

Electricity

Class 10 - CBSE Science | Chapter 11 | Worksheet & Test Paper

15 MCQs | 8 board questions | 8 practice problems

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SECTION A - Multiple Choice Questions (1 mark each)

1. The direction of conventional current in a circuit is:

- (a) the same as the direction in which the electrons move
- (b) opposite to the direction in which the electrons move
- (c) always from the lower to the higher potential
- (d) different in different parts of the same circuit

2. An ammeter and a voltmeter are to be connected in a circuit. The correct arrangement is:

- (a) both in series with the component
- (b) both in parallel with the component
- (c) ammeter in series, voltmeter in parallel
- (d) ammeter in parallel, voltmeter in series

3. Ohm's law holds only when which quantity is kept constant?

- (a) The temperature
- (b) The length of the conductor
- (c) The potential difference
- (d) The current

4. A wire is stretched so that its length doubles while its volume stays the same. Its new resistance is:

- (a) Half the original
- (b) Twice the original
- (c) Four times the original
- (d) Unchanged

5. Which quantity does NOT depend on the length or the thickness of a wire?

- (a) Its resistance
- (b) Its resistivity
- (c) The current through it
- (d) The heat produced in it

6. Heating elements of electric irons and toasters are made of an alloy such as nichrome because it:

- (a) is much cheaper than copper and easier to obtain
- (b) melts quickly so that the appliance switches itself off
- (c) conducts electricity better than any pure metal does
- (d) has high resistivity and does not oxidise readily when hot

7. Three resistors of 2 ohm, 3 ohm and 5 ohm are joined in series. The equivalent resistance is:

- (a) 10 ohm
- (b) 0.97 ohm
- (c) 3.33 ohm
- (d) 30 ohm

8. Two resistors of 6 ohm and 3 ohm are connected in parallel. The equivalent resistance is:

- (a) 9 ohm
- (b) 4.5 ohm
- (c) 2 ohm
- (d) 18 ohm

9. Domestic appliances are connected in parallel rather than in series mainly because:

- (a) each appliance gets the full voltage and works independently
- (b) a parallel circuit uses much less electrical energy overall
- (c) the total resistance of the circuit becomes larger that way
- (d) the very same current is then forced through every appliance

10. If the current through a heating element is doubled while its resistance stays the same, the heat produced in a given time becomes:

- (a) Twice as much
- (b) Half as much
- (c) Unchanged
- (d) Four times as much

11. An electric fuse is connected in series in a circuit and is made of a wire having:

- (a) low resistance and a high melting point
- (b) high resistance and a low melting point
- (c) high resistance and a high melting point
- (d) low resistance and a low melting point

12. A bulb is rated 60 W, 240 V. Its resistance while working is:

- (a) 4 ohm
- (b) 240 ohm
- (c) 960 ohm
- (d) 14400 ohm

13. One kilowatt hour is equal to:

- (a) 3.6×10^3 J
- (b) 3.6×10^6 J
- (c) 1000 J
- (d) 3600 J

14. The V-I graph for a metallic conductor at constant temperature is:

- (a) a curve bending towards the current axis
- (b) a straight line parallel to the current axis
- (c) a curve bending towards the voltage axis
- (d) a straight line through the origin

15. A 4 ohm and a 6 ohm resistor are in series, and this combination is connected across a 20 V supply. The current drawn is:

- (a) 2 A
- (b) 5 A
- (c) 0.5 A
- (d) 10 A

SECTION B - Board-style Questions

1. State Ohm's law. Draw the V-I graph for an ohmic conductor and explain how the resistance can be found from it. Why must the temperature be kept constant? [5 marks]

2. Derive the expression for the equivalent resistance of three resistors connected (a) in series and (b) in parallel. [5 marks]

3. A 6 ohm resistor and a 3 ohm resistor are connected in parallel, and this combination is joined in series with a 4 ohm resistor across a 12 V battery. Calculate (a) the equivalent resistance of the circuit, (b) the current drawn from the battery, and (c) the potential difference across the 4 ohm resistor. [5 marks]

