



CANADIAN BASIC AMATEUR RADIO EXAM PREPARATION

SECTION 5 A BASIC ELECTRONICS & THEORY





**THIS COURSE IS BEING TAUGHT TO THE JULY 15, 2025 UPDATE
OF THE CANADIAN BASIC AMATEUR RADIO EXAM QUESTIONS.**

SECTION 5 QUESTION CATEGORIES:

**B-005-001: METRIC PREFIXES AND UNIT CONVERSIONS IN
RADIO/ELECTRONICS**

B-005-002: BASIC ELECTRICAL CONCEPTS

B-005-003: ELECTRICAL POWER AND CIRCUIT CONDITIONS

B-005-004: OHM'S LAW AND ITS APPLICATIONS

B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

**B-005-006: POWER HANDLING AND RATINGS IN RESISTORS AND
CIRCUITS**

SECTION 5 QUESTION CATEGORIES:

B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

B-005-008: DECIBELS (dB) AND POWER RATIOS

B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

B-005-010: REACTANCE AND IMPEDANCE IN AC CIRCUITS

B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

B-005-012: RESONANCE IN TUNED CIRCUITS

B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

KEY INTRODUCTORY CONCEPTS



INTRODUCTORY CONCEPTS:

VOLTAGE (V OR E, MEASURED IN VOLTS, V):

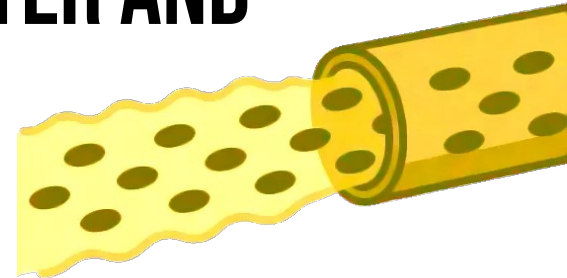
- THE "ELECTRICAL PRESSURE" OR PUSH THAT MAKES CURRENT FLOW, LIKE WATER PRESSURE IN A TOWER.
- HIGHER VOLTAGE CAN DRIVE CURRENT THROUGH MORE RESISTANCE.
- BATTERIES SUPPLY DC VOLTAGE; WALL OUTLETS SUPPLY AC VOLTAGE.



INTRODUCTORY CONCEPTS:

CURRENT (I , MEASURED IN AMPERES OR AMPS, A):

- THE FLOW OF ELECTRONS THROUGH A WIRE OR CIRCUIT, LIKE WATER FLOWING THROUGH A HOSE. MORE CURRENT MEANS MORE ELECTRONS MOVING PER SECOND.
- IN RADIO, CURRENT POWERS YOUR TRANSMITTER AND LIGHTS UP METERS.

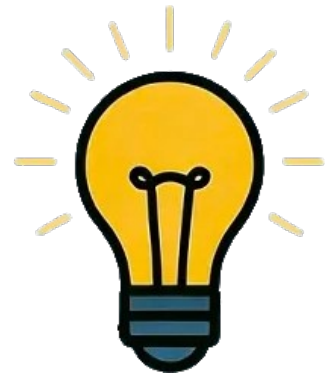


INTRODUCTORY CONCEPTS:

POWER (P, MEASURED IN WATTS, W):

- THE RATE AT WHICH ENERGY IS USED OR DELIVERED — BASICALLY HOW MUCH "WORK" ELECTRICITY DOES. SIMPLE
- FORMULA: POWER = VOLTAGE × CURRENT

$$P = V \times I$$



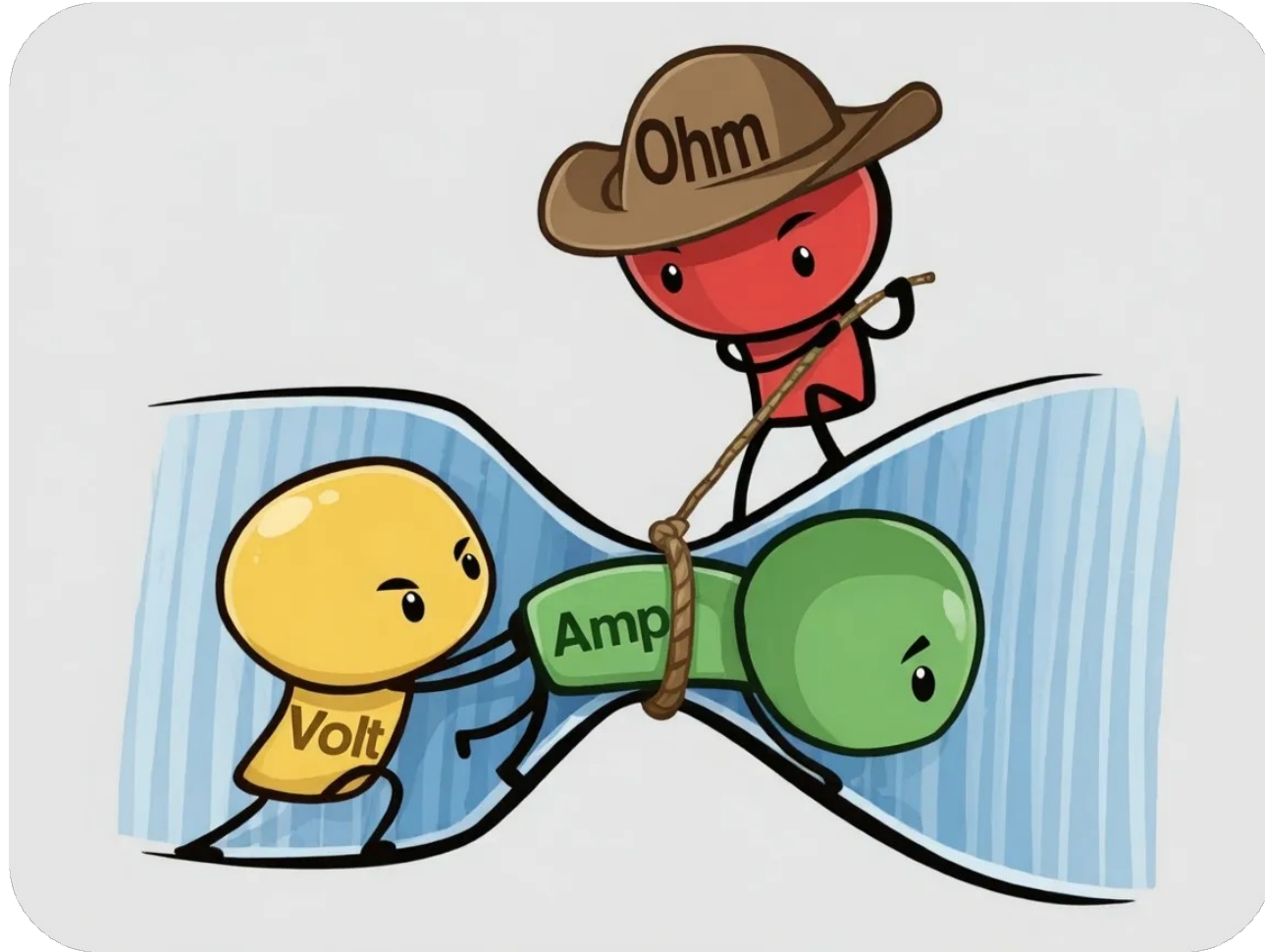
INTRODUCTORY CONCEPTS:

RESISTANCE (R, MEASURED IN OHMS Ω):



- **OPPOSITION TO CURRENT FLOW, LIKE NARROW SPOTS IN A HOSE SLOWING WATER. RESISTORS LIMIT CURRENT, DIVIDE VOLTAGE, OR PROTECT COMPONENTS.**
- **IN ANTENNAS AND CIRCUITS, TOO MUCH RESISTANCE WASTES POWER AS HEAT (BAD FOR EFFICIENCY).**

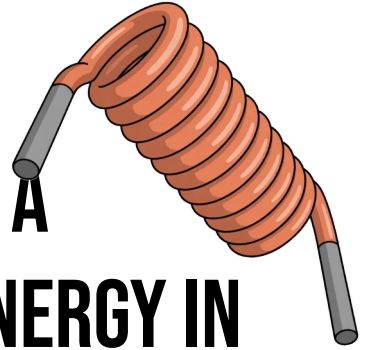
INTRODUCTORY CONCEPTS:



INTRODUCTORY CONCEPTS:

INDUCTORS:

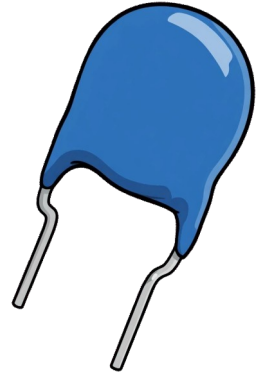
- **COILS OF WIRE (SOMETIMES WITH A CORE) THAT CREATE A MAGNETIC FIELD WHEN CURRENT FLOWS. THEY STORE ENERGY IN THAT FIELD.**
- **INDUCTORS BLOCK HIGH FREQUENCIES BUT PASS LOW ONES (OPPOSITE OF CAPACITORS).**
- **USED IN FILTERS, CHOKES (TO STOP RF FROM GOING WHERE IT SHOULDN'T) AND TUNING.**



INTRODUCTORY CONCEPTS:

CAPACITORS:

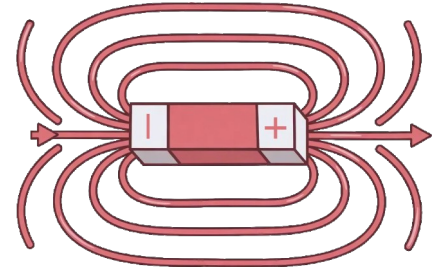
- **DEVICES MADE OF TWO PLATES SEPARATED BY AN INSULATOR THAT STORE ELECTRIC CHARGE.**
- **USED IN FILTERS, TUNING CIRCUITS (TO SELECT FREQUENCIES), POWER SUPPLY SMOOTHING AND BLOCKING DC WHILE PASSING AC SIGNALS IN RADIOS.**



INTRODUCTORY CONCEPTS:

INDUCTANCE (L):

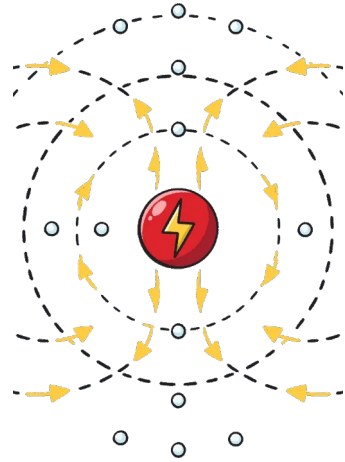
- **L, MEASURED IN HENRIES, H – USUALLY MILLIHENRIES MH OR MICROHENRIES μ H**
- **OPPOSITION TO CHANGES IN CURRENT FLOW DUE TO A MAGNETIC FIELD.**



INTRODUCTORY CONCEPTS:

CAPACITANCE (C):

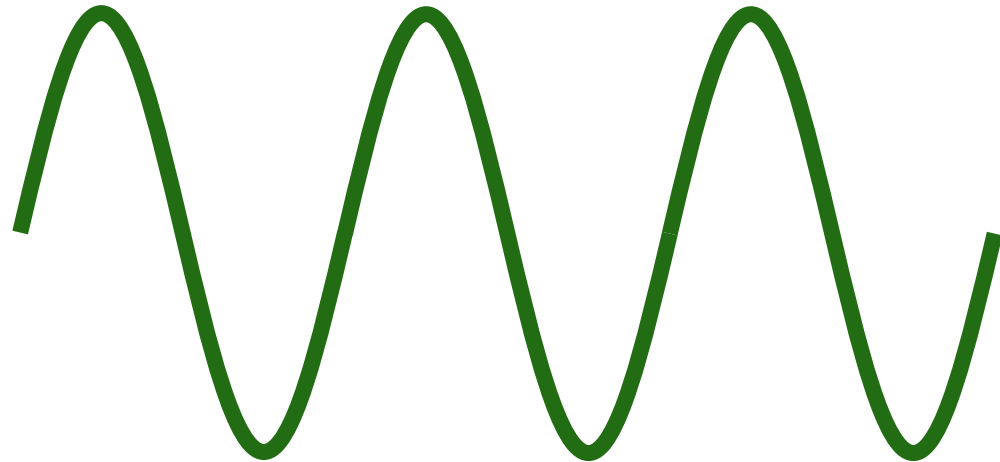
- **C, MEASURED IN FARADS, BUT USUALLY MICROFARADS μF , NANOFARADS nF , OR PICOFARADS pF)**
- **A COMPONENT'S (OR CIRCUIT'S) ABILITY TO STORE ELECTRIC CHARGE/ENERGY IN AN ELECTRIC FIELD, LIKE A TINY RECHARGEABLE BUCKET. CAPACITORS BLOCK DC BUT PASS AC — THE HIGHER THE FREQUENCY, THE EASIER AC PASSES THROUGH.**



INTRODUCTORY CONCEPTS:

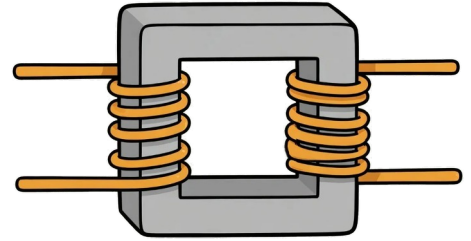
FREQUENCY (Hz):

- **F, MEASURED IN HERTZ Hz, OR CYCLES PER SECOND**
- **HOW FAST THE AC SIGNAL OSCILLATES (GOES UP AND DOWN).**
- **1 Hz = 1 CYCLE/SECOND.**
- **HAM BANDS USE:**
 - **KHz (THOUSANDS) FOR MF/HF**
 - **MHz (MILLIONS) FOR VHF/UHF.**



INTRODUCTORY CONCEPTS:

TRANSFORMERS:

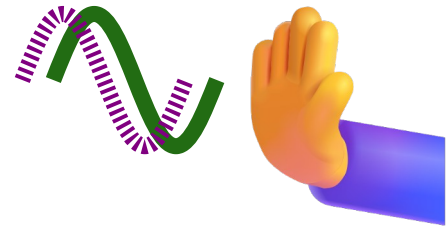


- **TWO (OR MORE) COILS WOUND ON A SHARED CORE. THEY TRANSFER AC ENERGY FROM ONE COIL (PRIMARY) TO ANOTHER (SECONDARY) VIA MAGNETIC COUPLING — NO DIRECT ELECTRICAL CONNECTION.**
- **THEY STEP VOLTAGE UP OR DOWN (EX: HIGH VOLTAGE FOR PLATE SUPPLIES IN OLD TUBE RADIOS, OR LOW VOLTAGE FOR MODERN GEAR). ONLY WORK ON AC, NOT DC. VERY USEFUL FOR IMPEDANCE MATCHING AND ISOLATION IN HAM EQUIPMENT.**

INTRODUCTORY CONCEPTS:

REACTANCE (X):

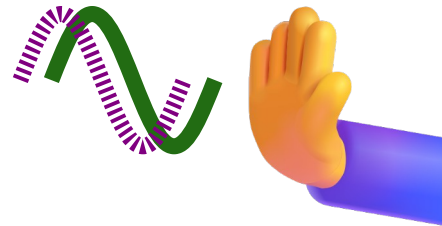
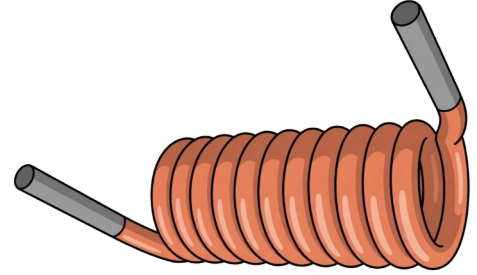
- IS THE OPPOSITION TO ALTERNATING CURRENT (AC) CAUSED SPECIFICALLY BY INDUCTORS AND CAPACITORS (NOT BY RESISTORS).
- UNLIKE RESISTANCE, REACTANCE DOES NOT DISSIPATE ENERGY AS HEAT — IT TEMPORARILY STORES ENERGY IN MAGNETIC OR ELECTRIC FIELDS AND THEN RETURNS IT TO THE CIRCUIT A QUARTER-CYCLE LATER.
- THIS CREATES A PHASE-SHIFT - THE CURRENT LAGS OR LEADS THE VOLTAGE!
- REACTANCE IS MEASURED IN OHMS (Ω) AND IS FREQUENCY-DEPENDENT.
- IT IS PAIRED WITH 'REAL' RESISTANCE AS THE 'IMAGINARY' PART OF IN COMPLEX IMPEDANCE CALCULATIONS.



INTRODUCTORY CONCEPTS:

INDUCTIVE REACTANCE (X_L):

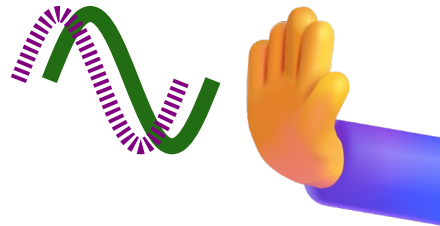
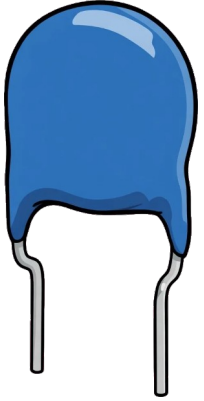
- THIS IS THE OPPOSITION OFFERED BY AN INDUCTOR (COIL) TO CHANGES IN CURRENT.
- CAUSES THE CURRENT TO LAG THE VOLTAGE BY 90°
- VOLTAGE LEADS CURRENT.



INTRODUCTORY CONCEPTS:

CAPACITIVE REACTANCE (X_c):

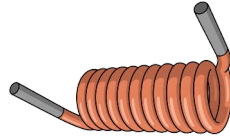
- THIS IS THE OPPOSITION OFFERED BY A CAPACITOR TO CHANGES IN VOLTAGE.
- CAUSES THE CURRENT TO LEAD THE VOLTAGE BY 90°
- VOLTAGE LAGS CURRENT



INTRODUCTORY CONCEPTS:

ELI THE ICE MAN!

