

Emf, internal resistance and kirchhoff's laws

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems begin with lost volts, junctions and simple dividers, then move to power banks, light sensors and graphs of terminal voltage. They suit A Level, IB Physics and CBSE Class 12 students. The last five problems use Kirchhoff's laws, maximum power and bridge circuits.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB B.5

Problem 1 Lost volts (easy)

A cell has emf 1.5 V and internal resistance $0.50\ \Omega$. It delivers a current of 0.60 A to a small lamp.

1. Calculate the lost volts.
2. Calculate the terminal potential difference.

Problem 2 Current in a complete circuit (easy)

A 12 V battery of internal resistance $0.20\ \Omega$ is connected across a $5.8\ \Omega$ heater coil. Calculate the current.

Problem 3 Junction rule (easy)

At a junction in a circuit, a wire carries 3.2 A towards the junction and a second wire carries 1.1 A towards it. Two wires carry current away: one carries 2.4 A. Calculate the current in the other wire.

Problem 4 Simple divider (easy)

A 12 V supply is connected across a $4.0\ \text{k}\Omega$ resistor and an $8.0\ \text{k}\Omega$ resistor in series.

1. Calculate the current.
2. Calculate the voltage across each resistor.

Problem 5 Ideas and definitions (easy)

1. Define the emf of a source.
2. Explain why the terminal p.d. of a battery is less than its emf when a current flows.
3. State what quantity is conserved in Kirchhoff's second law.

Problem 6 Jump-start accident (easy)

A car battery has emf 12.6 V and internal resistance 0.020 Ω . A dropped spanner connects its two terminals through a negligible resistance.

1. Calculate the short-circuit current.
2. Explain why this is dangerous.

Problem 7 Open circuit and load (medium)

Wanjiru measures the voltage across a cell as 1.58 V with nothing connected. With an 8.0 Ω resistor connected, the voltmeter reads 1.40 V.

1. State the emf of the cell.
2. Calculate the current through the resistor.
3. Calculate the internal resistance.

Problem 8 Power bank (medium)

A power bank has emf 5.0 V and internal resistance 0.15 Ω while it charges a tablet with a current of 2.0 A.

1. Calculate the terminal p.d.
2. Calculate the useful power delivered to the tablet.
3. Calculate the power wasted in the power bank and its efficiency.

Problem 9 Cells in series or in parallel (medium)

Two identical cells, each with emf 1.5 V and internal resistance 0.50 Ω , are connected to a 2.0 Ω resistor.

1. Calculate the current when the cells are in series.
2. Calculate the current when they are in parallel.
3. State which arrangement gives the larger current and why.

Problem 10 Meter loading (medium)

Two 10 k Ω resistors are connected in series across a 9.0 V supply. A voltmeter of resistance 10 k Ω is connected across the lower resistor.

1. State the voltage across the lower resistor before the voltmeter is connected.
2. Calculate the combined resistance of the lower resistor and the voltmeter.
3. Calculate the reading on the voltmeter.

Problem 11 Light sensor divider (medium)

Aarav in Pune builds a street-light prototype: a 6.0 V supply is connected across a 4.7 k Ω resistor in series with a light-dependent resistor (LDR). The output is taken across the LDR. In daylight the LDR has a resistance of 1.0 k Ω ; at night it has 100 k Ω .

1. Calculate the output voltage in daylight.
2. Calculate the output voltage at night.

3. Explain how the output changes as it gets dark.

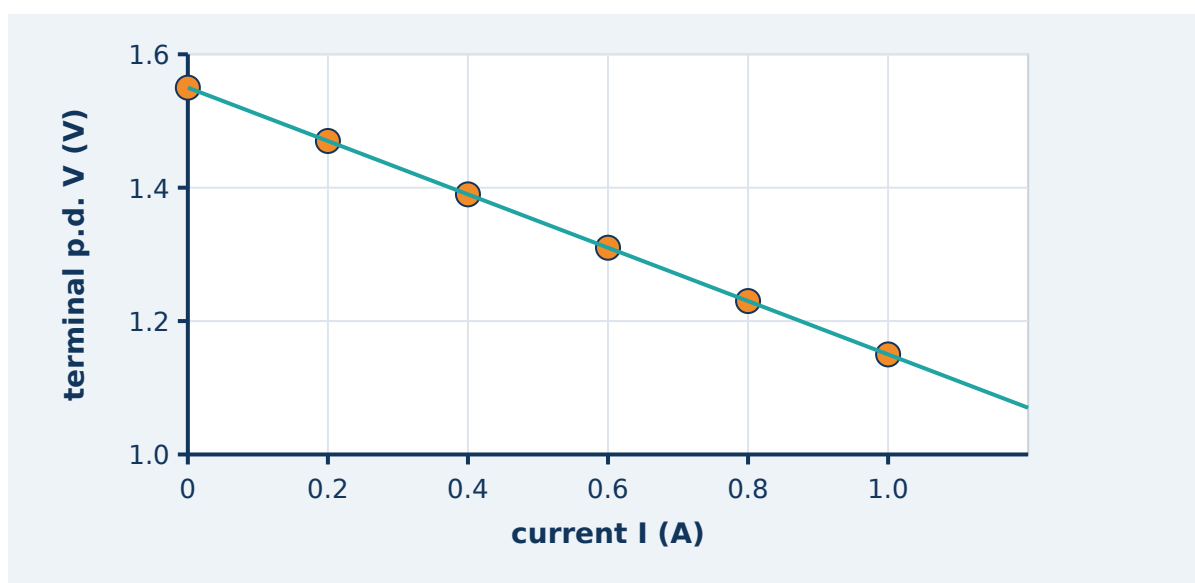
Problem 12 Battery feeding two lamps (medium)