4. State Joule's law of heating. An electric iron of resistance 20 ohm draws a current of 5 A. Calculate the heat produced in 30 seconds. [3 marks]

5. Why is tungsten used for the filament of an electric bulb? Why is the bulb filled with a chemically inactive gas? Why are the connecting wires of the bulb NOT made of tungsten? [3 marks]

6. Why are domestic appliances connected in parallel rather than in series? Give three reasons. [3 marks]

7. Define electric power and write its three forms. An electric bulb is rated 100 W, 220 V. Calculate (a) its resistance and (b) the energy it consumes in 5 hours, in kW h. [5 marks]

8. What is meant by the resistivity of a material? How does the resistance of a wire depend on its length and its area of cross-section? Why is copper used for connecting wires while nichrome is used for heating elements? [5 marks]

SECTION C - Practice Problems

1. A 4 ohm, a 6 ohm and a 12 ohm resistor are all connected in PARALLEL across a 12 V battery. Find (a) the equivalent resistance, (b) the current through each resistor, and (c) the total current drawn. Verify your answer for the total current in two different ways.

Hint: In parallel every resistor has the SAME potential difference across it.

2. A wire of resistance 10 ohm is cut into five equal pieces, and these five pieces are then joined in parallel. Find the resistance of the combination.

Hint: What happens to R when the length becomes one fifth? Then combine.

3. An electric heater of 1500 W is used for 4 hours a day. If electricity costs Rs. 6 per unit, calculate the cost of running it for 30 days.

Hint: Convert to kilowatts first - a 'unit' is a kilowatt hour.

4. Two lamps rated 100 W, 220 V and 60 W, 220 V are connected in parallel to a 220 V supply. Find the current drawn by each and the total current from the supply.

Hint: In parallel each lamp gets the full 220 V, so each works at its rated power.

5. You are given three resistors of 2 ohm, 3 ohm and 6 ohm. Show how you would connect them to obtain a total resistance of (a) 11 ohm and (b) 1 ohm.

Hint: For the largest total, think series; for a total smaller than every resistor, think parallel.

6. A copper wire has a resistance of 5 ohm. A second copper wire has twice the length and twice the diameter of the first. What is the resistance of the second wire? Explain each step.

Hint: Area depends on the SQUARE of the diameter - that is the step most students miss.

7. A fuse rated 5 A is fitted in a household circuit operating at 220 V. Determine the maximum total power of appliances that can be safely run, and state whether a 1500 W heater together with a 750 W iron can be used at the same time.

Hint: The fuse limits the CURRENT; convert that limit into a power limit.

8. A current of 0.5 A flows through a conductor for 4 minutes. Calculate (a) the charge that passes through it and (b) the number of electrons that constitute that charge.

Hint: Convert the time to seconds first, then use $Q = It$ and $Q = ne$.

ANSWER KEY

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Section A - MCQ answers

1. (b) opposite to the direction in which the electrons move

Electrons, being negative, drift from the negative terminal to the positive. Conventional current is defined as the direction positive charge would flow - from positive to negative - so it is opposite to the electron flow. This convention was fixed before the electron was discovered.

2. (c) ammeter in series, voltmeter in parallel

The ammeter must carry the same current as the component, so it goes in SERIES. The voltmeter must experience the same potential difference as the component, so it goes in PARALLEL, across it.

3. (a) The temperature

Ohm's law states V is directly proportional to I provided the physical conditions - chiefly the TEMPERATURE - remain unchanged. Omitting this condition when stating the law is one of the commonest ways to lose a mark.

4. (c) Four times the original

If the volume is constant and the length doubles, the area of cross-section must HALVE. Since $R = \rho L/A$, doubling L multiplies R by 2 and halving A multiplies it by 2 again, so the resistance becomes 4 times the original.

5. (b) Its resistivity

Resistivity (ρ) is a property of the MATERIAL alone - copper has the same resistivity whether the wire is long or short, thick or thin. Resistance, by contrast, does depend on the dimensions, through $R = \rho L/A$.

6. (d) has high resistivity and does not oxidise readily when hot

A heating element must have a high resistance so that plenty of heat is produced ($H = I^2 R t$), and it must survive being red hot without burning away. Nichrome satisfies both - high resistivity and resistance to oxidation at high temperature.