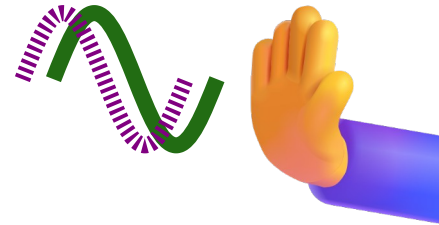
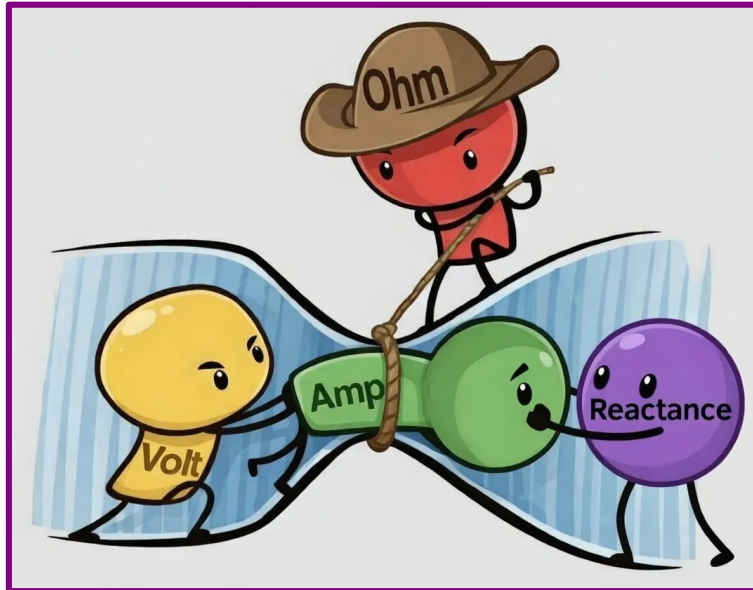
- APPLY VOLTAGE (**E**) TO INDUCTOR (**L**) IT LAGS (**I**)
- **I** IS BEHIND E AND L
- APPLY (**I**) TO CAPACITOR (**C**) IT LEADS (**E**)
- **E** IS BEHIND I AND C



INTRODUCTORY CONCEPTS:

IMPEDANCE (Z)

- IS THE TOTAL EFFECTIVE OPPOSITION TO AC CURRENT FLOW IN A CIRCUIT.





QUESTION SECTION B-005-001:
METRIC PREFIXES AND UNIT
CONVERSIONS IN RADIO/ELECTRONICS

B-005-001: METRIC PREFIXES AND UNIT CONVERSIONS IN RADIO/ELECTRONICS

UNDERSTANDING METRIC PREFIXES – ESSENTIAL CONVERSIONS FOR HAM RADIO

- HAM RADIO USES **THE INTERNATIONAL SYSTEM** OF UNITS (SI) WITH METRIC PREFIXES TO HANDLE VERY LARGE OR VERY SMALL VALUES. COMMON PREFIXES IN RADIO:
 - MEGA (M) = $\times 1,000,000$ (10^6)
 - KILO (K) = $\times 1,000$ (10^3)
 - MILLI (M) = $\times 0.001$ (10^{-3})
 - MICRO (μ) = $\times 0.000\ 001$ (10^{-6})
 - NANO (N) = $\times 0.000\ 000\ 001$ (10^{-9})
 - PICO (P) = $\times 0.000\ 000\ 000\ 001$ (10^{-12})
- TO CONVERT: MOVE THE DECIMAL POINT (OR MULTIPLY/DIVIDE BY POWERS OF 1,000).



B-005-001: METRIC PREFIXES AND UNIT CONVERSIONS IN RADIO/ELECTRONICS

FREQUENCY CONVERSIONS

- **FREQUENCY** IS MEASURED IN **HERTZ** (Hz).
- HAM BANDS ARE OFTEN IN kHz (HF) OR MHz (VHF/UHF).
- 1 kHz = 1 000 Hz
- TO GO FROM MHz TO kHz: MULTIPLY BY 1,000 (MOVE DECIMAL 3 PLACES RIGHT).
- EXAMPLE: DIAL READS 3.525 MHz → 3 525 kHz (MULTIPLY BY 1,000)
- EXAMPLE: 7040 kHz → 7.040 MHz (DIVIDE BY 1,000)
- TO GHz FROM MHz: DIVIDE BY 1,000 (EX: 1,200 MHz = 1.2 GHz)

B-005-001: METRIC PREFIXES AND UNIT CONVERSIONS IN RADIO/ELECTRONICS

POWER, CURRENT, AND VOLTAGE CONVERSIONS

- **POWER:** MILLIWATTS (mW) TO WATTS (W).
 - $500 \text{ mW} = 0.5 \text{ W}$ (DIVIDE BY 1,000)
- **CURRENT:** AMPERES (A) AND MILLIAMPERES (mA).
 - $3,000 \text{ mA} = 3\text{A}$ (DIVIDE BY 1,000)
 - $0.25 \text{ A} = 250\text{mA}$ (MULTIPLY BY 1,000)
- **VOLTAGE:** VOLTS (V) TO MILLIVOLTS (mV).
 - $2\text{V} = 2,000 \text{ mV}$ (MULTIPLY BY 1,000)



RESISTANCE, CAPACITANCE, AND INDUCTANCE

- RESISTANCE: 1 KILOHM ($k\Omega$) = 1000 OHMS

- CAPACITANCE: 1,000,000 pF = 1 μ F

(MICROFARAD; DIVIDE BY 1,000,000 OR MOVE DECIMAL 6 PLACES LEFT)

- INDUCTANCE: 10,000 μ H = 10 mH (MILLIHENRIES; DIVIDE BY 1,000)



QUESTION SECTION B-005-002:

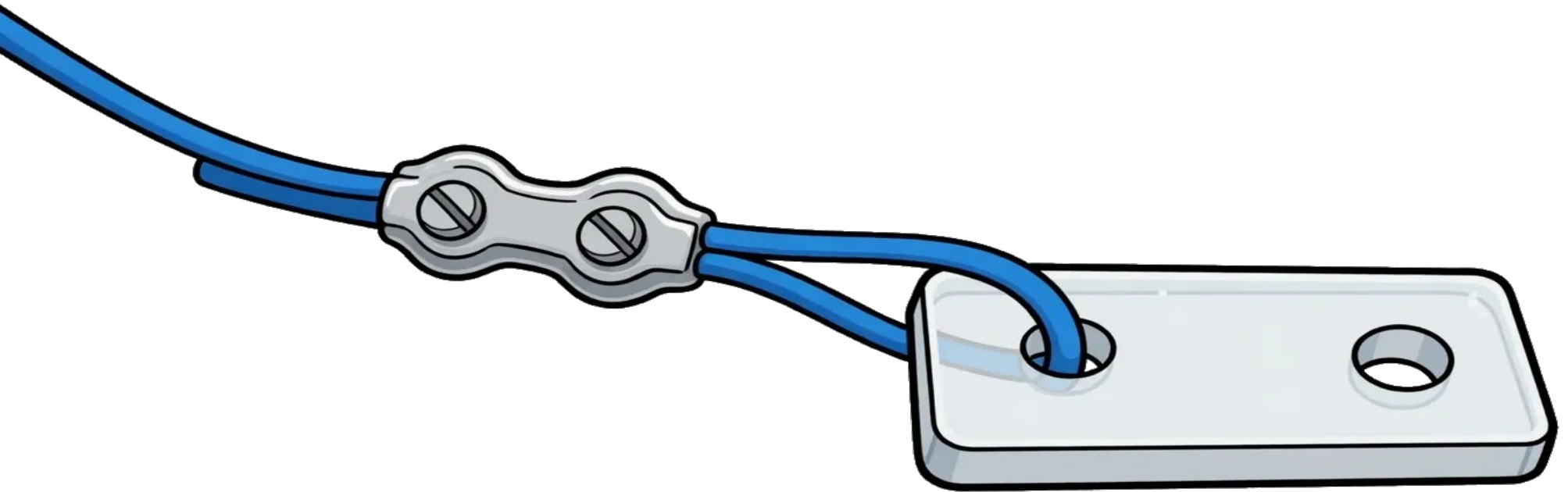
BASIC ELECTRICAL CONCEPTS

B-005-002: BASIC ELECTRICAL CONCEPTS

CONDUCTORS VS. INSULATORS

- **CONDUCTORS** READILY ALLOW ELECTRIC CURRENT TO FLOW BECAUSE THEY HAVE **LOW RESISTANCE**.
 - BEST CONDUCTOR AMONG COMMON MATERIALS: **COPPER** (WIDELY USED IN HAM WIRE, COAX, PCBS).
 - THREE GOOD ELECTRICAL CONDUCTORS: **GOLD, SILVER AND ALUMINUM** (GOLD FOR CONNECTORS DUE TO NO CORROSION; SILVER BEST BUT EXPENSIVE; ALUMINUM LIGHTWEIGHT FOR ANTENNAS).
- **INSULATORS** RESIST CURRENT FLOW (HIGH RESISTANCE).
 - THREE GOOD ELECTRICAL INSULATORS: **GLASS, AIR AND PORCELAIN** (PORCELAIN FOR HIGH-VOLTAGE INSULATORS ON ANTENNAS; AIR GAPS IN COAX; GLASS IN OLD INSULATORS)

CONDUCTORS VS. INSULATORS



CURRENT AND POLARITY

- THE FLOW OF ELECTRIC CHARGE IN A CIRCUIT IS CALLED **CURRENT** (MEASURED IN **AMPERES**).
- IN DC CIRCUITS (LIKE BATTERIES, MOST HAM POWER SUPPLIES), CURRENT HAS A SPECIFIC DIRECTION – THIS IS DESCRIBED BY **POLARITY** (POSITIVE TO NEGATIVE FLOW CONVENTION).

RESISTANCE AND RELATED CONCEPTS

- THE SYMBOL FOR **RESISTANCE** IS **R** (MEASURED IN **OHMS**, Ω).
- THE INVERSE OF RESISTANCE IS **CONDUCTANCE** (HOW EASILY CURRENT FLOWS; MEASURED IN SIEMENS, BUT RARELY USED IN BASIC HAM WORK).
- RESISTANCE OF A CONDUCTOR CHANGES WITH **TEMPERATURE** — FOR MOST METALS (LIKE COPPER WIRE), IT INCREASES AS TEMPERATURE RISES (IMPORTANT FOR LONG ANTENNA RUNS OR HOT FINALS).

VOLTAGE DROP

- A **VOLTAGE DROP** IS THE LOSS OF VOLTAGE CAUSED BY THE FLOW OF CURRENT THROUGH A CIRCUIT (MAINLY ACROSS RESISTORS OR WIRES).
- IN HAM RADIO: VOLTAGE DROPS IN LONG COAX RUNS REDUCE POWER TO THE ANTENNA; IN POWER SUPPLIES, THEY AFFECT VOLTAGE REGULATION.



QUESTION SECTION B-005-003:

ELECTRICAL POWER AND CIRCUIT CONDITIONS

B-005-003: ELECTRICAL POWER AND CIRCUIT CONDITIONS

POWER

- **POWER** IS THE RATE AT WHICH ELECTRICAL ENERGY IS USED OR DELIVERED IN A CIRCUIT — MEASURED IN **WATTS (W)**. IN HAM RADIO, POWER TELLS YOU:
 - HOW MUCH ENERGY YOUR TRANSMITTER PUTS OUT (EX: 100 W ON HF).
 - HOW FAST YOUR BATTERY DRAINS OR POWER SUPPLY WORKS.
 - WHY A RESISTOR OR FINAL TRANSISTOR OVERHEATS IF OVERLOADED.
 - WHY FUSES BLOW TO PROTECT EQUIPMENT.
- FORMULA: POWER (P) = VOLTAGE (V) × CURRENT (I).

$$P = V \times I$$

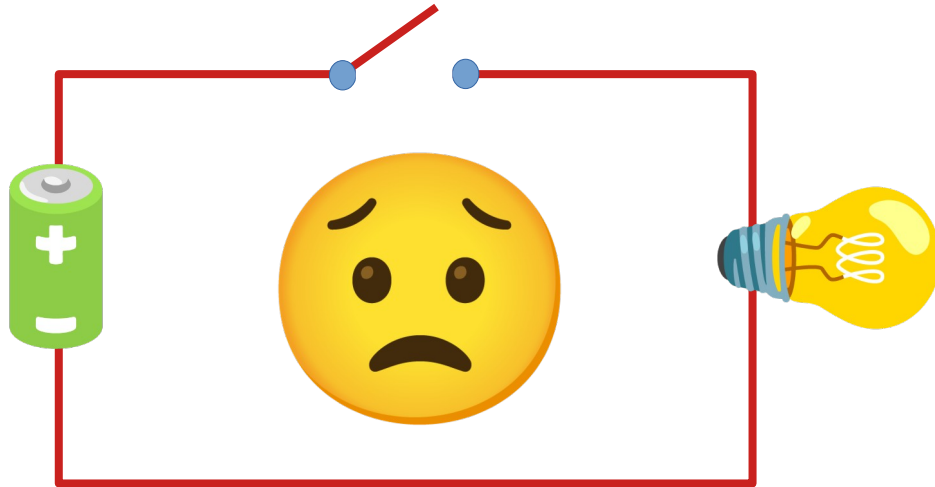
POWER IN ACTION – LIGHT BULB EXAMPLE

- **HIGHER WATTAGE** MEANS THE DEVICE CONSUMES ELECTRICAL ENERGY AT A **HIGHER RATE** (USES MORE POWER).
- AMONG 40W, 50W, 60W, AND 100W BULBS, THE **100-WATT BULB** CONSUMES THE MOST ENERGY PER SECOND – IT BURNS BRIGHTER AND HOTTER.



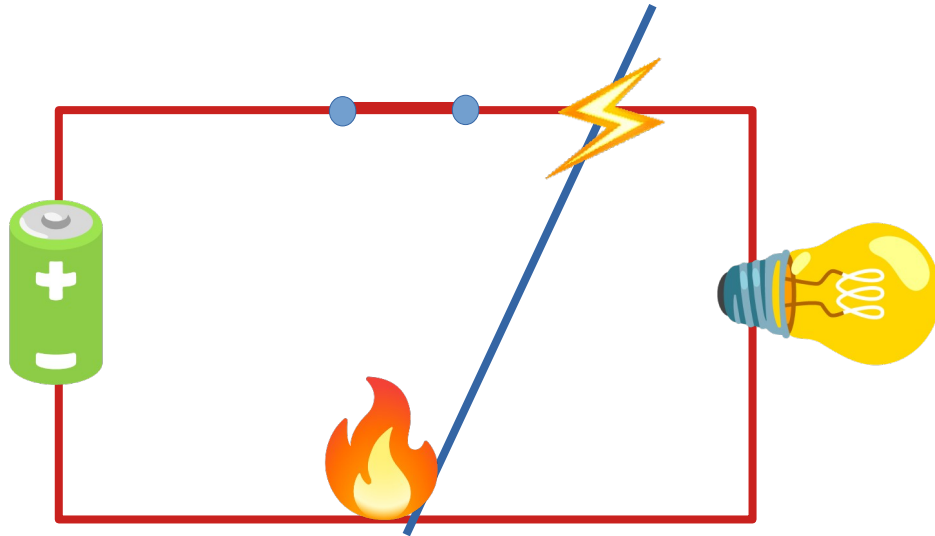
CIRCUIT MALFUNCTIONS – OPEN VS. SHORT

- **OPEN CIRCUIT**: NO COMPLETE PATH FOR CURRENT → NO CURRENT FLOWS (EX: SWITCH OFF, BROKEN WIRE, BLOWN FUSE).
- A BATTERY + LOAD RESISTOR DRAWS **NO CURRENT** IF THERE'S AN OPEN CIRCUIT.



CIRCUIT MALFUNCTIONS – OPEN VS. SHORT

- **SHORT CIRCUIT:** VERY LOW RESISTANCE PATH (EX: WIRES TOUCHING, FAILED COMPONENT) → EXCESSIVE CURRENT FLOWS. DRAWS TOO MUCH CURRENT, OVERHEATS WIRES, BLOWS FUSES INSTANTLY.



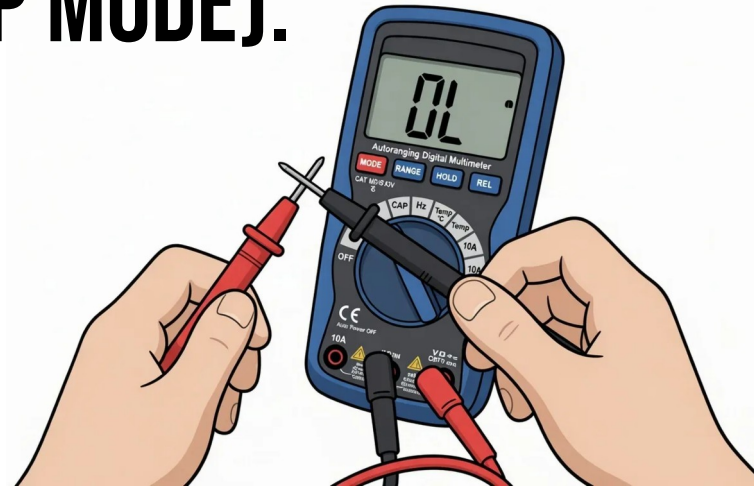
OVERHEATING AND DISSIPATION

- **COMPONENTS LIKE RESISTORS OR TRANSISTORS CONVERT ELECTRICAL POWER TO HEAT.**
- **IF A RESISTOR GETS VERY HOT AND STARTS TO BURN, IT'S DISSIPATING TOO MUCH POWER.**



CONTINUITY – A KEY TROUBLESHOOTING TERM

- **CONTINUITY** MEANS THE CIRCUIT IS A **CLOSED CIRCUIT** – COMPLETE PATH FOR CURRENT (LOW RESISTANCE, MEASURABLE WITH MULTIMETER BEEP MODE).
- **NO CONTINUITY** = **OPEN CIRCUIT**.





