal{E}_2 = \mathcal{E} = 9\) V, 
\(r_1 = r_2 = 2.4\) Ω, and 
\(R = 4.1\) Ω.

We are given that \(\mathcal{E}_1 = \mathcal{E}_2\) and \(r_1 = r_2\). This implies that \(i_1 = i_2\). (Why? Look at the loops
DCFED and ABFEA and see if there are any similarities.) Hence the junction rule yields
\[ i_1 + i_2 = 2i_2 = i \]
\[ \Rightarrow i_2 = \frac{i}{2} . \]
Substituting this into the loop equation DCFED,
\[ \varepsilon_2 - i R - i \frac{r_2}{2} = 0 \]
Solving for \( i \) yields
\[ i = \frac{\varepsilon_2}{R + \frac{r_2}{2}} = \frac{9 \text{ V}}{4.1 \Omega + \frac{2.4 \Omega}{2}} \]
\[ = 1.69811 \text{ A} . \]

7. \( I_{t=0} = (R_1 + R_2) V_o \)

8. \( I_{t=0} = \frac{V_o}{R_1} \) **correct**

Explanation:
When the switch is in position “a” at \( t = 0 \), there is no potential drop across the capacitor.

Note: There is no current flowing through \( R_2 \), so the entire potential drop, \( V_o \), is across the resistor \( R_1 \).

From Ohm’s law,
\[ I = \frac{V_o}{R_1} . \]

032 (part 2 of 3) 0 points
Leave the switch at position “a” for a long time, then move the switch from “a” to “b”.
When the switch is in position “b”, what is the time constant, \( \tau \), of the circuit?

1. \( \tau = \frac{R_1}{C} \)

2. \( \tau = R_1 C \)

3. \( \tau = \frac{R_2}{C} \)

4. \( \tau = \frac{R_1 R_2}{R_1 + R_2} C \)

5. \( \tau = \frac{R_1 R_2}{(R_1 + R_2) C} \)

6. \( \tau = \frac{(R_1 + R_2)}{C} \)

7. \( \tau = \frac{R_1 + R_2}{R_1 R_2 C} \)

8. \( \tau = \frac{R_1 + R_2}{R_1 R_2 C} \)

9. \( \tau = R_2 C \)

10. \( \tau = (R_1 + R_2) C \) **correct**

Explanation:
When the switch is in position “b”, \( R_1 \) and \( R_2 \) are now in series so the equivalent resistance is \( R = R_1 + R_2 \). By definition, the time constant is
\[ \tau = RC = (R_1 + R_2) C . \]

031 (part 1 of 3) 0 points
Consider the circuit shown below, the capacitor is initially uncharged.

After \( S \) is switched to position “a”, the initial current through \( R_1 \) is

1. \( I_{t=0} = \frac{R_1 R_2}{R_1 + R_2} V_o \)

2. \( I_{t=0} = R_1 V_o \)

3. \( I_{t=0} = \frac{V_o}{R_1 + R_2} \)

4. \( I_{t=0} = R_2 V_o \)

5. \( I_{t=0} = \frac{R_1 + R_2}{R_1 R_2} V_o \)

6. \( I_{t=0} = \frac{V_o}{R_2} \)
Let: \( V_o = 9 \text{ V}, \ C = 1 \ \mu \text{F}, \ R_1 = 7 \ \Omega, \) and \( R_2 = 20 \ \Omega. \)

At a time \( \frac{3}{2} \tau \) after \( S \) has been switched to position “b”, what is the power consumption of the circuit?
Correct answer: 0.149361 W.

Explanation:

Given:
\( V_o = 9 \text{ V}, \)
\( C = 1 \ \mu \text{F}, \)
\( R_1 = 7 \ \Omega, \) and \( R_2 = 20 \ \Omega. \)

While the capacitor is discharging, the magnitude of the current decreases as a function of time as
\[
I(t) = \frac{V_o}{R_1 + R_2} e^{-t/\tau}.
\]

Noting that \( R = R_1 + R_2, \) the power consumed by the circuit at \( t = \frac{3}{2} \tau \) is
\[
P = I^2(R_1 + R_2)
= \left[ \frac{V_o}{R_1 + R_2} e^{-3/2} \right]^2 (R_1 + R_2)
= \frac{V_o^2}{R_1 + R_2} e^{-3}
= \frac{(9 \text{ V})^2}{7 \ \Omega + 20 \ \Omega} e^{-3}
= 0.149361 \text{ W}.
\]

The switch on the circuit is closed at \( t = 0. \)
Find the charge on the capacitor at 4.73 s.
Correct answer: 19.626 \( \mu \text{C}. \)

Explanation:

Given:
\[
t = 4.73 \text{ s},
R = 1.1 \ \text{M} \Omega = 1.1 \times 10^6 \ \Omega,
C = 1.4 \ \mu \text{F} = 1.4 \times 10^{-6} \ \text{F}, \) and \( \mathcal{E} = 14.7 \ \text{V}. \)

At \( t = 4.73 \text{ s}, \)
\[
q = C \mathcal{E} \left(1 - e^{-t/(RC)}\right)
= (1.4 \times 10^{-6} \ \text{F})(14.7 \ \text{V}) \times
\left\{1 - \exp \left[-\frac{4.73 \text{ s}}{(1.1 \times 10^6 \ \Omega) (1.4 \times 10^{-6} \ \text{F})}\right]\right\}
= 1.9626 \times 10^{-5} \ \text{C}
= 19.626 \ \mu \text{C}.
\]
At 4.73 s the current in the resistor is $I$ (Part 2) and the charge on the capacitor is $q$ (Part 1).

What is the power delivered by the battery?
Correct answer: $9.10621 \ \mu W$.

**Explanation:**
In the time interval $\Delta t$, work done by the battery in pushing charge $\Delta q$ across the battery is

$$\Delta W_{\text{battery}} = \Delta q \cdot E.$$  

Correspondingly, the power is

$$\frac{dW_{\text{battery}}}{dt} = E \frac{dq}{dt} = I E.$$  

The power dissipated in a resistor is

$$\frac{dW_{\text{resistor}}}{dt} = I^2 R.$$  

The power to create the electric field in a capacitor is

$$\frac{dW_{\text{capacitor}}}{dt} = I \frac{q}{C}.$$  

Thus the total power dissipated in the capacitor and resistor, that is the power delivered by the battery is

$$\frac{dW_{\text{battery}}}{dt} = I \left( I R + \frac{q}{C} \right)$$  

$$= (6.1947 \times 10^{-7} \ \text{A})$$  

$$\times \left[ (6.1947 \times 10^{-7} \ \text{A}) (1.1 \times 10^6 \ \Omega)$$  

$$+ \frac{(1.9626 \times 10^{-5} \ \text{C})}{(1.4 \times 10^{-6} \ \text{F})} \right]$$  

$$= 9.10621 \times 10^{-6} \ \text{W}$$  

$$= 9.10621 \ \mu W.$$