7. (a) 10 ohm

In series the resistances simply add: $R_s = 2 + 3 + 5 = 10$ ohm. Note that this is larger than the largest individual resistance (5 ohm), which is always true for a series combination.

8. (c) 2 ohm

$1/R_p = 1/6 + 1/3 = 1/6 + 2/6 = 3/6 = 1/2$, so $R_p = 2$ ohm. Using the product-over-sum shortcut for two resistors gives the same: $(6 \times 3)/(6 + 3) = 18/9 = 2$ ohm. Note it is smaller than the smaller resistance, 3 ohm.

9. (a) each appliance gets the full voltage and works independently

In parallel every appliance is across the same two supply points, so each receives the full 220 V, each draws the current it needs, each can be switched independently, and one failing does not break the circuit for the others.

10. (d) Four times as much

By Joule's law $H = I^2 R t$, the heat is proportional to the SQUARE of the current. Doubling I multiplies H by $2^2 = 4$. This square dependence is exactly why a small rise in current can overheat a wire.

11. (b) high resistance and a low melting point

A fuse must heat up strongly when the current is excessive (so it needs HIGH resistance, since $H = I^2 R t$) and must then melt before the appliance is damaged (so it needs a LOW melting point). Being in series, its melting breaks the whole circuit.

12. (c) 960 ohm

Use $P = V^2/R$, so $R = V^2/P = (240 \times 240)/60 = 57600/60 = 960$ ohm. Choosing the right form of the power equation for the quantities given is the whole skill in these numericals.

13. (b) 3.6×10^6 J

$1 \text{ kW h} = 1000 \text{ W} \times 3600 \text{ s} = 3,600,000 \text{ J} = 3.6 \times 10^6 \text{ J}$. This is the 'unit' you are charged for on an electricity bill - the commercial unit of electrical ENERGY, not of power.

14. (d) a straight line through the origin

Ohm's law makes V directly proportional to I , and a direct proportionality always plots as a straight line passing through the origin. The slope of that line, V/I , is the resistance of the conductor.

15. (a) 2 A

In series, $R = 4 + 6 = 10$ ohm. Then by Ohm's law $I = V/R = 20/10 = 2$ A. Since it is a series circuit, this same 2 A flows through both resistors.

Section B - Model answers

1. State Ohm's law. Draw the V-I graph for an ohmic conductor and explain how the resistance can be found from it. Why must the temperature be kept constant?

OHM'S LAW: the potential difference across the ends of a conductor is directly proportional to the current flowing through it, provided the physical conditions - in particular the TEMPERATURE - remain constant. That is, V is directly proportional to I , and hence $V = IR$, where the constant R is the resistance of the conductor, measured in ohms (Ω). GRAPH: plotting V (on the y-axis) against I (on the x-axis) gives a STRAIGHT LINE PASSING THROUGH THE ORIGIN. FINDING R : since $V = IR$, the SLOPE of that line equals R ; taking any point on the line, $R = V/I$. A steeper line therefore means a greater resistance. WHY TEMPERATURE MUST BE CONSTANT: the resistance of a conductor changes with temperature (for a metal it increases as the temperature rises). If the conductor heated up during the experiment, R would no longer be constant, V would not stay proportional to I , and the graph would curve instead of remaining straight.

2. Derive the expression for the equivalent resistance of three resistors connected (a) in series and (b) in parallel.

(a) SERIES. The resistors R_1 , R_2 and R_3 are joined end to end, so the SAME current I flows through each. The potential differences add: $V = V_1 + V_2 + V_3$. Applying Ohm's law to each, $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$, and to the whole combination, $V = IR_s$. Substituting: $IR_s = IR_1 + IR_2 + IR_3$. Dividing throughout by I gives $R_s = R_1 + R_2 + R_3$. (b) PARALLEL. The resistors are joined between the same two points, so the SAME potential difference V is across each. The currents add: $I = I_1 + I_2 + I_3$. Applying Ohm's law to each branch, $I_1 = V/R_1$, $I_2 = V/R_2$, $I_3 = V/R_3$, and to the whole combination, $I = V/R_p$. Substituting: $V/R_p = V/R_1 + V/R_2 + V/R_3$. Dividing throughout by V gives $1/R_p = 1/R_1 + 1/R_2 + 1/R_3$. NOTE: R_s is always greater than the largest resistance, while R_p is always smaller than the smallest.