QUESTION SECTION B-005-004:

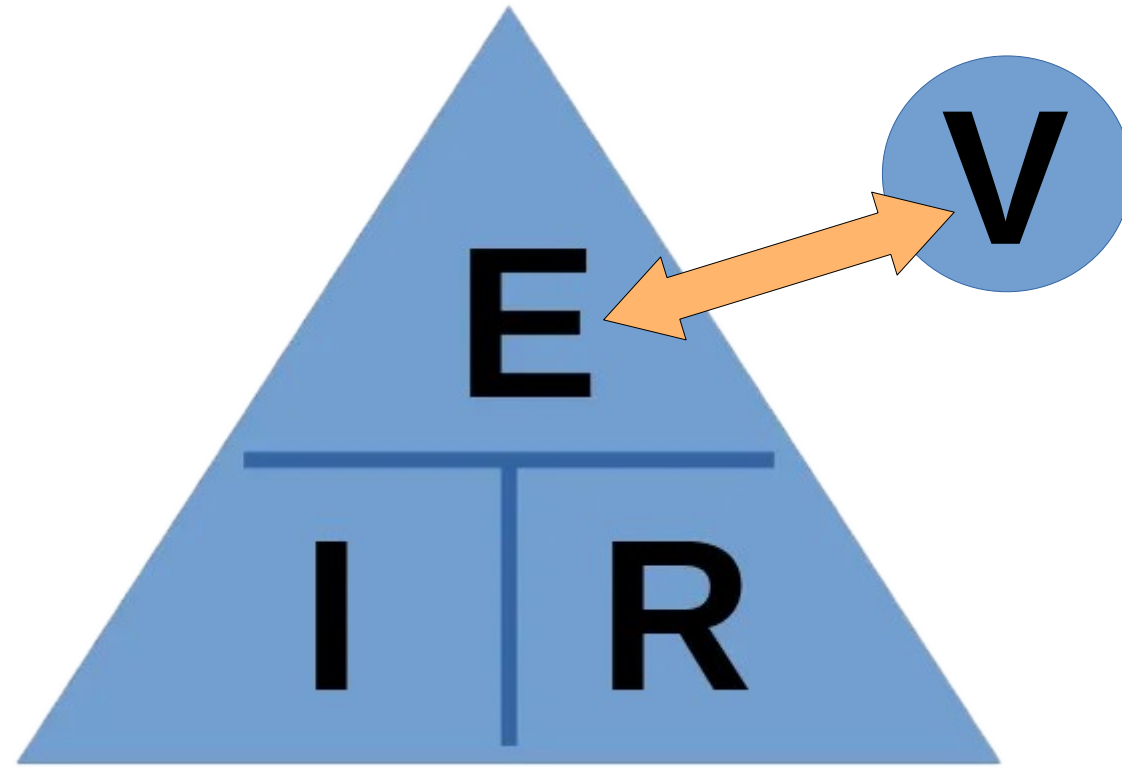
OHM'S LAW AND ITS APPLICATIONS

B-005-004: OHM'S LAW AND ITS APPLICATIONS

OHM'S LAW – THE FUNDAMENTAL RELATIONSHIP IN DC CIRCUITS

- **OHM'S LAW** STATES THAT IN A DC CIRCUIT, THE VOLTAGE (V OR E) ACROSS A CONDUCTOR IS DIRECTLY PROPORTIONAL TO THE CURRENT (I) FLOWING THROUGH IT, AND INVERSELY PROPORTIONAL TO THE RESISTANCE (R).
- **THE CORE FORMULA IS:** $V = I \times R$
- (VOLTAGE IN VOLTS = CURRENT IN AMPERES × RESISTANCE IN OHMS)

B-005-004: OHM'S LAW AND ITS APPLICATIONS

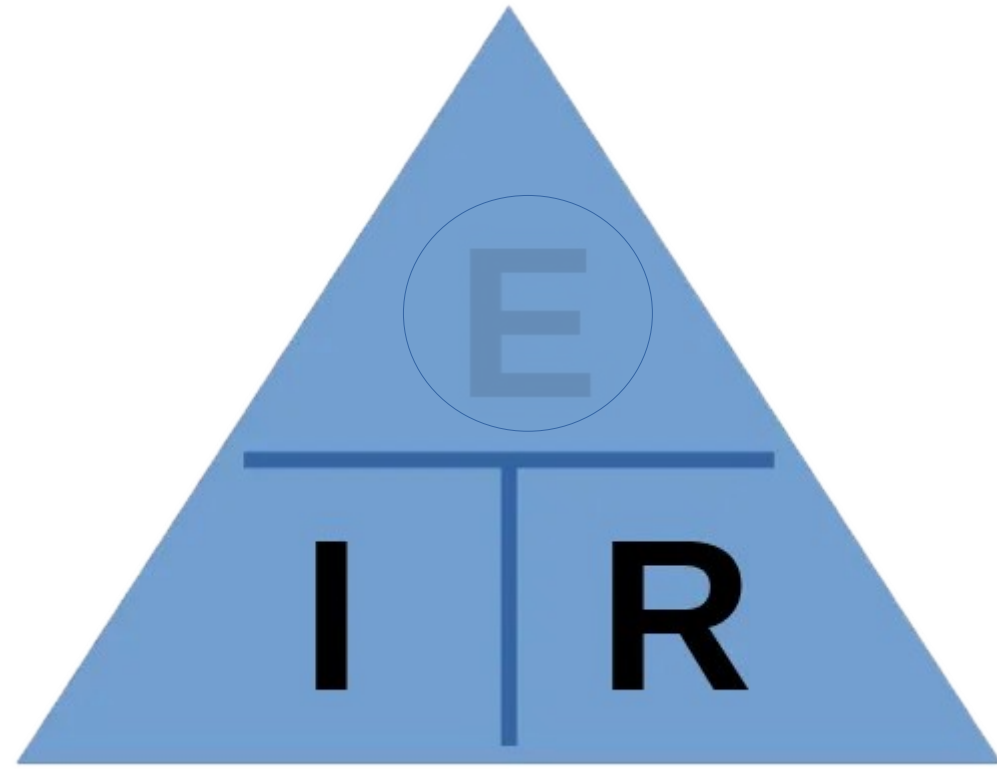


“OHM’S TRIANGLE”

**E (ELECTROMOTIVE FORCE) V (VOLTS)
ARE INTERCHANGABLE**

**YOU CAN SOLVE FOR ANY VALUE USING
OHM’S TRIANGLE BY COVERING THE VALUE
YOU WANT TO FIND.**

B-005-004: OHM'S LAW AND ITS APPLICATIONS



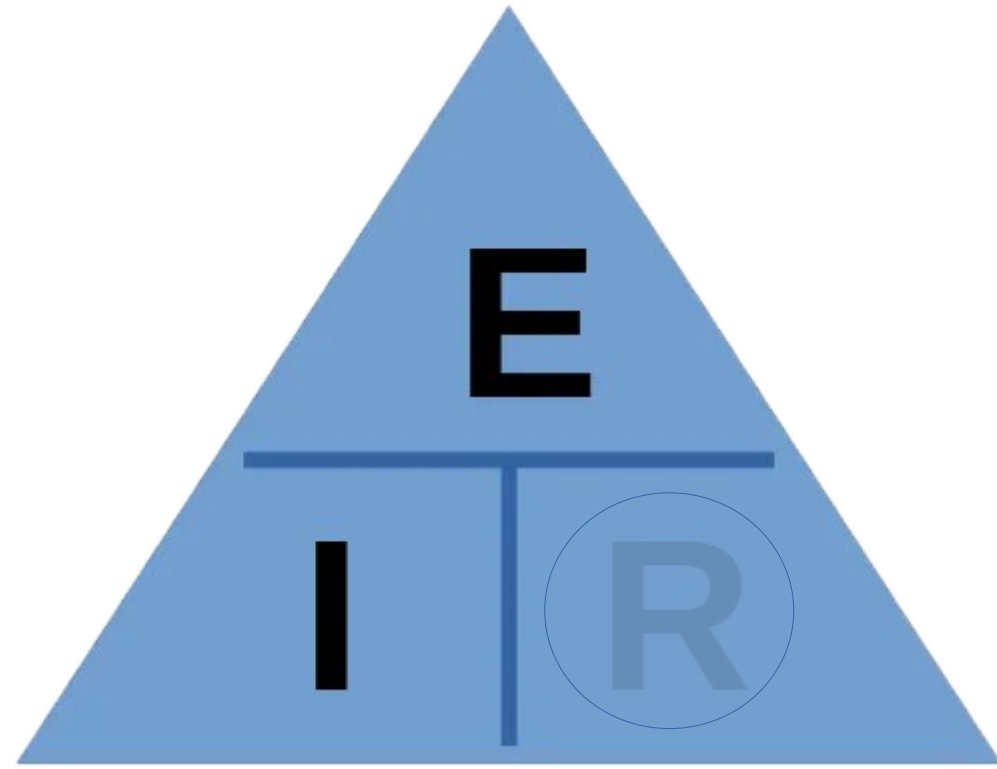
“OHM’S TRIANGLE”

EXAMPLE: SOLVE FOR VOLTS

$$E = I \times R$$

$$1\text{ V} = .5\text{ A} \times 2\Omega$$

B-005-004: OHM'S LAW AND ITS APPLICATIONS

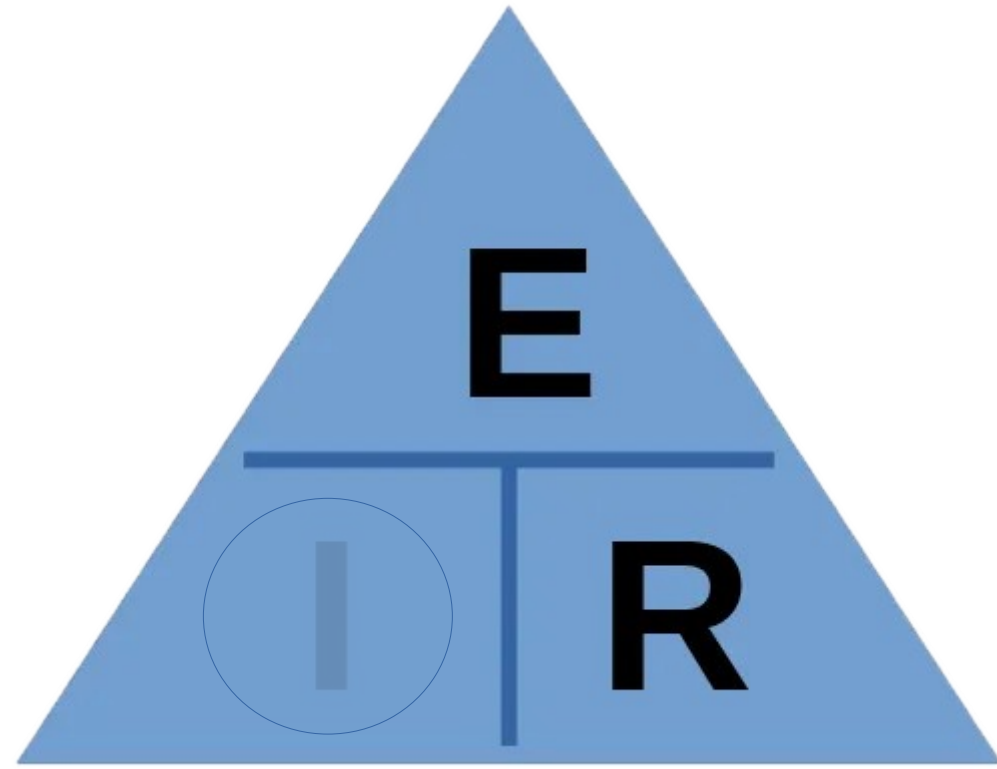


“OHM’S TRIANGLE”

EXAMPLE: SOLVE FOR RESISTANCE

$$R = \frac{E}{I}$$
$$48 \, \Omega = \frac{12 \, \text{V}}{.25 \, \text{A}}$$

B-005-004: OHM'S LAW AND ITS APPLICATIONS



“OHM’S TRIANGLE”

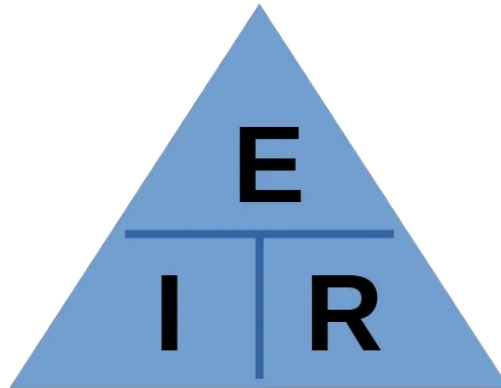
EXAMPLE: SOLVE FOR CURRENT

$$I = \frac{E}{R}$$
$$.2 A = \frac{6 V}{30 \Omega}$$

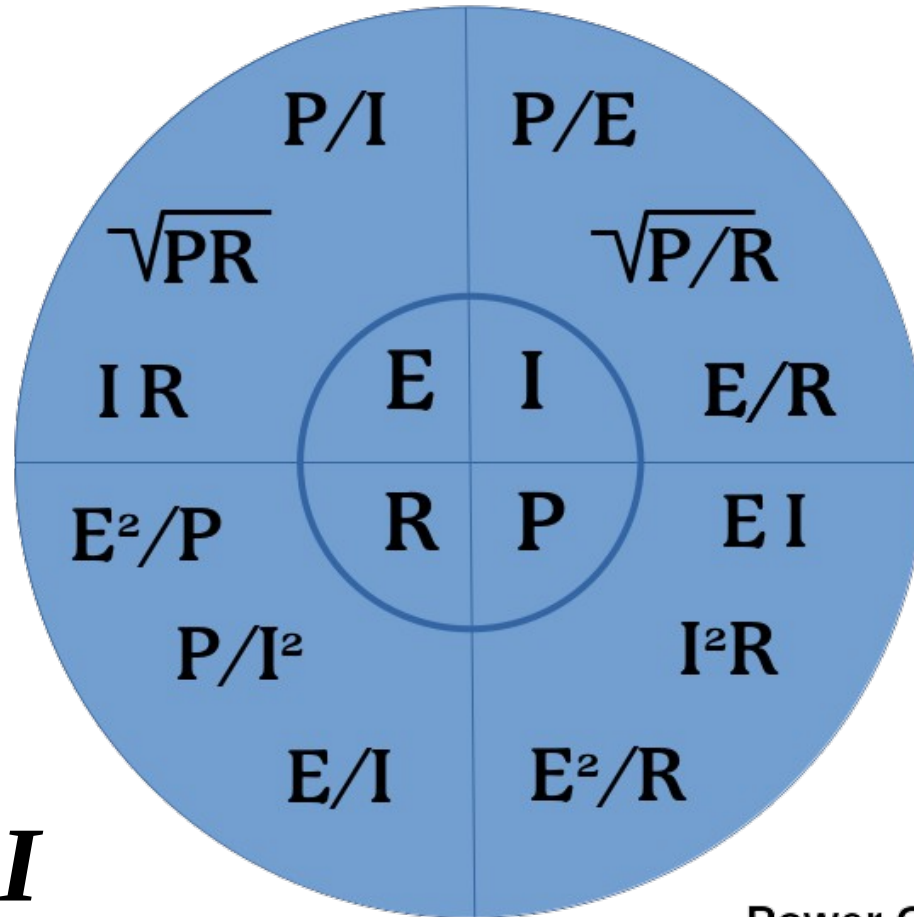
B-005-004: OHM'S LAW AND ITS APPLICATIONS

MORE PRACTICAL EXAMPLES AND CALCULATIONS

- RESISTANCE TO DROP 9V AT 10mA (0.01 A): $R = 9 / 0.01 = 900 \text{ OHMS}$
- VOLTAGE ACROSS 50Ω WITH 0.44A: $V = 0.44 \times 50 = 22 \text{ VOLTS}$
- VOLTAGE FOR 200mA (0.2A) THROUGH 25Ω RELAY: $V = 0.2 \times 25 = 5 \text{ VOLTS}$
- RESISTANCE DRAWING 300mA (0.3A) FROM 3 V: $R = 3 / 0.3 = 10 \text{ OHMS}$

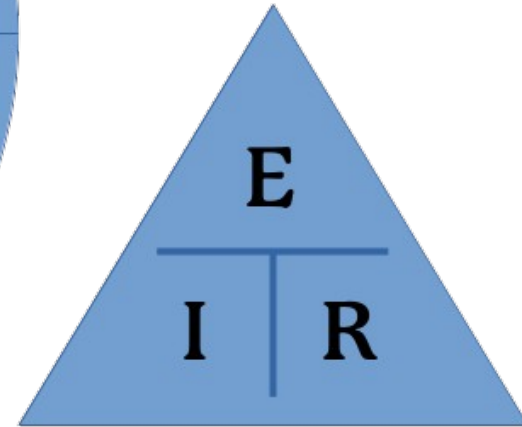


B-005-004: OHM'S LAW AND ITS APPLICATIONS



P = POWER IN WATTS
 I = CURRENT IN AMPS
 E = VOLTS
 R = RESISTANCE IN OHMS

$$P = V \times I$$



Power Circle Replaces Ohm's Triangle



QUESTION SECTION B-005-005:

SERIES AND PARALLEL RESISTOR COMBINATIONS

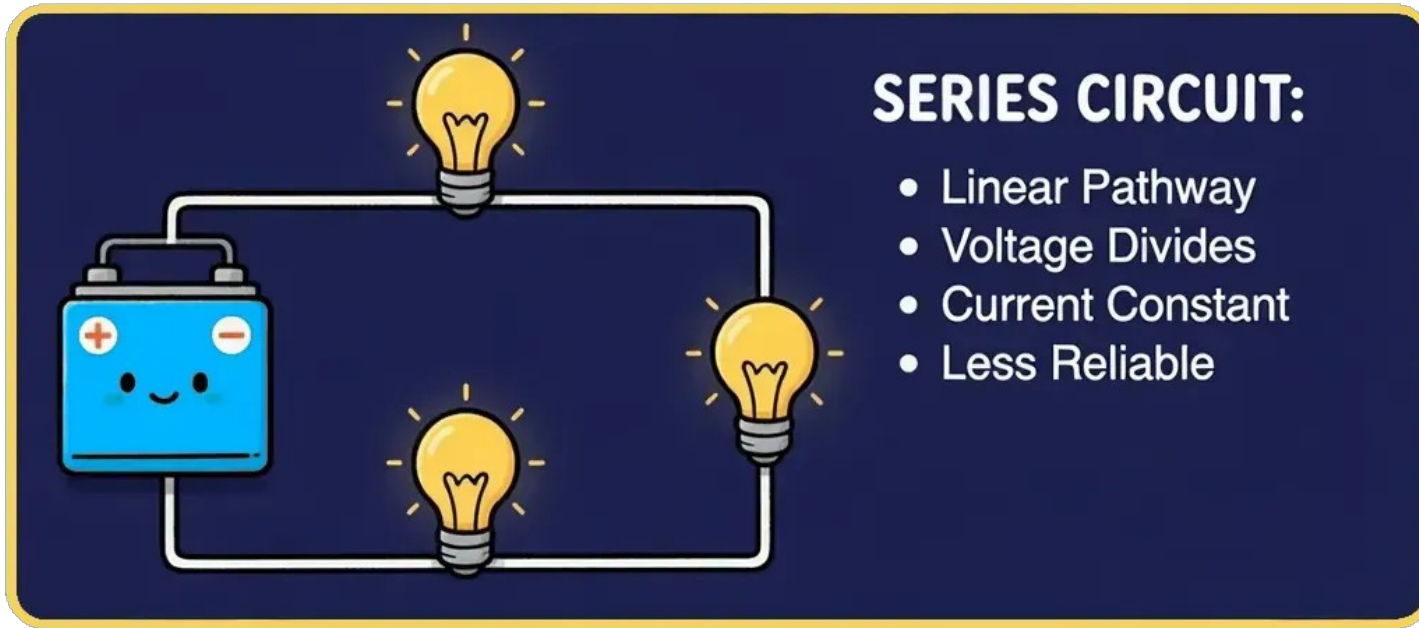
B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

SERIES AND PARALLEL RESISTOR COMBINATIONS – HOW CURRENT AND RESISTANCE BEHAVE

- RESISTORS CAN BE CONNECTED IN TWO BASIC WAYS:
 - **SERIES**: END-TO-END, SINGLE PATH FOR CURRENT.
 - **PARALLEL**: SIDE-BY-SIDE, MULTIPLE PATHS FOR CURRENT.
- THESE CONFIGURATIONS CHANGE TOTAL RESISTANCE, CURRENT DRAW FROM THE SOURCE (BATTERY/POWER SUPPLY), AND HOW VOLTAGE/CURRENT SPLITS — KEY FOR DESIGNING BIAS NETWORKS, SWR BRIDGES, OR COMBINING LOADS IN HAM PROJECTS.