A 9.0 V battery with internal resistance 1.0Ω is connected to a 6.0Ω lamp and a 3.0Ω lamp in parallel.

1. Calculate the resistance of the parallel pair.
2. Calculate the current drawn from the battery.
3. Calculate the terminal p.d. and the current in each lamp.

Problem 13 Reading a cell graph (medium)

The graph shows readings of terminal p.d. against current for a cell.

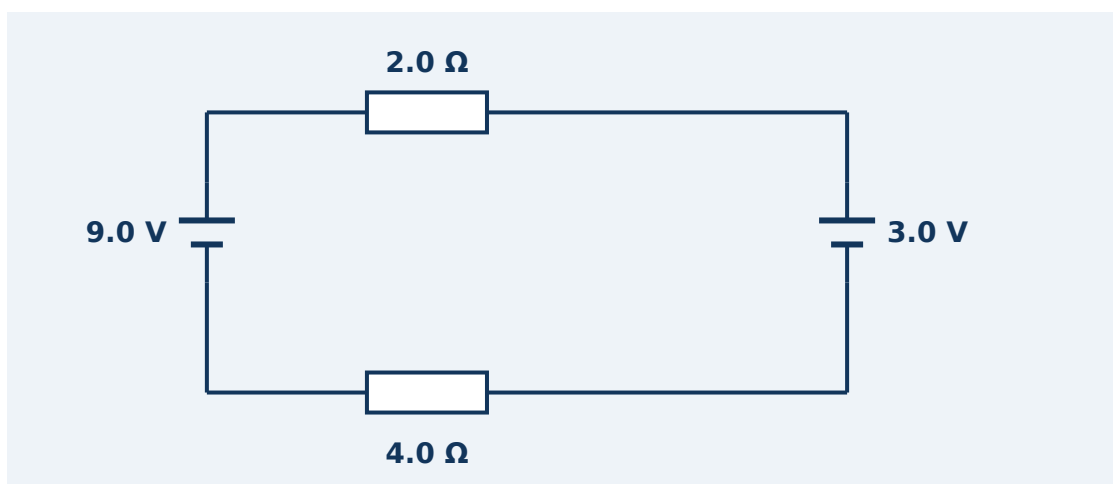


Six readings of terminal p.d. against current for a cell: (0, 1.55), (0.2, 1.47), (0.4, 1.39), (0.6, 1.31), (0.8, 1.23), (1.0, 1.15).

1. State the emf of the cell.
2. Calculate the gradient of the line.
3. State the internal resistance and the p.d. when the current is 0.50 A.

Problem 14 Opposing cells (medium)

Two cells of negligible internal resistance are connected in a loop with two resistors as shown.



Single loop with two cells that oppose each other.

1. Calculate the net emf around the loop.
2. Calculate the current.
3. Calculate the p.d. across each resistor and check Kirchhoff's second law.

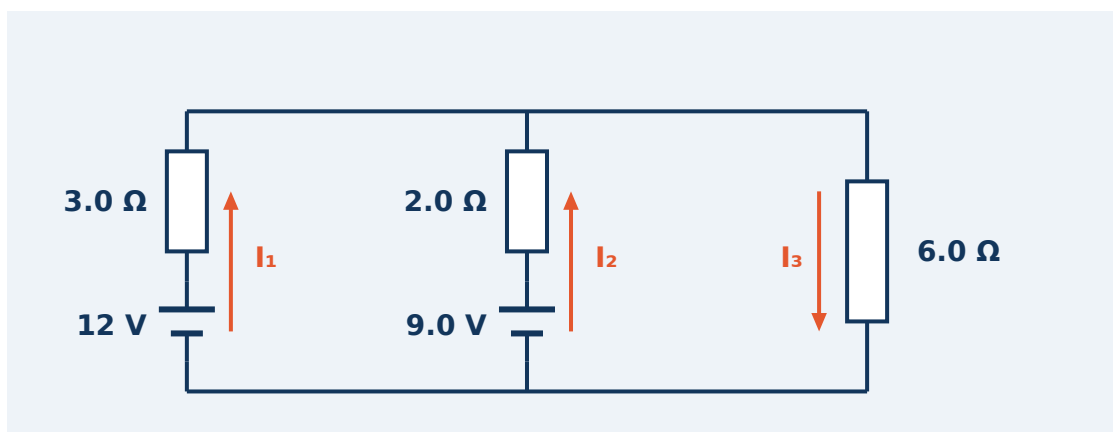
Problem 15 Spot the error (medium)