3. A 6 ohm resistor and a 3 ohm resistor are connected in parallel, and this combination is joined in series with a 4 ohm resistor across a 12 V battery. Calculate (a) the equivalent resistance of the circuit, (b) the current drawn from the battery, and (c) the potential difference across the 4 ohm resistor.

(a) EQUIVALENT RESISTANCE. First the parallel pair: $1/R_p = 1/6 + 1/3 = 1/6 + 2/6 = 3/6 = 1/2$, so $R_p = 2$ ohm. This is in series with 4 ohm, so $R = R_p + 4 = 2 + 4 = 6$ ohm. (b) CURRENT FROM THE BATTERY. By Ohm's law, $I = V/R = 12/6 = 2$ A. (c) POTENTIAL DIFFERENCE ACROSS THE 4 ohm RESISTOR. The whole 2 A passes through it because it is in series, so $V_4 = IR = 2 \times 4 = 8$ V. (CHECK: the potential difference across the parallel section is $2 \times 2 = 4$ V, and $8 + 4 = 12$ V, which equals the supply - so the answer is consistent.)

4. State Joule's law of heating. An electric iron of resistance 20 ohm draws a current of 5 A. Calculate the heat produced in 30 seconds.

JOULE'S LAW OF HEATING: the heat produced in a resistor is directly proportional to (i) the SQUARE of the current, (ii) the resistance of the resistor, and (iii) the time for which the current flows. That is, $H = I^2Rt$. CALCULATION: given $I = 5$ A, $R = 20$ ohm, $t = 30$ s. $H = I^2Rt = (5)^2 \times 20 \times 30 = 25 \times 20 \times 30 = 500 \times 30 = 15000$ J. So the heat produced is 15000 J, that is 1.5×10^4 J.

5. Why is tungsten used for the filament of an electric bulb? Why is the bulb filled with a chemically inactive gas? Why are the connecting wires of the bulb NOT made of tungsten?

TUNGSTEN FOR THE FILAMENT: tungsten has a VERY HIGH MELTING POINT (about 3380°C), so it can be raised to a white-hot temperature and emit light without melting, and it also has a high resistivity, so a great deal of heat is produced in it. CHEMICALLY INACTIVE GAS: the bulb is filled with nitrogen or argon, which do not react with the hot filament; this prevents the filament from burning away and so makes it last much longer. CONNECTING WIRES NOT OF TUNGSTEN: the connecting wires must carry the current WITHOUT heating up, so they need a LOW resistance and low resistivity - copper is used. If they were made of tungsten they too would become hot and waste energy.

6. Why are domestic appliances connected in parallel rather than in series? Give three reasons.

(1) EACH APPLIANCE GETS THE FULL SUPPLY VOLTAGE. In a parallel connection every appliance is joined across the same two supply points, so each receives the full 220 V it is designed for. In series the supply voltage would be shared among them and none would work properly. (2) EACH CAN BE OPERATED INDEPENDENTLY, and if one appliance fails or is switched off, the circuit is not broken for the others, which keep working. In series, one failure would stop everything. (3) EACH APPLIANCE CAN DRAW THE DIFFERENT CURRENT IT NEEDS, since the total resistance in parallel is low and the current divides between the branches according to each appliance's resistance.

7. Define electric power and write its three forms. An electric bulb is rated 100 W, 220 V. Calculate (a) its resistance and (b) the energy it consumes in 5 hours, in kW h.