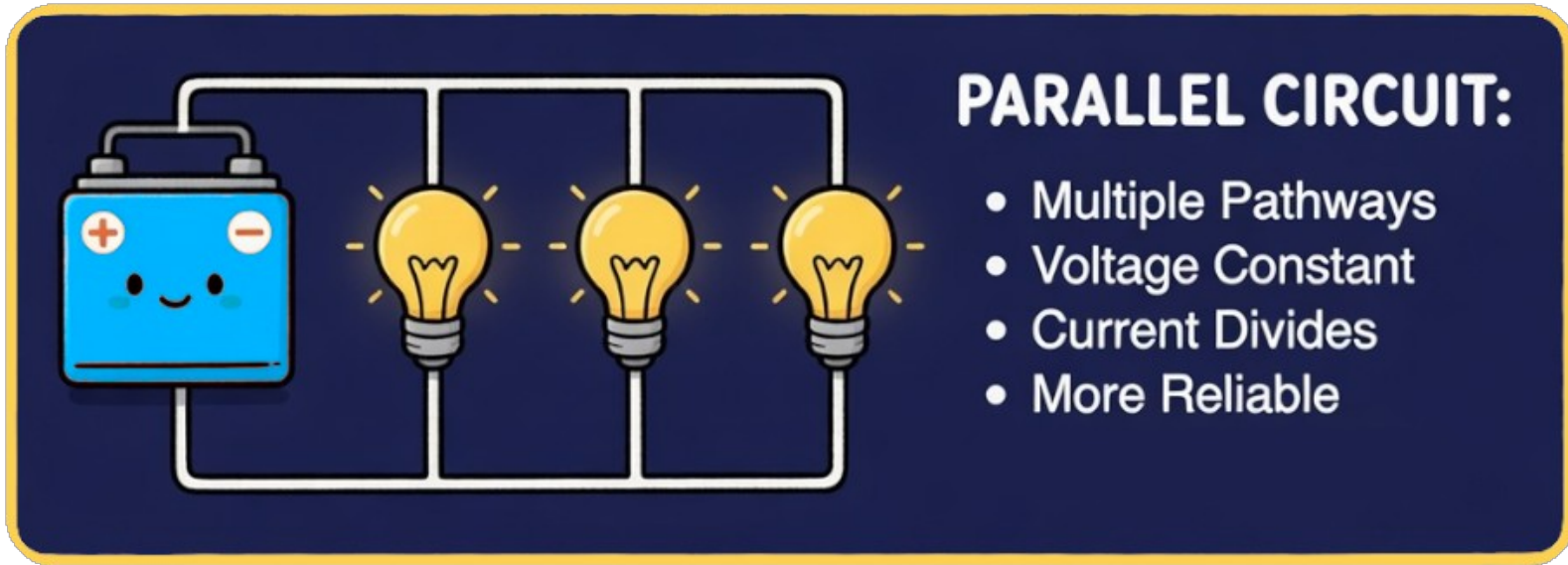
B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

SERIES CIRCUITS



B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

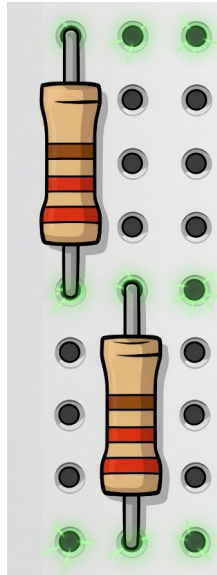
PARALLEL CIRCUITS



B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

SERIES CIRCUITS

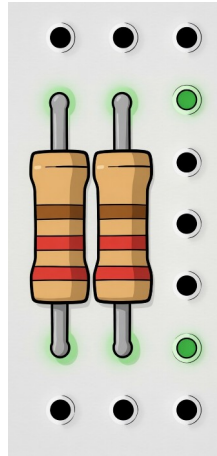
- CURRENT IS THE SAME THROUGH EVERY RESISTOR.
- TOTAL RESISTANCE **ADDS UP**: $R_{TOTAL} = R_1 + R_2 + R_3 \dots$
- TOTAL RESISTANCE **IS GREATER** THAN ANY SINGLE RESISTOR.
- VOLTAGE DROPS ACROSS EACH RESISTOR (ADDS TO SOURCE VOLTAGE).
- EX: FIVE 10Ω RESISTORS IN SERIES $\rightarrow$ **50 OHMS TOTAL**.
- EX: TO REPLACE A SINGLE 120Ω RESISTOR: FIVE 24Ω RESISTORS ($5 \times 24 = 120\Omega$).



B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS

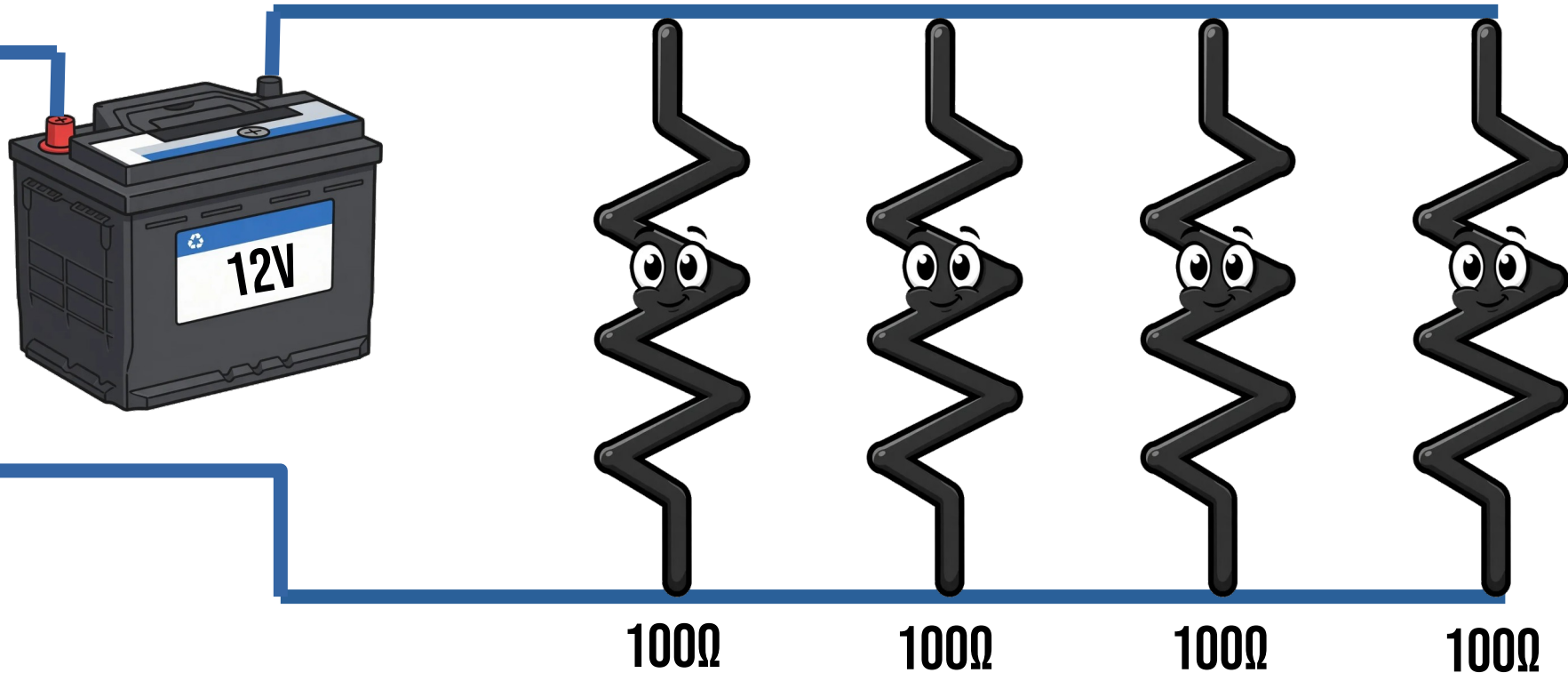
- VOLTAGE IS THE SAME ACROSS EVERY RESISTOR (EQUAL TO SOURCE VOLTAGE).
- TOTAL CURRENT IS THE **SUM OF BRANCH CURRENTS**: $I_{TOTAL} = I_1 + I_2 + I_3 \dots$
- TOTAL (EQUIVALENT) RESISTANCE IS **LESS THAN** THE SMALLEST INDIVIDUAL RESISTOR (MORE PATHS = EASIER CURRENT FLOW).
- FORMULA FOR TWO RESISTORS: $\frac{1}{R_{TOTAL}} = \frac{1}{R_1} + \frac{1}{R_2}$ OR $R_{TOTAL} = \frac{R_1 \times R_2}{R_1 + R_2}$
- FOR N EQUAL RESISTORS OF VALUE: $R_{TOTAL} = \frac{R}{N}$ ← NUMBER OF BRANCHES



B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS – EXAMPLES
SOLVE FOR CURRENT:

$$R_{TOTAL} = \frac{R}{n} = \frac{100\ \Omega}{4} = 25\ \Omega \quad \frac{12\ V}{25\ \Omega} = 0.48\ A\ (480\ mA)$$



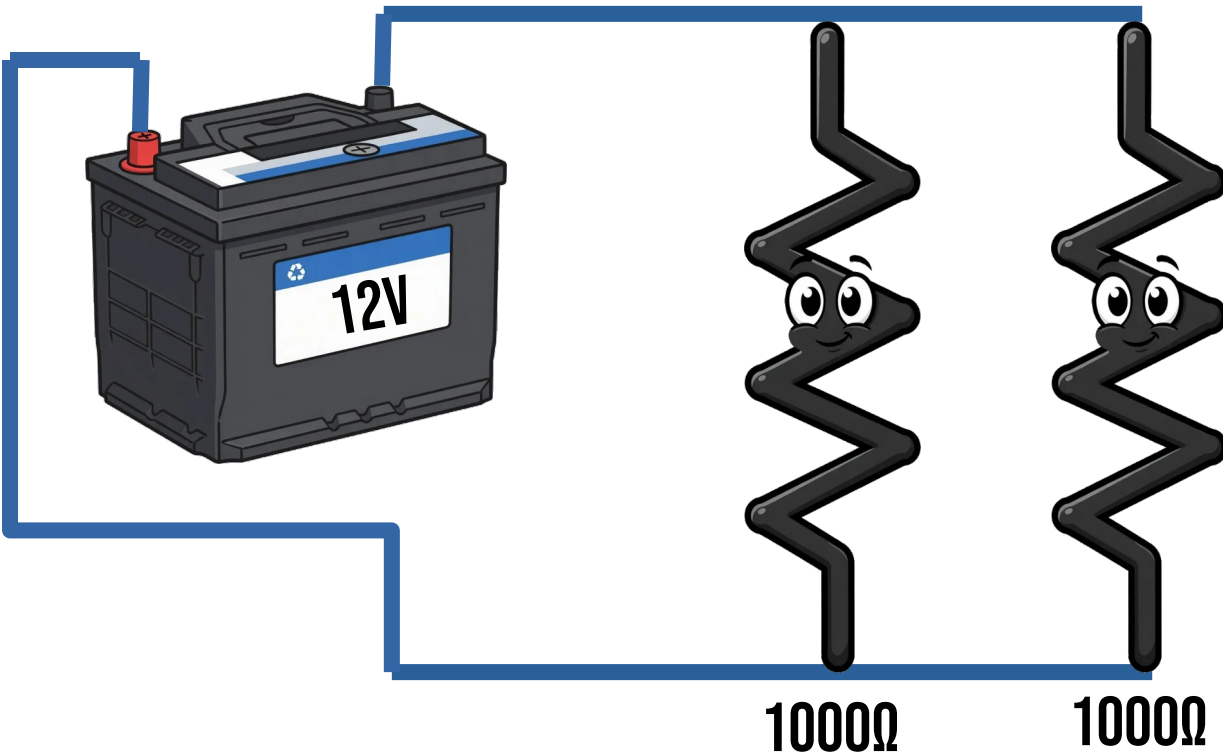
B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS – EXAMPLES

SOLVE FOR CURRENT:

$$R_{TOTAL} = \frac{1}{1000} + \frac{1}{1000} = \frac{2}{1000} = \frac{1000}{2} = 500 \Omega$$

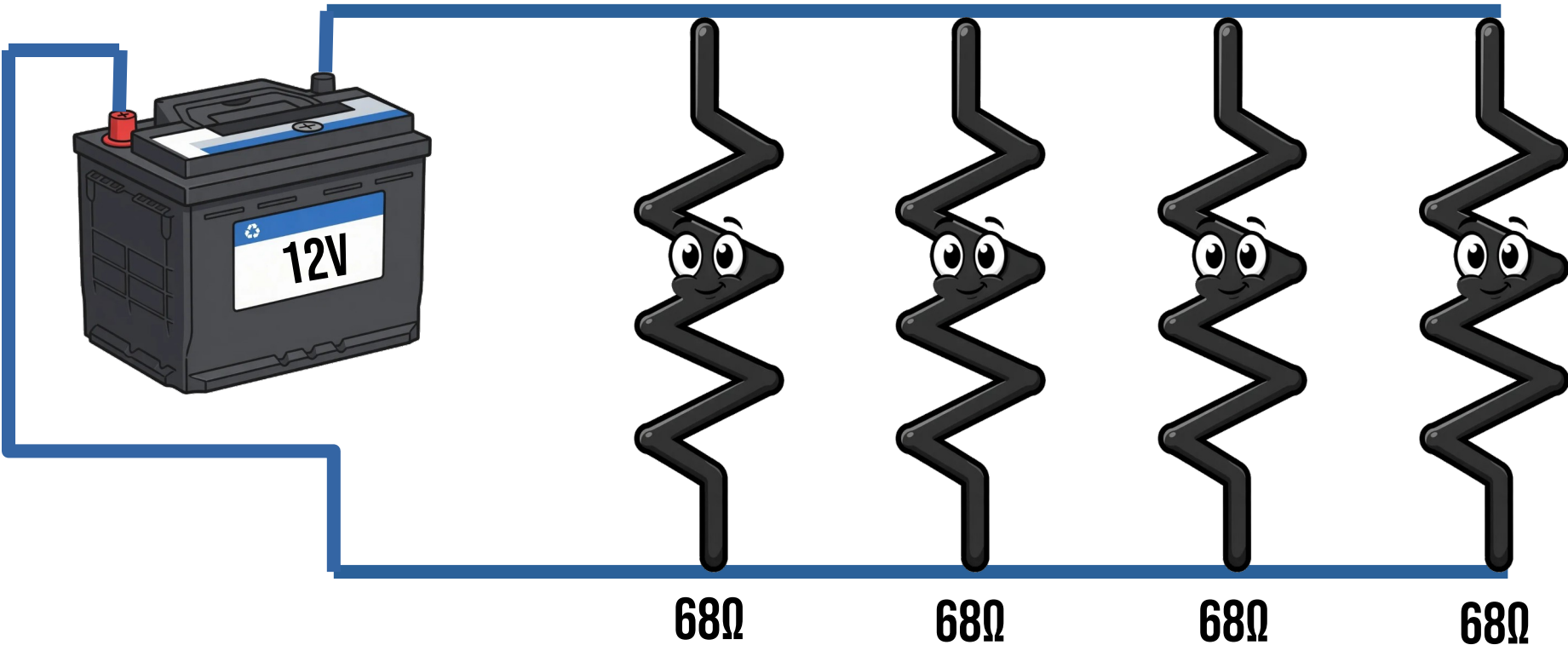
$$\frac{12 V}{500 \Omega} = 0.024 A (24 mA)$$



B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS - EXAMPLES
SOLVE FOR TOTAL RESISTANCE

$$R_{TOTAL} = \frac{R}{n} = \frac{68\ \Omega}{4} = 17\ \Omega$$



B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS - EXAMPLES

- **B-005-005-003 SEVERAL RESISTORS OF VARIOUS VALUES ARE CONNECTED IN PARALLEL. HOW DOES THE TOTAL RESISTANCE OF THE COMBINATION COMPARE TO THE INDIVIDUAL RESISTORS? ANSWER: IT IS LESS THAN THE SMALLEST RESISTOR**

B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS - EXAMPLES

- B-005-005-010 TWO RESISTORS ARE IN PARALLEL. RESISTOR “A” CARRIES TWICE THE CURRENT OF RESISTOR “B,” WHICH MEANS THAT: **ANSWER: “A” HAS HALF THE RESISTANCE OF “B”**