A student writes: "A cell with $\varepsilon = 6.0 \text{ V}$ and $r = 1.0 \Omega$ is connected to a 5.0Ω resistor. The current is $6.0 / 5.0 = 1.2 \text{ A}$, and the terminal p.d. is 6.0 V because that is the voltage of the cell."

1. Identify the two mistakes.
2. Calculate the correct current.
3. Calculate the correct terminal p.d.

Problem 16 Two sources, one load (hard)

Use Kirchhoff's laws on the circuit shown (negligible internal resistances).



Two sources sharing a 6.0Ω resistor (cells have negligible internal resistance).

1. Write the junction equation and the two loop equations.
2. Solve them for I_1 , I_2 and I_3 .
3. Calculate the p.d. across the 6.0Ω resistor and the power dissipated in it.

Problem 17 Maximum power transfer (hard)

A battery has emf 12 V and internal resistance 2.0 Ω . It supplies a variable load resistor R.

1. Show that the power in the load is $P = \varepsilon^2 R / (R + r)^2$.
2. Calculate P for $R = 0.50 \Omega$, 2.0 Ω and 8.0 Ω .
3. State the value of R that gives maximum power, the maximum power, and the efficiency at that point.

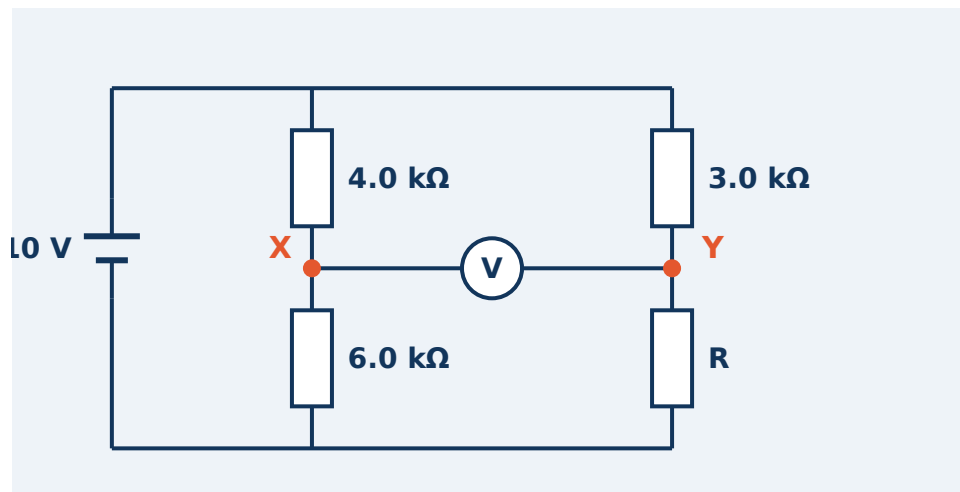
Problem 18 Charging a battery (hard)

A small solar panel with emf 18.0 V and internal resistance 6.0 Ω charges a battery of emf 12.0 V and internal resistance 1.0 Ω . The panel and battery are connected positive to positive and negative to negative.

1. Calculate the charging current.
2. Show that the terminal p.d. is the same for the panel and the battery.
3. Calculate the power converted to chemical energy and the power lost as heat in the two internal resistances.

Problem 19 Balancing a bridge (hard)

Two potential dividers are connected across a 10 V supply, as shown. The voltmeter has a very large resistance.



A bridge made of two potential dividers; the voltmeter is connected between X and Y.

1. Calculate the potential at X, measured from the bottom rail.
2. Calculate the value of R that makes the voltmeter read zero.
3. Calculate the voltmeter reading when $R = 5.0 \text{ k}\Omega$.

Problem 20 Linearising the cell equation (hard)

Diego in Texas connects a cell to four different load resistors and measures the terminal p.d.:

R (Ω)	1.0	2.0	4.0	10.0
V (V)	1.00	1.20	1.33	1.43

1. Show that $1/V = (r/\epsilon)(1/R) + 1/\epsilon$.
2. Calculate $1/V$ and $1/R$ for each reading.
3. Use the first and last points of a graph of $1/V$ against $1/R$ to find ϵ and r .