DEFINITION: electric power is the RATE at which electrical energy is consumed (or dissipated) in a circuit. THREE FORMS: $P = VI$, and using $V = IR$, also $P = I^2R$ and $P = V^2/R$. Unit: the watt (W); $1 \text{ W} = 1 \text{ J/s}$. (a) RESISTANCE: use $P = V^2/R$, so $R = V^2/P = (220 \times 220)/100 = 48400/100 = 484$ ohm. (b) ENERGY IN 5 HOURS: energy = power $\times$ time = $100 \text{ W} \times 5 \text{ h} = 500 \text{ W h} = 0.5 \text{ kW h}$. So the bulb consumes 0.5 kW h, that is half a 'unit' of electricity.

8. What is meant by the resistivity of a material? How does the resistance of a wire depend on its length and its area of cross-section? Why is copper used for connecting wires while nichrome is used for heating elements?

RESISTIVITY: the resistance of a wire is given by $R = \rho L/A$, where the constant ρ is the RESISTIVITY of the material. It is a characteristic of the MATERIAL alone and does not depend on the dimensions of the wire. Its SI unit is the ohm metre (ohm m). DEPENDENCE: resistance is DIRECTLY PROPORTIONAL to length (a longer wire has more resistance) and INVERSELY PROPORTIONAL to the area of cross-section (a thicker wire has less resistance). COPPER FOR CONNECTING WIRES: copper has a very LOW resistivity, so connecting wires made of it offer little resistance, waste very little energy as heat, and deliver almost the full voltage to the appliance.

NICHROME FOR HEATING ELEMENTS: nichrome has a HIGH resistivity, so a great deal of heat is produced in it ($H = I^2Rt$), and it does NOT oxidise readily even when red hot, so the element survives repeated heating.

Section C - Solutions

1. A 4 ohm, a 6 ohm and a 12 ohm resistor are all connected in PARALLEL across a 12 V battery. Find (a) the equivalent resistance, (b) the current through each resistor, and (c) the total current drawn. Verify your answer for the total current in two different ways.

(a) EQUIVALENT RESISTANCE: $1/R_p = 1/4 + 1/6 + 1/12$. Taking the LCM 12: $1/R_p = 3/12 + 2/12 + 1/12 = 6/12 = 1/2$, so $R_p = 2$ ohm. (Note it is smaller than the smallest resistor, 4 ohm, as it must be.) (b) CURRENT THROUGH EACH: each resistor has the full 12 V across it. $I_4 = 12/4 = 3$ A; $I_6 = 12/6 = 2$ A; $I_{12} = 12/12 = 1$ A. (c) TOTAL CURRENT - first way: add the branch currents, $I = 3 + 2 + 1 = 6$ A. Second way: use the equivalent resistance, $I = V/R_p = 12/2 = 6$ A. The two methods agree, which confirms the working.

2. A wire of resistance 10 ohm is cut into five equal pieces, and these five pieces are then joined in parallel. Find the resistance of the combination.

STEP 1 - resistance of each piece. Resistance is directly proportional to length, so cutting the wire into five equal pieces gives each piece one fifth of the original resistance: each piece = $10/5 = 2$ ohm. STEP 2 - join the five 2 ohm pieces in parallel. $1/R_p = 1/2 + 1/2 + 1/2 + 1/2 + 1/2 = 5/2$, so $R_p = 2/5 = 0.4$ ohm. (SHORTCUT: for n identical resistors of resistance r in parallel, $R_p = r/n = 2/5 = 0.4$ ohm. Note also that the answer is the original resistance divided by 25 - dividing by 5 for the cutting and by 5 again for the parallel joining.)

3. An electric heater of 1500 W is used for 4 hours a day. If electricity costs Rs. 6 per unit, calculate the cost of running it for 30 days.

STEP 1 - power in kilowatts: $1500 \text{ W} = 1.5 \text{ kW}$. STEP 2 - energy used per day = power $\times$ time = $1.5 \text{ kW} \times 4 \text{ h} = 6 \text{ kW h}$ per day. STEP 3 - energy in 30 days = $6 \times 30 = 180 \text{ kW h}$, that is 180 units. STEP 4 - cost = 180 units $\times$ Rs. 6 per unit = Rs. 1080. So running the heater costs Rs. 1080 for the month.

4. Two lamps rated 100 W, 220 V and 60 W, 220 V are connected in parallel to a 220 V supply. Find the current drawn by each and the total current from the supply.