B-005-005: SERIES AND PARALLEL RESISTOR COMBINATIONS

PARALLEL CIRCUITS - EXAMPLES

- B-005-005-008 IF TEN RESISTORS OF EQUAL VALUE “R” ARE WIRED IN PARALLEL, WHAT FORMULA YIELDS THE TOTAL RESISTANCE? **ANSWER: $R / 10$**



QUESTION SECTION B-005-006:
POWER HANDLING AND RATINGS IN
RESISTORS AND CIRCUITS

B-005-006: POWER HANDLING AND RATINGS IN RESISTORS AND CIRCUITS

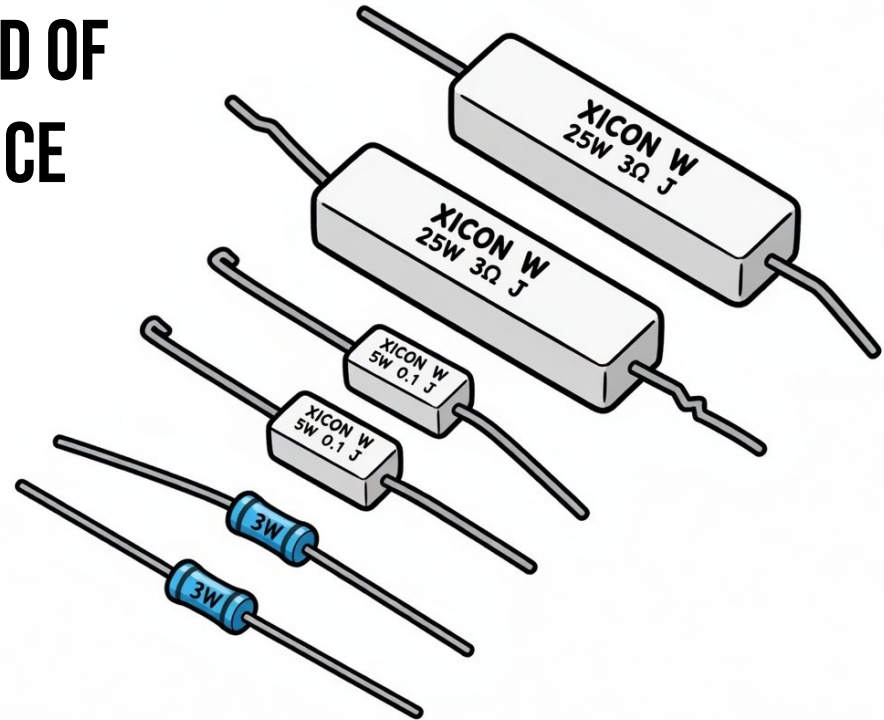
RESISTOR POWER RATINGS – WATTAGE, DISSIPATION, AND SAFE DESIGN IN HAM CIRCUITS

- RESISTORS CONVERT ELECTRICAL ENERGY TO HEAT $P = I^2 R$ $P = \frac{V^2}{R}$
- THE WATTAGE RATING TELLS HOW MUCH POWER (HEAT) A RESISTOR CAN SAFELY DISSIPATE WITHOUT BURNING UP OR CHANGING VALUE EXCESSIVELY.
- RESISTOR WATTAGE RATINGS ARE DETERMINED BY HEAT DISSIPATION QUALITIES — LARGER PHYSICAL SIZE MEANS BETTER HEAT SPREADING AND HIGHER RATING (EVEN FOR THE SAME RESISTANCE VALUE).

B-005-006: POWER HANDLING AND RATINGS IN RESISTORS AND CIRCUITS

RESISTOR POWER RATINGS – WATTAGE, DISSIPATION, AND SAFE DESIGN IN HAM CIRCUITS

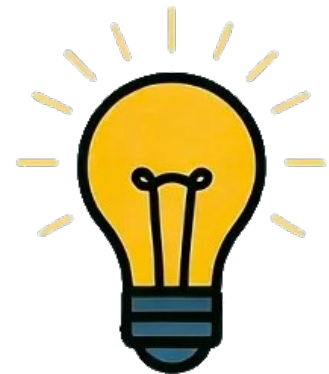
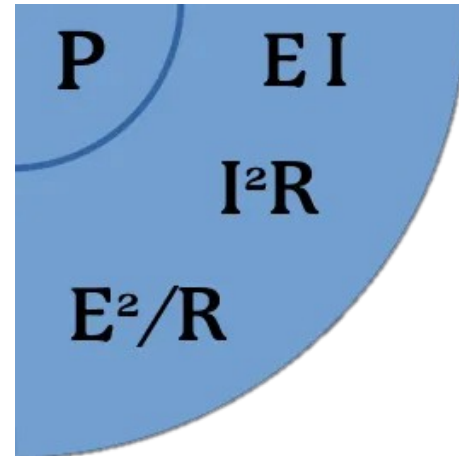
- A **LARGE SIZE RESISTOR** IS USED INSTEAD OF A SMALLER ONE OF THE SAME RESISTANCE FOR **GREATER POWER DISSIPATION** (EX: WIREWOUND OR CERAMIC VS. TINY FILM TYPES).



B-005-006: POWER HANDLING AND RATINGS IN RESISTORS AND CIRCUITS

CALCULATING POWER IN DC CIRCUITS - EXAMPLES

- 12V DC AT 5A LOAD → MINIMUM POWER TRANSFORMER RATING 60 WATTS ($P = 12 \times 5$).
- TRANSMITTER AT 12V DRAWING 500mA (0.5 A) → DC INPUT POWER 6 WATTS.
- 12V, 30W LIGHT BULB → CURRENT 2.5A ($I = P / V = 30 / 12$).
- TWO 10Ω RESISTORS IN SERIES ACROSS 10V → TOTAL $R = 20 \Omega$ → $I = 10 / 20 = 0.5 \text{ A}$ → POWER 5 WATTS (TOTAL DISSIPATED)



B-005-006: POWER HANDLING AND RATINGS IN RESISTORS AND CIRCUITS

POWER RATING IN SERIES AND PARALLEL COMBINATIONS

- **IN SERIES:** POWER RATINGS ADD DIRECTLY (EACH RESISTOR DISSIPATES PART OF TOTAL POWER). TWO 500Ω 1W RESISTORS IN SERIES → MAX TOTAL POWER **2 WATTS**.
- **IN PARALLEL:** POWER RATINGS ADD (SAME VOLTAGE, CURRENT SPLITS). TWO 500Ω 1W IN PARALLEL → MAX TOTAL POWER **2 WATTS**.
- ADVANTAGE OF REPLACING 50Ω WITH TWO 100Ω (SAME RATING) IN PARALLEL: **SAME RESISTANCE BUT GREATER POWER RATING** (DOUBLE THE DISSIPATION CAPABILITY).

VOLTAGE CHANGES AND POWER SCALING

- POWER SCALES (IS PROPORTIONAL) WITH THE SQUARE OF VOLTAGE ($P \propto V^2$ IF R IS FIXED).
- IF VOLTAGE ACROSS TWO SERIES RESISTORS IS DOUBLED → TOTAL POWER INCREASES **FOUR TIMES** (EX: FROM 5W TO 20W).



PRACTICAL HAM APPLICATION: DUMMY LOADS

- **A DUMMY LOAD PROVIDES A 50Ω MATCH FOR TESTING TRANSMITTERS WITHOUT RADIATING. USE MULTIPLE RESISTORS IN PARALLEL TO SPREAD HEAT AND INCREASE POWER HANDLING.**

B-005-006: POWER HANDLING AND RATINGS IN RESISTORS AND CIRCUITS

PRACTICAL HAM APPLICATION: DUMMY LOADS

- WHICH OF THESE COMBINATIONS OF RESISTORS COULD MAKE UP A 50-OHM DUMMY LOAD CAPABLE OF SAFELY DISSIPATING 5 WATTS?

ANSWER: FOUR 2-WATT 200-OHM RESISTORS IN PARALLEL

$$\text{TOTAL POWER RATING} = 2\text{ W} + 2\text{ W} + 2\text{ W} + 2\text{ W} = 8\text{ W}$$

$$R = \frac{200\ \Omega}{4} = 50\ \Omega$$





QUESTION SECTION B-005-007:

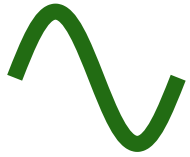
ALTERNATING CURRENT (AC)

FUNDAMENTALS

B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

AC FUNDAMENTALS – FREQUENCY, WAVELENGTH, PHASE AND HARMONICS IN RADIO

- **UNLIKE STEADY DC (FROM BATTERIES), ALTERNATING CURRENT (AC) REVERSES DIRECTION PERIODICALLY, CREATING OSCILLATING WAVEFORMS USED IN ALL RADIO TRANSMISSION AND RECEPTION.**
- **KEY PROPERTIES INCLUDE FREQUENCY (HOW FAST IT OSCILLATES), WAVELENGTH (PHYSICAL DISTANCE PER CYCLE), PHASE (TIMING OFFSET), AND HARMONICS (MULTIPLES THAT CAN CAUSE INTERFERENCE).**



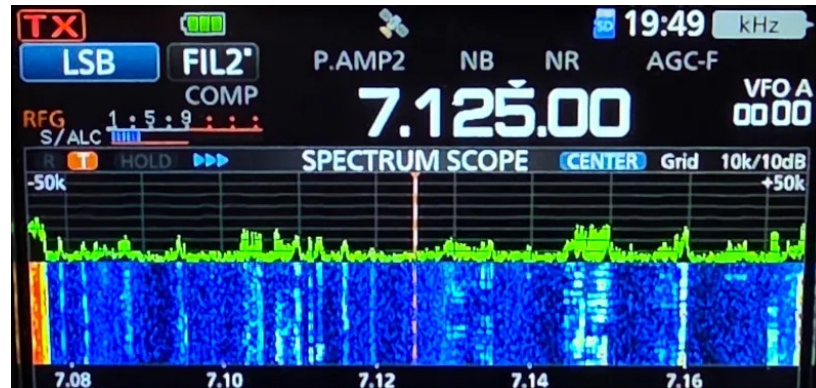
FREQUENCY – CYCLES PER SECOND

- **FREQUENCY** IS THE NUMBER OF TIMES PER SECOND AN AC SIGNAL COMPLETES A FULL POSITIVE-TO-NEGATIVE-TO-POSITIVE CYCLE MEASURED IN **HERTZ (Hz)**.
- 60 Hz MEANS **60 CYCLES PER SECOND** (STANDARD HOUSEHOLD POWER IN NORTH AMERICA).
- HUMAN HEARING RANGE: APPROXIMATELY **20 Hz TO 20,000 Hz (20 kHz)** — THAT'S WHY THIS IS CALLED **AUDIO FREQUENCIES** (HUMAN EAR SENSES SOUND VIBRATIONS IN THIS RANGE).

B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

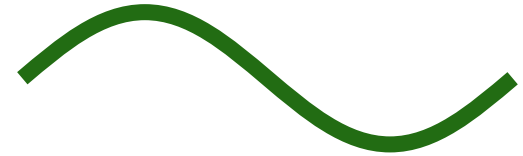
RADIO FREQUENCY BANDS – EXAMPLE: HF

- HAM RADIO USES HIGHER FREQUENCIES FOR PROPAGATION OVER LONG DISTANCES.
- 7125 kHz (7.125 MHz) FALLS IN THE HIGH FREQUENCY (HF) RANGE (3–30 MHz), HOME TO MOST AMATEUR VOICE, CW, AND DIGITAL MODES.



B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

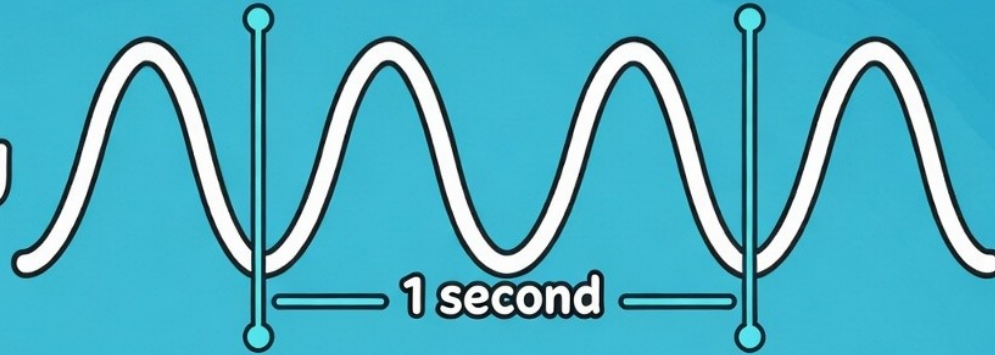
WAVELENGTH – DISTANCE PER CYCLE



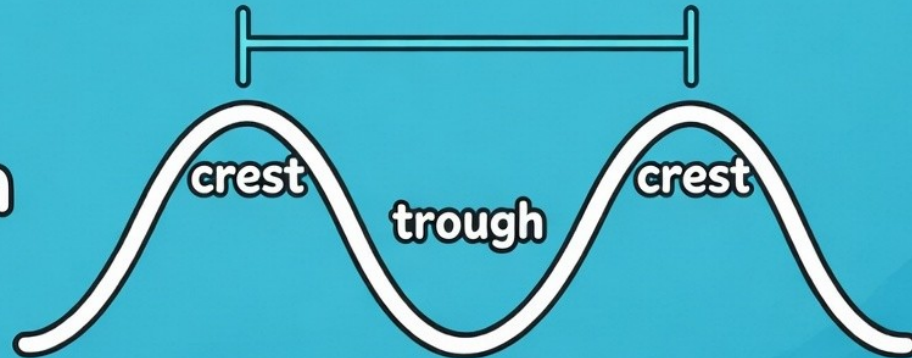
- **WAVELENGTH** IS 'THE PHYSICAL DISTANCE' AN AC SIGNAL TRAVELS DURING ONE COMPLETE CYCLE (MEASURED IN METERS).
- RELATIONSHIP: HIGHER FREQUENCY → SHORTER WAVELENGTH (INVERSE PROPORTION).
- WAVELENGTH = SPEED OF LIGHT / FREQUENCY;
- SPEED OF LIGHT $\approx 300,000,000$ M/S).
$$\lambda (\text{Meters}) = \frac{300 \text{ m/sec}}{\text{Frequency MHz}}$$
- AS **FREQUENCY INCREASES**, **WAVELENGTH DECREASES**
- AS **WAVELENGTH SHORTENS**, **FREQUENCY INCREASES**.

B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

Frequency



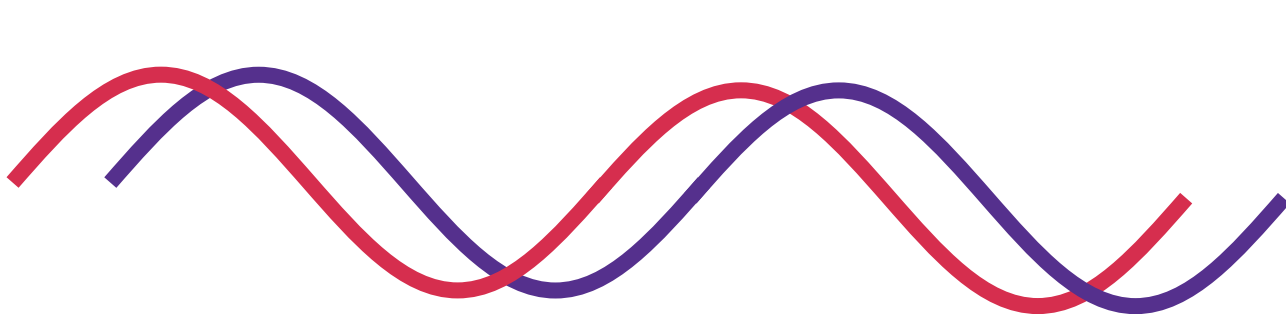
Wavelength



B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

WAVEFORM SHAPE AND PHASE

- HOUSEHOLD AC FROM A RECEPTACLE IS A SINE WAVE (SINUSOIDAL) — SMOOTH, PURE OSCILLATION.
- **PHASE** DESCRIBES THE TIMING DIFFERENCE WHEN TWO AC WAVEFORMS OF THE SAME FREQUENCY DON'T START THEIR CYCLES AT THE SAME INSTANT (EX: ONE LEADS OR LAGS THE OTHER BY DEGREES).



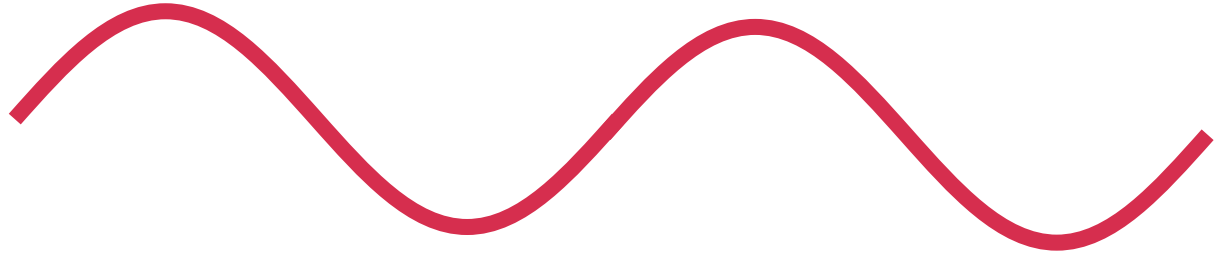
B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

HARMONICS – MULTIPLES OF THE FUNDAMENTAL

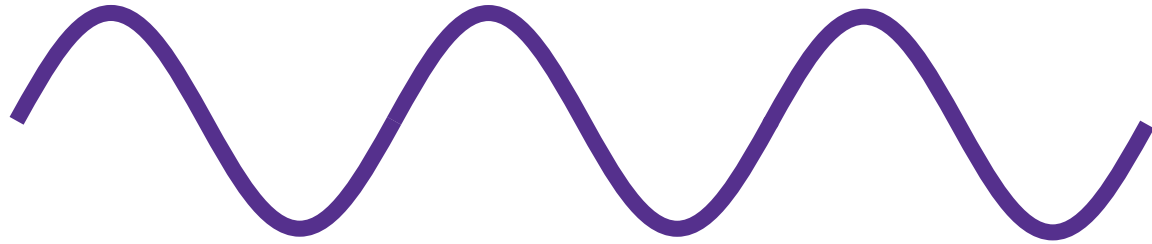
- A SIGNAL WITH A **FUNDAMENTAL FREQUENCY** (EX: 2 kHz BASE TONE) CAN INCLUDE HIGHER MULTIPLES CALLED **HARMONICS** (2ND = 4 kHz, 3RD = 6 kHz, ETC.).
- HARMONICS ADD RICHNESS TO SOUND (MUSIC) BUT IN RADIO CAN CAUSE INTERFERENCE IF NOT FILTERED (EX: OVERDRIVEN TRANSMITTER PRODUCES UNWANTED HARMONICS).

B-005-007: ALTERNATING CURRENT (AC) FUNDAMENTALS

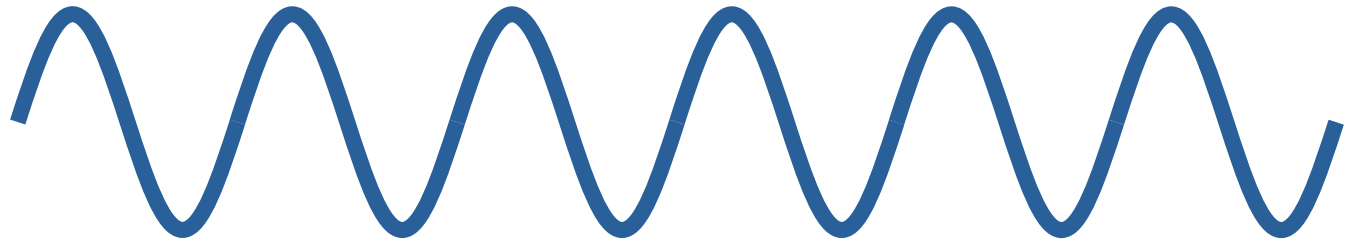
FUNDAMENTAL



2ND HARMONIC



3RD HARMONIC





QUESTION SECTION B-005-008:

DECIBELS (dB) AND POWER RATIOS

DECIBELS – MEASURING POWER CHANGES AND SIGNAL STRENGTH IN HAM RADIO

- THE **DECIBEL** (dB) MEASURES **THE RATIO** BETWEEN TWO POWER LEVELS (OR VOLTAGE/CURRENT IN SOME CASES).
- IT'S NOT AN ABSOLUTE UNIT LIKE WATTS — IT'S RELATIVE:
"HOW MANY TIMES STRONGER/WEAKER?"

B-005-008: DECIBELS (dB) AND POWER RATIOS

DECIBELS – MEASURING POWER CHANGES AND SIGNAL STRENGTH IN HAM RADIO

- **KEY RULE: A 3 dB CHANGE = POWER RATIO OF 2 (DOUBLE OR HALF).**

- **BECAUSE IT'S LOGARITHMIC:**

- **+3 dB $\approx$ $\times 2$ POWER**
- **+6 dB $\approx$ $\times 4$ POWER**
- **+10 dB $\approx$ $\times 10$ POWER**
- **-3 dB $\approx$ $\div 2$ POWER**



- **THIS MAKES dB PERFECT FOR DESCRIBING HUGE RANGES (EX: FROM MILLIWATTS TO KILOWATTS) IN ANTENNA SYSTEMS, AMPLIFIERS, AND PROPAGATION.**

BASIC POWER CHANGES IN dB

- **DOUBLING POWER ($\times 2$) = +3 dB (INCREASE).**
- **HALVING POWER ($\div 2$) = -3 dB (DECREASE).**
- **QUADRUPLING POWER ($\times 4$) = +6 dB.**
- **$\times 10$ POWER = +10 dB.**
- **1W TO 2W = +3 dB**
- **5W TO 50W = $\times 10$ = +10 dB GAIN (LINEAR AMPLIFIER).**

APPLYING dB TO REAL HAM SCENARIOS

- **ADDING GAIN: 2W HANDHELD + 9 dB AMPLIFIER**
→ **OUTPUT 16 WATTS ($2 \times 8 \approx 16$ W, SINCE $+9$ dB $\approx \times 8$).**
- **FEEDLINE LOSS: 100 W TRANSMITTER - 6 dB LINE LOSS**
→ **25 W AT ANTENNA ($100 \div 4 = 25$ W).**

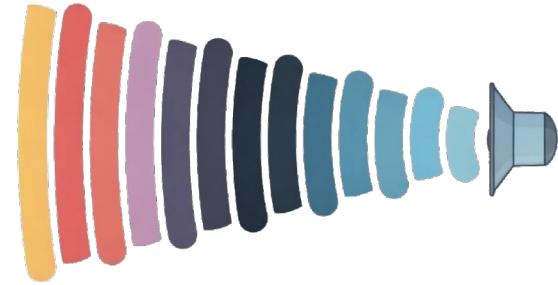
APPLYING dB TO REAL HAM SCENARIOS

- **S-METER READINGS: EACH 10 dB IS ONE S-UNIT OVER S9 (S9 = REFERENCE STRONG SIGNAL). "10 dB OVER S9" MEANS 10× STRONGER THAN S9.**
- **REDUCE POWER BY 10 dB ($\div 10$) → DROPS TO S9.**
- **REDUCE BY 20 dB ($\div 100$)**
→ **DROPS BY TWO S-UNITS (S7 IF ORIGINAL WAS 20 DB OVER S9).**

B-005-008: DECIBELS (dB) AND POWER RATIOS

APPLYING dB TO REAL HAM SCENARIOS

- **200W → "10 dB OVER S9" REDUCE TO 20 W ($\div 10 = -10$ dB) → S9**
- **150W → "20 dB OVER S9"; REDUCE TO 15 W ($\div 10 = -10$ dB) → S9 PLUS 10 dB (STILL ONE 10 dB STEP ABOVE S9).**
- **100W ON 2M SIMPLEX → "30 dB OVER S9"**
 - **TO REACH S9, REDUCE BY 30 dB ($\div 1000$) → 0.1 W.**



PURPOSE OF DECIBELS

- THE DECIBEL IS USED **TO MEASURE THE RATIO OF TWO SIGNALS** — IDEAL FOR GAIN/LOSS IN SYSTEMS (ANTENNAS, AMPS, COAX, PATH LOSS) WITHOUT DEALING WITH HUGE NUMBERS.



QUESTION SECTION B-005-009:

INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

INDUCTORS & CAPACITORS

- AFTER RESISTORS (RESIST CURRENT) AND BASIC CIRCUITS, WE MOVE TO **INDUCTORS** (L, MEASURED IN HENRIES OR MILLIHENRIES) AND **CAPACITORS** (C, MEASURED IN FARADS, MICROFARADS, OR PICOFARADS). THESE ARE KEY IN HAM APPLICATIONS:
 - **INDUCTORS**: RF CHOKES, LOADING COILS ON ANTENNAS, TANK CIRCUITS IN TRANSMITTERS.
 - **CAPACITORS**: TUNING, COUPLING, DECOUPLING, FILTERS, BYPASS IN POWER SUPPLIES.

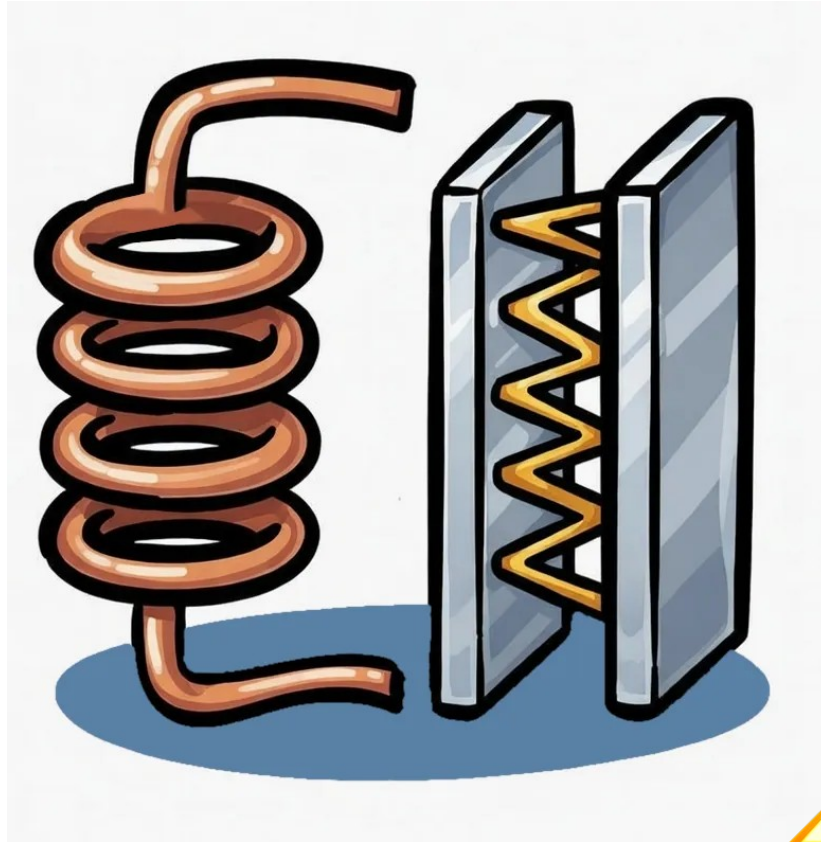
B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

INDUCTORS:

**COIL IN WHICH AN
ELECTRIC CURRENT IS
INDUCED.**

INDUCTANCE:

**CURRENT RUNNING
THROUGH A CONDUCTOR
CREATES A MAGNETIC
FIELD.**



CAPACITORS:

**STORES ELECTRICAL
ENERGY (LIKE A BATTERY
BUT STORES IN AN
ELECTRIC FIELD).**

CAPACITANCE:

**CAPACITANCE IS THE
ABILITY OF A COMPONENT
(A CAPACITOR) TO STORE
ELECTRICAL CHARGE.**



B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

INDUCTORS IN SERIES AND PARALLEL

- INDUCTORS BEHAVE LIKE RESISTORS: TOTAL **INDUCTANCE ADDS IN SERIES**
- **REDUCES IN PARALLEL** (FOR EQUAL VALUES WITHOUT MUTUAL COUPLING).
- TWO EQUAL-VALUE INDUCTORS IN SERIES:
 - TOTAL INDUCTANCE **TWICE** THE VALUE OF ONE.
- TWO EQUAL-VALUE INDUCTORS IN PARALLEL
 - TOTAL INDUCTANCE **HALF** THE VALUE OF ONE.
- EX: TWO 12mH CHOKES IN SERIES → 24 MILLIHENRIES.
- EX: TWO 20mH INDUCTORS IN PARALLEL → 10 MILLIHENRIES.

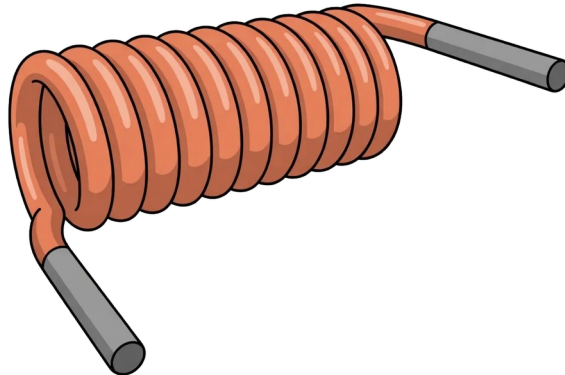
CAPACITORS IN SERIES AND PARALLEL

- CAPACITORS ARE OPPOSITE TO RESISTORS/INDUCTORS
- TOTAL CAPACITANCE ADDS IN PARALLEL, REDUCES IN SERIES.
- TWO EQUAL-VALUE CAPACITORS IN SERIES
 - TOTAL CAPACITANCE HALF THE VALUE OF EITHER.
- TWO EQUAL-VALUE CAPACITORS IN PARALLEL
 - TOTAL CAPACITANCE TWICE THE VALUE OF ONE.
- EX: TWO 20 μF CAPACITORS IN SERIES → 10 MICROFARADS.
- EX: TWO 24 μF CAPACITORS IN PARALLEL → 48 MICROFARADS

B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

WHAT DETERMINES INDUCTANCE AND CAPACITANCE?

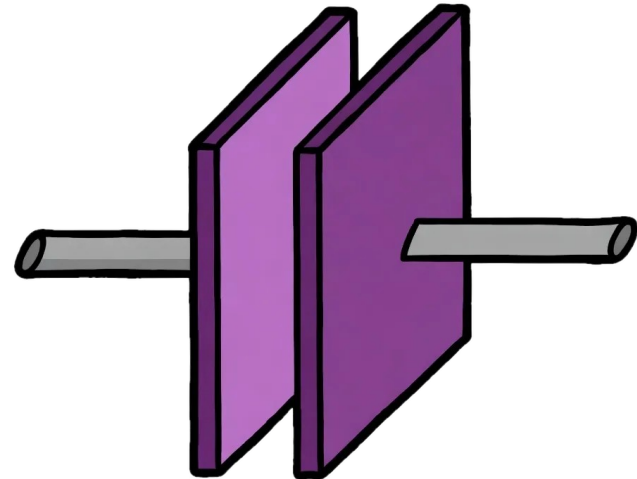
- FOR AN **AIR-CORE INDUCTOR** (COIL OF WIRE, NO MAGNETIC CORE):
 - INDUCTANCE DEPENDS ON **COIL DIAMETER**, **COIL LENGTH**, AND NUMBER OF TURNS OF WIRE.
 - MORE TURNS, LARGER DIAMETER, OR SHORTER LENGTH → HIGHER INDUCTANCE.



B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

WHAT DETERMINES INDUCTANCE AND CAPACITANCE?

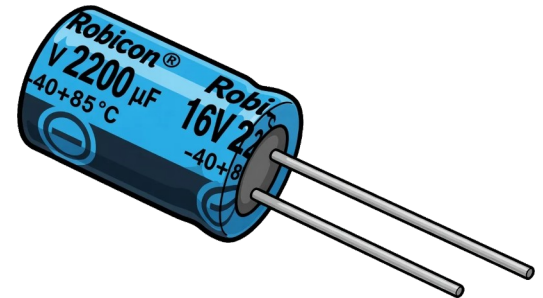
- FOR A BASIC **PARALLEL-PLATE CAPACITOR** (TWO METAL PLATES SEPARATED BY AIR):
 - CAPACITANCE DEPENDS ON:
 - **SURFACE AREA OF THE PLATES** (LARGER = MORE C)
 - **SPACING BETWEEN THE PLATES** (CLOSER = MORE C).



B-005-009: INDUCTORS AND CAPACITORS IN SERIES/PARALLEL

SAFETY WITH POLARIZED CAPACITORS

- MANY ELECTROLYTIC CAPACITORS (COMMON IN POWER SUPPLIES, AUDIO FILTERS) ARE **POLARIZED** — THEY HAVE A POSITIVE AND NEGATIVE LEAD.
- PRECAUTION: **NEVER APPLY A REVERSE VOLTAGE** — IT CAN CAUSE THE CAPACITOR TO LEAK, OVERHEAT, EXPLODE, OR FAIL CATASTROPHICALLY. ALWAYS OBSERVE POLARITY MARKINGS (+/- OR STRIPE ON NEGATIVE SIDE).





QUESTION SECTION B-005-010:

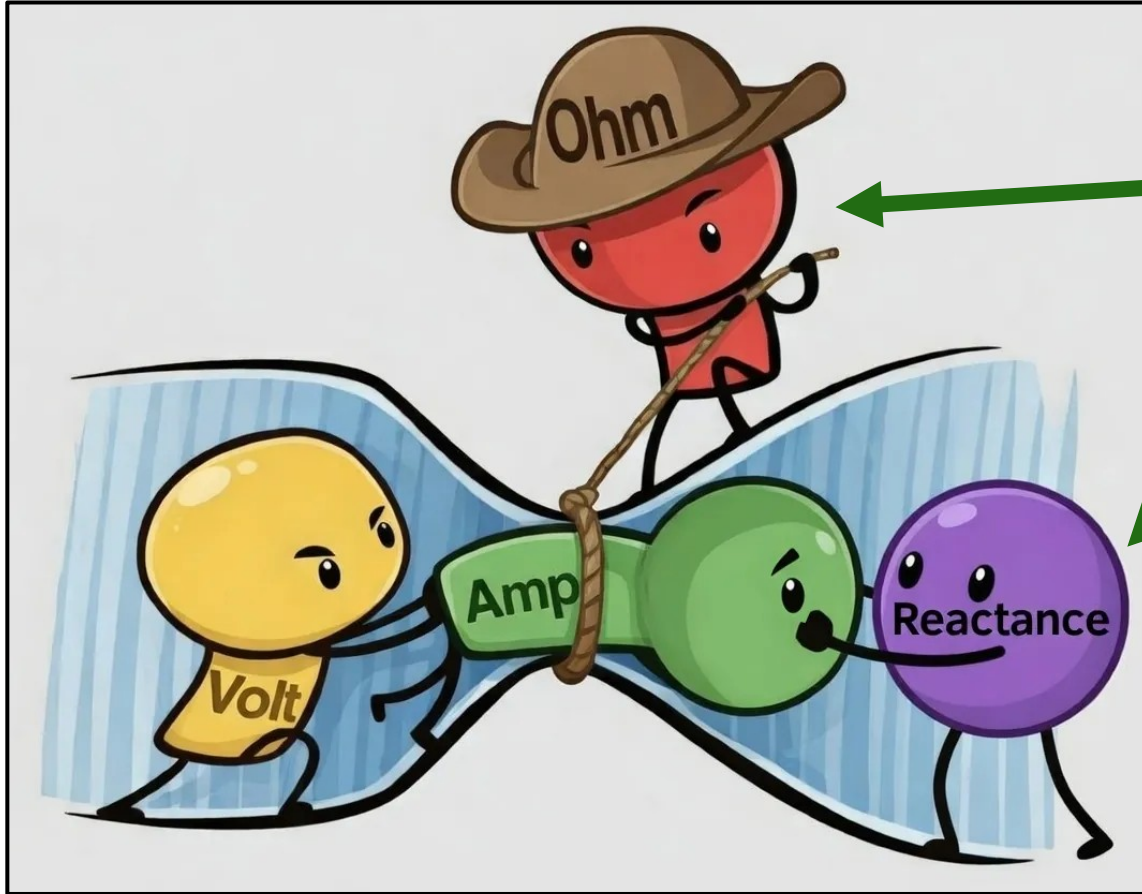
REACTANCE AND IMPEDANCE IN AC CIRCUITS

B-005-010: REACTANCE AND IMPEDANCE IN AC CIRCUITS

REACTANCE

- IN DC CIRCUITS, ONLY RESISTANCE (R) OPPOSES CURRENT.
- IN AC, INDUCTORS AND CAPACITORS ADD **REACTANCE** (X_L FOR INDUCTORS, X_C FOR CAPACITORS), WHICH CHANGES WITH FREQUENCY.
- REACTANCE IS THE **OPPOSITION** DUE TO INDUCTANCE OR CAPACITANCE (MEASURED IN OHMS, LIKE RESISTANCE).
- **IMPEDANCE (Z)** IS THE TOTAL OPPOSITION: COMBINED EFFECT OF RESISTANCE AND REACTANCE

B-005-010: REACTANCE AND IMPEDANCE IN AC CIRCUITS



**RESISTANCE
+
REACTANCE**

=

IMPEDANCE!

$$Z = \sqrt{R^2 + X^2}$$



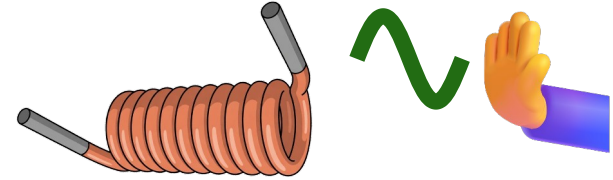
IMPEDANCE – TOTAL OPPOSITION IN AC

- **IMPEDANCE** COMBINES RESISTANCE AND REACTANCE TO EQUAL THE TOTAL OPPOSITION TO AC
- ALSO DEFINED AS THE RATIO OF AC VOLTAGE TO AC CURRENT IN A CIRCUIT OR SYSTEM.