Because the lamps are in PARALLEL, each has the full 220 V across it and therefore operates at its rated power. LAMP 1: $P = VI$, so $I_1 = 100/220 = 0.4545... \sim 0.45$ A. LAMP 2: $I_2 = 60/220 = 0.2727... \sim 0.27$ A. TOTAL CURRENT: keep the UNROUNDED values to the last step - $I = 100/220 + 60/220 = 160/220 = 0.727... \sim 0.73$ A. CHECK: total power = $100 + 60 = 160 \text{ W}$, so $I = P/V = 160/220 = 0.73 \text{ A}$ - exactly the same, which confirms the working. IMPORTANT: adding the already-rounded branch currents ($0.45 + 0.27$) would give 0.72 A, which is wrong in the second decimal. Always round ONLY at the final step.

5. You are given three resistors of 2 ohm, 3 ohm and 6 ohm. Show how you would connect them to obtain a total resistance of (a) 11 ohm and (b) 1 ohm.

(a) 11 ohm - connect ALL THREE IN SERIES: $R_s = 2 + 3 + 6 = 11$ ohm. This is the largest total obtainable from these three resistors, and it exceeds the largest individual resistance, as a series combination always must. (b) 1 ohm - connect ALL THREE IN PARALLEL: $1/R_p = 1/2 + 1/3 + 1/6$. Taking the LCM 6: $1/R_p = 3/6 + 2/6 + 1/6 = 6/6 = 1$, so $R_p = 1$ ohm. This is the smallest total obtainable, and it is less than the smallest individual resistance (2 ohm), as a parallel combination always must be.

6. A copper wire has a resistance of 5 ohm. A second copper wire has twice the length and twice the diameter of the first. What is the resistance of the second wire? Explain each step.

Use $R = \rho L/A$. The material is the same, so ρ is unchanged. LENGTH: doubling L would double the resistance. AREA: the diameter doubles, and area is proportional to the square of the diameter ($A = \pi d^2/4$), so the area becomes $2^2 = 4$ times as large. Since R is inversely proportional to A , this divides the resistance by 4. COMBINING: $R_2 = 5 \times (2/4) = 5 \times 0.5 = 2.5$ ohm. So the second wire has a resistance of 2.5 ohm. The common error is to assume the area merely doubles when the diameter doubles, which would wrongly give 5 ohm.

7. A fuse rated 5 A is fitted in a household circuit operating at 220 V. Determine the maximum total power of appliances that can be safely run, and state whether a 1500 W heater together with a 750 W iron can be used at the same time.

STEP 1 - maximum safe power. The fuse melts if the current exceeds 5 A, so the greatest power that can be drawn is $P = VI = 220 \times 5 = 1100 \text{ W}$. STEP 2 - the proposed load. Heater + iron = $1500 + 750 = 2250 \text{ W}$. STEP 3 - compare. 2250 W is far greater than the 1100 W limit; the current drawn would be $I = P/V = 2250/220 \sim 10.2 \text{ A}$, which is about twice the fuse rating. CONCLUSION: NO, they cannot be used together - the fuse would melt and

break the circuit. That is precisely its protective purpose: without it, such a current could overheat the wiring and cause a fire.

8. A current of 0.5 A flows through a conductor for 4 minutes. Calculate (a) the charge that passes through it and (b) the number of electrons that constitute that charge.

STEP 1 - time in seconds: $t = 4 \text{ minutes} = 4 \times 60 = 240 \text{ s}$. STEP 2 - charge: from $I = Q/t$, $Q = I t = 0.5 \times 240 = 120 \text{ C}$. STEP 3 - number of electrons: charge is quantised, $Q = n e$, where $e = 1.6 \times 10^{-19} \text{ C}$. So $n = Q / e = 120 / (1.6 \times 10^{-19}) = 75 \times 10^{19} = 7.5 \times 10^{20}$ electrons. ANSWER: 120 C of charge, carried by 7.5×10^{20} electrons. (Sanity check: 1 C is about 6.25×10^{18} electrons, and $120 \times 6.25 \times 10^{18} = 7.5 \times 10^{20}$ - the same.)