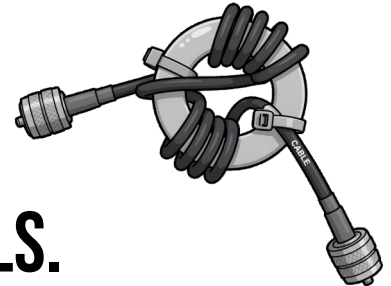
$$Z = \frac{V}{I}$$

B-005-010: REACTANCE AND IMPEDANCE IN AC CIRCUITS

INDUCTIVE REACTANCE (X_L) $X_L = 2\pi fL$



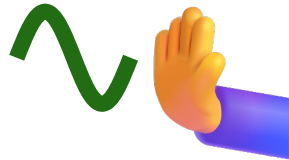
- AN INDUCTOR (COIL) OPPOSES CHANGES IN CURRENT.
- AS AC **FREQUENCY INCREASES**, INDUCTIVE REACTANCE **INCREASES** DIRECTLY PROPORTIONAL TO f .
- HIGH REACTANCE AT RADIO FREQUENCIES MAKES FERRITE-CORE COILS EXCELLENT **RF CHOKES** — THEY BLOCK OFFENDING RF SIGNALS (EX: IN POWER LINES TO PREVENT INTERFERENCE).
- LOW REACTANCE AT LOW (AUDIO) FREQUENCIES MEANS RF CHOKES HAVE LITTLE EFFECT ON INTENDED DC OR AUDIO SIGNALS.



B-005-010: REACTANCE AND IMPEDANCE IN AC CIRCUITS

CAPACITIVE REACTANCE (X_C)

$$X_C = \frac{1}{2\pi fC}$$



- A CAPACITOR OPPOSES CHANGES IN VOLTAGE.
- AS AC **FREQUENCY INCREASES**, CAPACITIVE REACTANCE **DECREASES** INVERSELY PROPORTIONAL TO f .
- LOW REACTANCE AT RADIO FREQUENCIES MAKES BYPASS CAPACITORS EXCELLENT FOR SHUNTING RF INTERFERENCE TO GROUND (EX: IN AUDIO CIRCUITS TO PREVENT RF FROM ENTERING).
- HIGH REACTANCE AT AUDIO FREQUENCIES MEANS RF BYPASS CAP HAS LITTLE EFFECT ON DESIRED AUDIO SIGNALS (PASSES AUDIO, BLOCKS RF).



QUESTION SECTION B-005-011:

TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

TRANSFORMERS

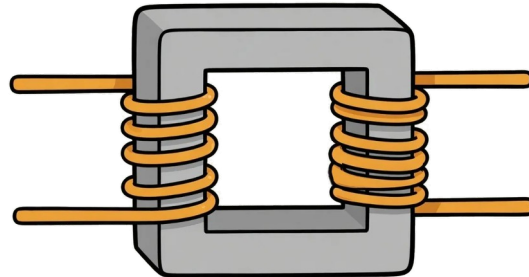
- A **TRANSFORMER** USES ELECTROMAGNETIC INDUCTION TO TRANSFER AC ENERGY FROM A PRIMARY WINDING TO A SECONDARY WINDING VIA A SHARED MAGNETIC FIELD (USUALLY IN A LAMINATED IRON CORE). IDEAL TRANSFORMERS ARE 100% EFFICIENT (POWER IN = POWER OUT), SO

$$P_{\text{PRIMARY}} = P_{\text{SECONDARY}} \quad V_P \times I_P = V_S \times I_S$$

B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

TRANSFORMERS

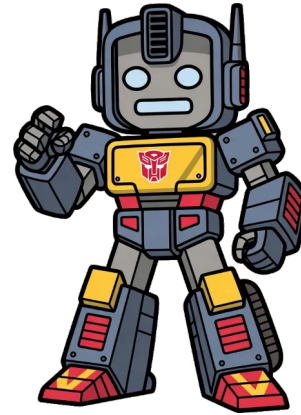
- **STEP-UP**: MORE SECONDARY TURNS $\rightarrow$ HIGHER VOLTAGE, LOWER CURRENT.
- **STEP-DOWN**: FEWER SECONDARY TURNS $\rightarrow$ LOWER VOLTAGE, HIGHER CURRENT.
- TRANSFORMERS ARE EVERYWHERE IN HAM GEAR: IMPEDANCE MATCHING IN ANTENNAS, VOLTAGE STEPPING IN POWER SUPPLIES, ISOLATION IN AUDIO/RF CIRCUITS, ETC.



B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

TRANSFORMER TURNS RATIO AND VOLTAGE/CURRENT RELATIONSHIPS

- **VOLTAGE RATIO = TURNS RATIO** $\frac{V_S}{V_P} = \frac{N_S}{N_P}$
- **CURRENT RATIO IS INVERSE** $\frac{I_S}{I_P} = \frac{N_P}{N_S}$
- **POWER CONSERVED: HIGHER V $\rightarrow$ LOWER I, AND VICE VERSA.**
- **PRIMARY (P), SECONDARY (S), TURNS (N)**



B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

TRANSFORMER TURNS RATIO AND VOLTAGE/CURRENT RELATIONSHIPS

- B-005-011-003 A TRANSFORMER WITH A SINGLE 12-VOLT SECONDARY DRAWS 0.5 AMPERES THROUGH ITS 120-VOLT PRIMARY. ASSUMING NO LOSSES, WHAT CURRENT IS DRAWN FROM THE SECONDARY? **ANSWER: 5 AMPERES**

$$\begin{aligned} P &= V \times I \\ V_P \times I_P &= V_S \times I_S \\ 120 \text{ V} \times 0.5 \text{ A} &= 12 \text{ V} \times ? \\ 60 \text{ W} &= 12 \text{ v} \times ? \end{aligned} \quad \rightarrow \quad \frac{60 \text{ W}}{12 \text{ V}} = 5 \text{ A}$$



B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

TRANSFORMER TURNS RATIO AND VOLTAGE/CURRENT RELATIONSHIPS

- B-005-011-004 THE PRIMARY WINDING OF A TRANSFORMER HAS 250 TURNS, AND THE SECONDARY HAS 500 TURNS. IF THE INPUT VOLTAGE IS 120 VOLTS, WHAT IS THE SECONDARY VOLTAGE? **ANSWER: 240 V**

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} \quad \frac{?}{120 \text{ V}} = \frac{500}{250}$$



$$120 \text{ V} \times 2 = 240 \text{ V}$$

B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

TRANSFORMER TURNS RATIO AND VOLTAGE/CURRENT RELATIONSHIPS

- B-005-011-008 A STEP-UP TRANSFORMER WITH A PRIMARY TO SECONDARY TURNS RATIO OF 1:5 DELIVERS 50 MILLIAMPERES TO A LOAD. ASSUMING 100% EFFICIENCY, WHAT IS THE PRIMARY CURRENT? **ANSWER: 250 mA**

$$P = V \times I$$
$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$
$$\frac{?}{50 \text{ mA}} = \frac{5}{1}$$

$$I_P = 50 \text{ mA} \times 5 = 250 \text{ mA}$$

POWER AND CURRENT CALCULATIONS

- **NEGLECTING LOSSES:**

PRIMARY POWER = SECONDARY POWER.

- **120V PRIMARY SUPPLYING 250W TO TRANSMITTER**

→ **PRIMARY CURRENT ≈ 2.1 A**

$$(2.1\text{A} = 250\text{W} / 120\text{V})$$

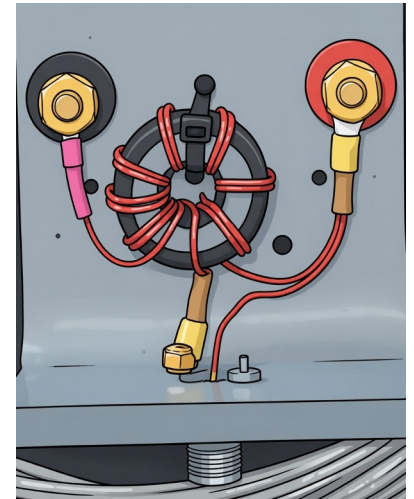
$$I = \frac{P}{V}$$

B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

IMPEDANCE TRANSFORMATION $\frac{Z_S}{Z_P} = \left(\frac{N_S}{N_P} \right)^2$

IMPEDANCE PRIMARY & SECONDARY
N TURNS PRIMARY & SECONDARY

- TRANSFORMERS CHANGE (TRANSFORM) IMPEDANCE BETWEEN WINDINGS BY CARRYING DIFFERENT VOLTAGES AND CURRENTS IN EACH WINDING.
- USEFUL IN HAM RADIO FOR MATCHING ANTENNA IMPEDANCE TO TRANSMITTER
- EX: 50Ω TO 200Ω BALUN



B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

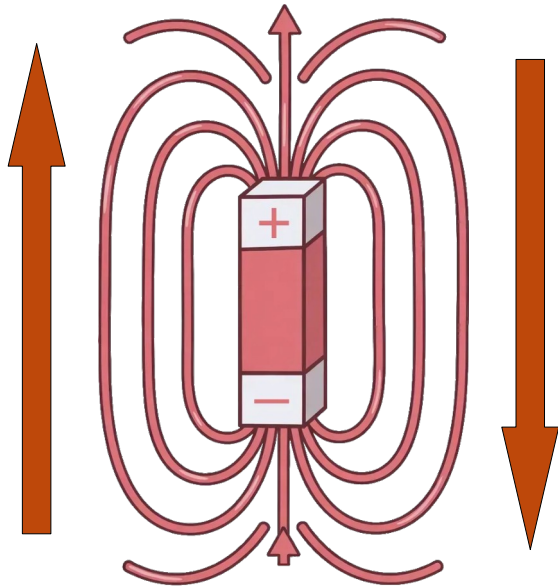
MAGNETIC INDUCTION BASICS

- MAGNETIC FIELD STRENGTH AROUND A CONDUCTOR IN AIR IS:
DIRECTLY PROPORTIONAL TO THE CURRENT
- MAXIMUM INDUCED VOLTAGE IN A COIL OCCURS WHEN CURRENT CHANGES AT ITS:
GREATEST RATE
- COUPLING (INDUCTION) BETWEEN TWO WIRES IS MAXIMUM WHEN THEY ARE:
CLOSE AND PARALLEL (MUTUAL INDUCTANCE).
- PERMANENT MAGNETS ARE MOST LIKELY MADE FROM **STEEL** (RETAINS MAGNETISM WELL).

B-005-011: TRANSFORMERS AND ELECTROMAGNETIC INDUCTION

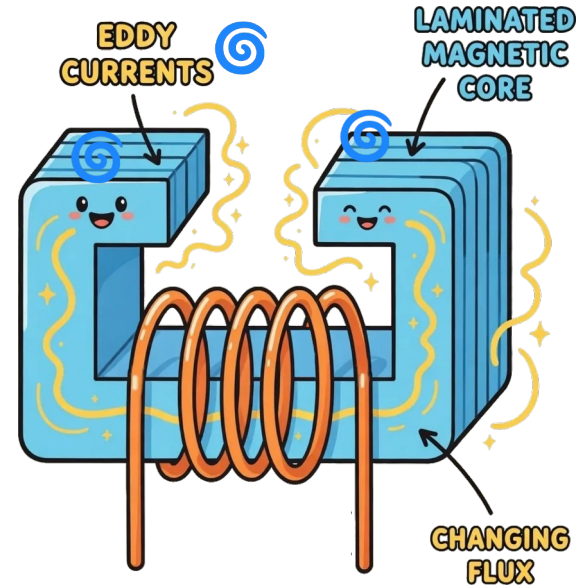
MAGNETIC INDUCTION BASICS

- B-005-011-011 WHAT CONFIRMS THE FACT THAT THE TRANSFER OF ENERGY FROM THE PRIMARY TO THE SECONDARY OF A TRANSFORMER IS NOT PERFECT? **ANSWER: WARM IRON LAMINATIONS**



"HYSTERESIS LOSS"

THIS IS THE "INTERNAL FRICTION" OF THE MAGNETIC DOMAINS FLIPPING BACK AND FORTH.



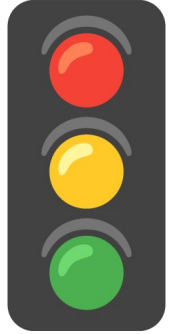


QUESTION SECTION B-005-012:

RESONANCE IN TUNED CIRCUITS

THE HEART OF RADIO SELECTIVITY

- A TUNED CIRCUIT (ALSO CALLED A RESONANT OR LC CIRCUIT) COMBINES AN **INDUCTOR (L)** AND A **CAPACITOR (C)** TO RESONATE AT A SPECIFIC FREQUENCY.
AT RESONANCE:
 - INDUCTIVE REACTANCE (X_L) EXACTLY EQUALS CAPACITIVE REACTANCE (X_C) IN MAGNITUDE.
 - THEY ARE **EQUAL AND OPPOSITE IN SIGN** (X_L IS POSITIVE, X_C IS NEGATIVE), SO THEY CANCEL EACH OTHER OUT.



THE HEART OF RADIO SELECTIVITY

- THIS CANCELLATION CREATES EXTREME BEHAVIOR:
 - VERY HIGH IMPEDANCE IN PARALLEL CIRCUITS (BLOCKS CURRENT)
 - VERY LOW IMPEDANCE IN SERIES CIRCUITS (PASSES CURRENT EASILY).
- THE TWO COMPONENTS REQUIRED: **INDUCTOR** AND **CAPACITOR**.

DEFINING RESONANCE

- RESONANCE OCCURS WHEN: **INDUCTIVE REACTANCE** AND **CAPACITIVE REACTANCE** ARE EQUAL (AND OPPOSITE IN SIGN).
- FORMULA:
$$F_{RES} = \frac{1}{2\pi\sqrt{LC}}$$
- RESONANT FREQUENCY DEPENDS ONLY ON L AND C VALUES.
- ADDING A **RESISTOR** DOES NOT CHANGE THE RESONANT FREQUENCY (IT AFFECTS **DAMPING/BANDWIDTH** BUT NOT THE CENTER FREQUENCY).

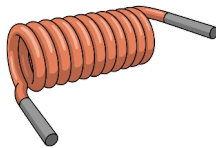
PARALLEL VS. SERIES TUNED CIRCUITS AT RESONANCE

- **SERIES LC: AT RESONANCE** ($X_L = X_C$)
- → TOTAL REACTANCE CANCELS → ONLY RESISTANCE REMAINS → **LOW IMPEDANCE** (ALMOST SHORT CIRCUIT).
- CURRENT REACHES **MAXIMUM** FOR THE SOURCE FREQUENCY.

B-005-012: RESONANCE IN TUNED CIRCUITS

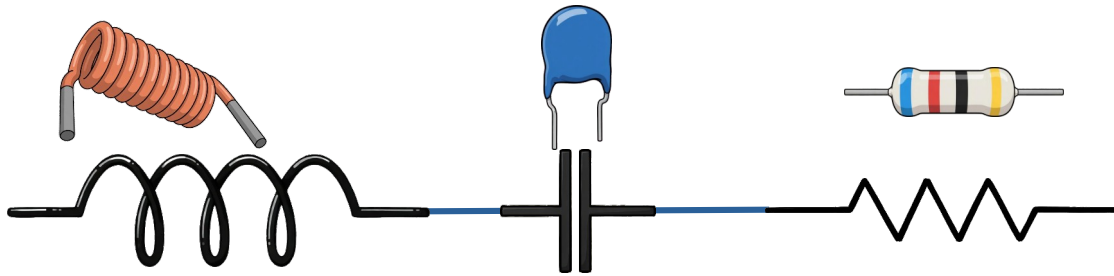
SERIES LC: AT RESONANCE – AKA “THE ACCEPTOR” 🤗

- IN A SERIES CIRCUIT, THE INDUCTOR (L), CAPACITOR (C) ARE CONNECTED IN A SINGLE LINE.
- NOTE: IN A WORLD WITHOUT RESISTANCE, IF YOU CHARGED THE CAPACITOR AND CONNECTED IT TO THE INDUCTOR, THE ENERGY WOULD SLOSH BACK AND FORTH BETWEEN THE TWO FOREVER. (THE “FOREVER” OSCILLATOR). 🌟



SERIES LC: AT RESONANCE – AKA “THE ACCEPTOR” 🤗

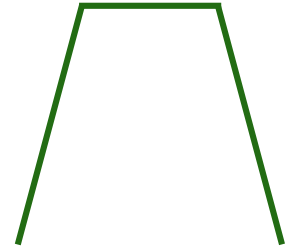
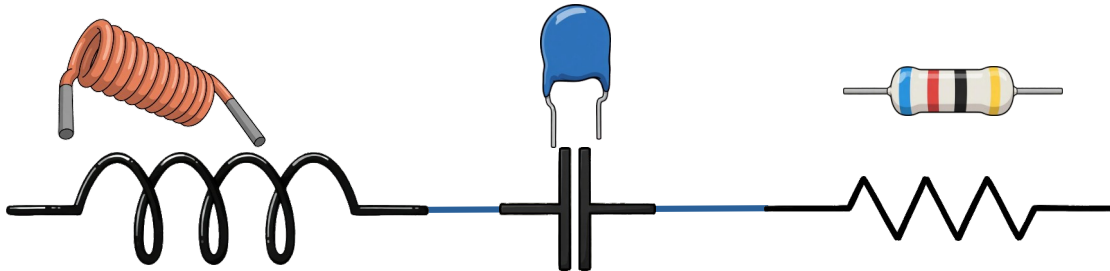
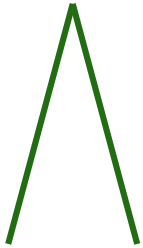
- IN REALITY, EVERY LC CIRCUIT IS ACTUALLY AN LCR CIRCUIT (INDUCTOR-CAPACITOR-RESISTOR) - EVEN IF YOU DON'T PHYSICALLY SOLDER A RESISTOR INTO YOUR CIRCUIT. THERE ARE ALWAYS LOSSES IN THE WIRE & “LEAKAGE.”



B-005-012: RESONANCE IN TUNED CIRCUITS

SERIES LC: AT RESONANCE – AKA “THE ACCEPTOR” 🤗

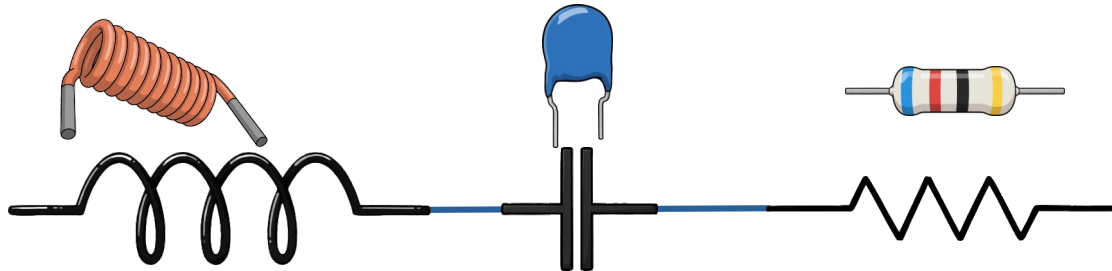
- INTENTIONALLY ADDING A RESISTOR “FLATTENS” THE RESONANCE PEAK. IF YOU WANT YOUR RADIO TO PICK UP A RANGE OF FREQUENCIES (LIKE A HIGH-FIDELITY AUDIO SIGNAL) RATHER THAN JUST ONE HYPER-SPECIFIC NEEDLE-POINT FREQUENCY, YOU ADD RESISTANCE TO WIDEN THE BANDWIDTH.



B-005-012: RESONANCE IN TUNED CIRCUITS

SERIES LC: AT RESONANCE – AKA “THE ACCEPTOR” 🤗

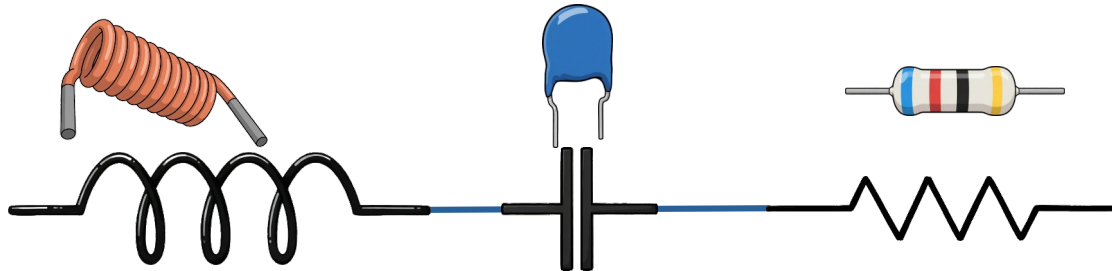
- **AT RESONANCE:** THE REACTIVE VOLTAGES ACROSS THE INDUCTOR AND CAPACITOR ARE EQUAL AND OPPOSITE, EFFECTIVELY CANCELING EACH OTHER OUT.
- **IMPEDANCE:** IT DROPS TO ITS MINIMUM VALUE (EQUAL ONLY TO THE RESISTANCE R).
- **CURRENT:** BECAUSE IMPEDANCE IS AT A MINIMUM, CURRENT IS AT ITS MAXIMUM.



B-005-012: RESONANCE IN TUNED CIRCUITS

SERIES LC: AT RESONANCE – AKA “THE ACCEPTOR” 🤗

- **BEST USE: IT ACTS AS A "GATEKEEPER" THAT ONLY LETS ONE SPECIFIC FREQUENCY PASS THROUGH EASILY. THIS IS WHY IT'S USED IN TUNING STAGES OF RADIO RECEIVERS TO "ACCEPT" A STATION.**



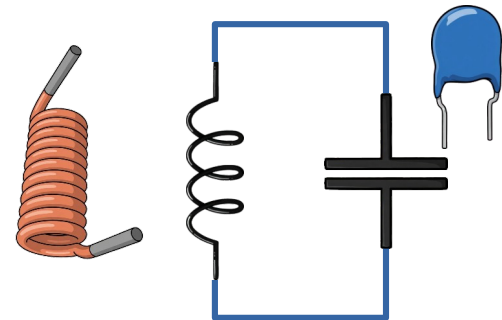
PARALLEL VS. SERIES TUNED CIRCUITS AT RESONANCE

- **PARALLEL LC (TANK CIRCUIT):** AT RESONANCE, $X_L = X_C \rightarrow$ CURRENTS IN L AND C CIRCULATE BACK AND FORTH (FLYWHEEL EFFECT), MINIMAL CURRENT FROM SOURCE $\rightarrow$ **HIGH IMPEDANCE** (ALMOST OPEN CIRCUIT).
- USED IN RECEIVER FRONT-ENDS TO SELECT DESIRED FREQUENCY WHILE REJECTING OTHERS.

PARALLEL LC: AT RESONANCE – AKA “THE REJECTOR”



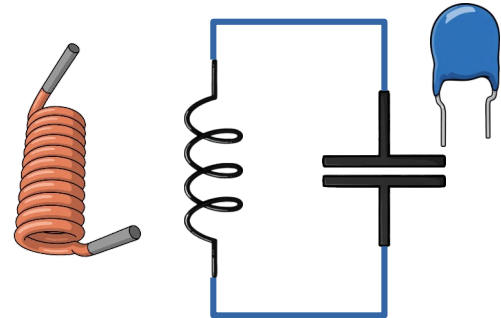
- IN A PARALLEL CIRCUIT, THE INDUCTOR (L) AND CAPACITOR (C) ARE PLACED SIDE-BY-SIDE.
- AT RESONANCE: THE ENERGY BOUNCES BACK AND FORTH BETWEEN THE INDUCTOR AND CAPACITOR (LIKE A PENDULUM). VERY LITTLE CURRENT NEEDS TO ENTER FROM THE OUTSIDE SOURCE TO KEEP THIS OSCILLATION GOING.



PARALLEL LC: AT RESONANCE – AKA “THE REJECTOR”



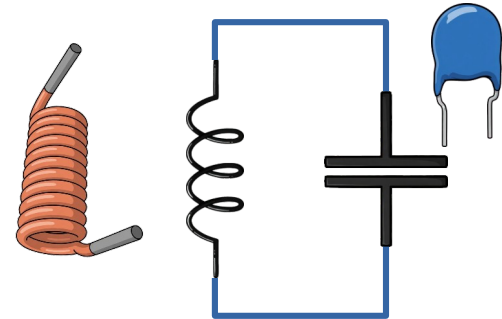
- **IMPEDANCE: IT RISES TO ITS MAXIMUM VALUE (THEORETICALLY INFINITE IN AN IDEAL CIRCUIT).**
- **CURRENT: THE LINE CURRENT FROM THE SOURCE IS AT ITS MINIMUM.**
- **LIKE THE SERIES VERSION, THERE ARE REAL WORLD RESISTIVE LOSSES.**



PARALLEL LC: AT RESONANCE – AKA “THE REJECTOR”



- **BEST USE: IT ACTS AS A "WALL" FOR A SPECIFIC FREQUENCY. IT IS OFTEN CALLED A TANK CIRCUIT BECAUSE IT STORES ENERGY AT THAT FREQUENCY AND IS USED IN OSCILLATORS AND FILTERS TO "REJECT" OR TRAP SPECIFIC SIGNALS.**



BANDWIDTH – THE "SHARPNESS" OF RESONANCE

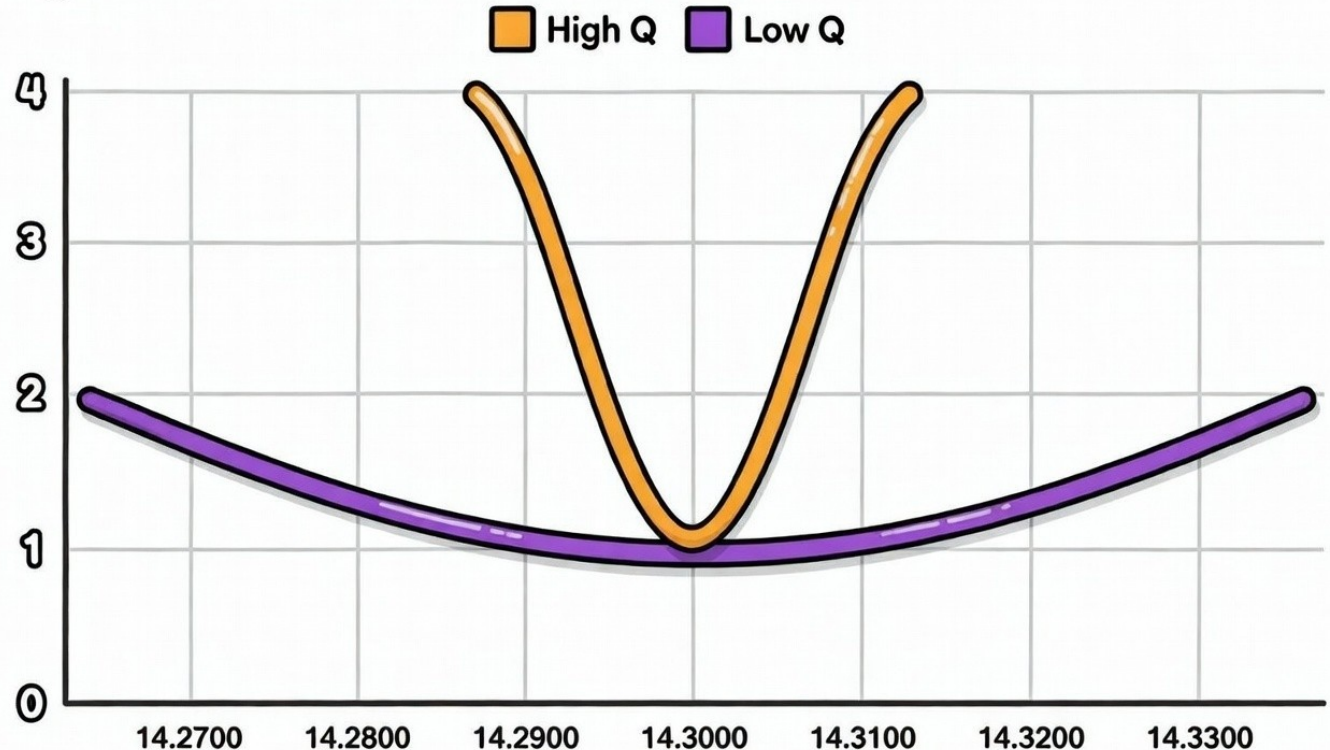
- RESONANCE IS SHARPEST AT A SINGLE FREQUENCY, BUT THE EFFECT (HIGH/LOW IMPEDANCE) IS SIGNIFICANT OVER A SMALL RANGE AROUND IT.
- THIS RANGE IS CALLED **BANDWIDTH** — NARROWER BANDWIDTH = SHARPER TUNING (BETTER SELECTIVITY), WIDER = BROADER RESPONSE.

BANDWIDTH – THE "SHARPNESS" OF RESONANCE

"Q" – QUALITY FACTOR

- **HIGH – VERY SELECTIVE**
- **LOW – VERY BROADBAND**
- **ADVANTAGES AND DISADVANTAGES TO BOTH**
- **GENERALLY FAVOUR LOWER Q FOR CONVENIENCE!**

High Q and Low Q

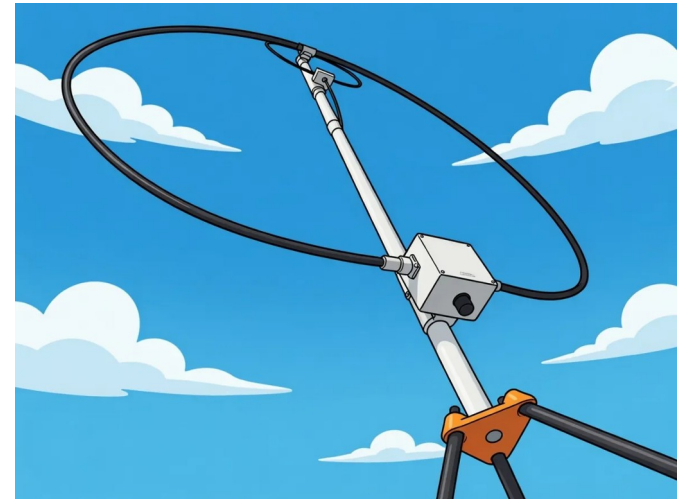


B-005-012: RESONANCE IN TUNED CIRCUITS

BANDWIDTH – THE "SHARPNESS" OF RESONANCE

HIGH Q ANTENNA EXAMPLE: MAG LOOP

- **NARROW BANDWIDTH** — OFTEN JUST A FEW kHz (YOU RETUNE FREQUENTLY WHEN CHANGING FREQUENCY EVEN SLIGHTLY).
- **SHARP SELECTIVITY** — EXCELLENT FOR REJECTING OFF-FREQUENCY NOISE AND QRM (GREAT RECEIVE PERFORMANCE, LOW NOISE FLOOR).
- **HIGH EFFICIENCY POSSIBLE DESPITE SMALL SIZE** — IF R LOSS IS KEPT VERY LOW (GOOD MATERIALS), EFFICIENCY CAN REACH 70-95% ON UPPER BANDS
- **TRADE-OFF** — THE HIGH Q MAKES THEM PICKY (NEED PRECISE TUNING, SENSITIVE TO NEARBY OBJECTS/HAND CAPACITANCE), AND THEY CAN HAVE HIGH VOLTAGES/CURRENTS (SAFETY NOTE FOR QRP OR HIGHER POWER).



PRACTICAL HAM RADIO APPLICATIONS

- IN RECEIVERS: RESONANT CIRCUITS **SELECT THE DESIRED SIGNAL FREQUENCIES** (TUNE TO YOUR STATION, REJECT OTHERS).
- IN TRANSMITTERS: RESONANT TANK CIRCUITS MATCH IMPEDANCE, MAXIMIZE POWER TRANSFER TO ANTENNA.
- FILTERS: SERIES FOR PASSING A BAND, PARALLEL FOR BLOCKING INTERFERENCE.



QUESTION SECTION B-005-013:

MEASURING INSTRUMENTS IN ELECTRONICS

B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

ACCURATE MEASUREMENTS ARE ESSENTIAL IN HAM RADIO FOR:

- CHECKING POWER SUPPLY VOLTAGE AND CURRENT DRAW
- VERIFYING TRANSMITTER OUTPUT
- TROUBLESHOOTING CIRCUITS
- EX: NO VOLTAGE AT A STAGE, EXCESSIVE CURRENT
- ENSURING SAFE OPERATION (AVOID BLOWING FUSES OR BURNING COMPONENTS)

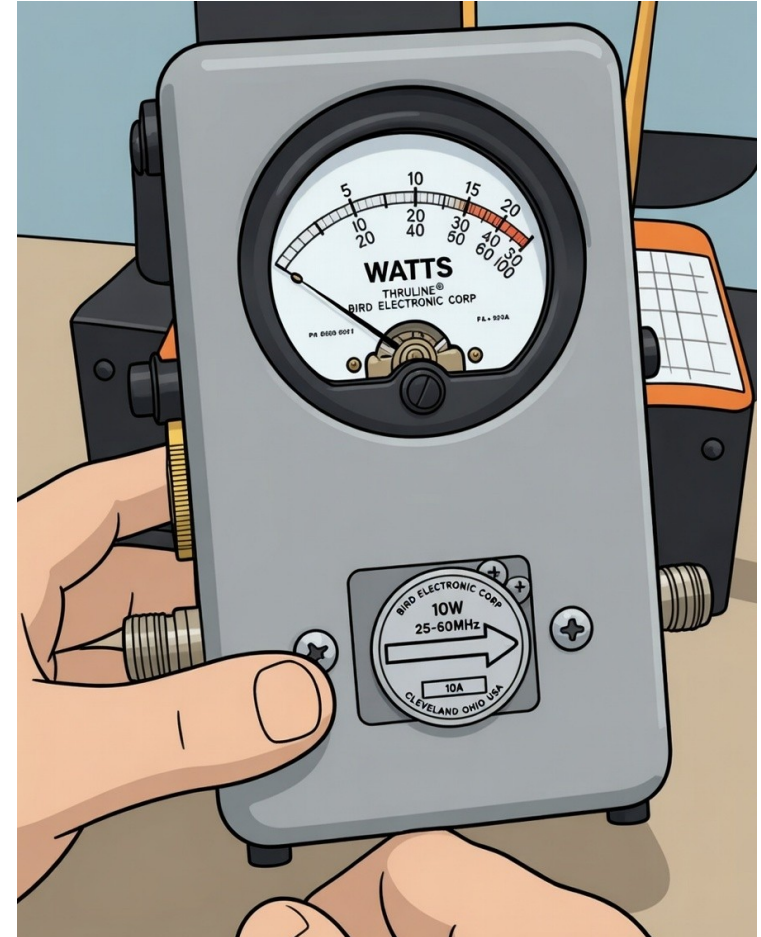
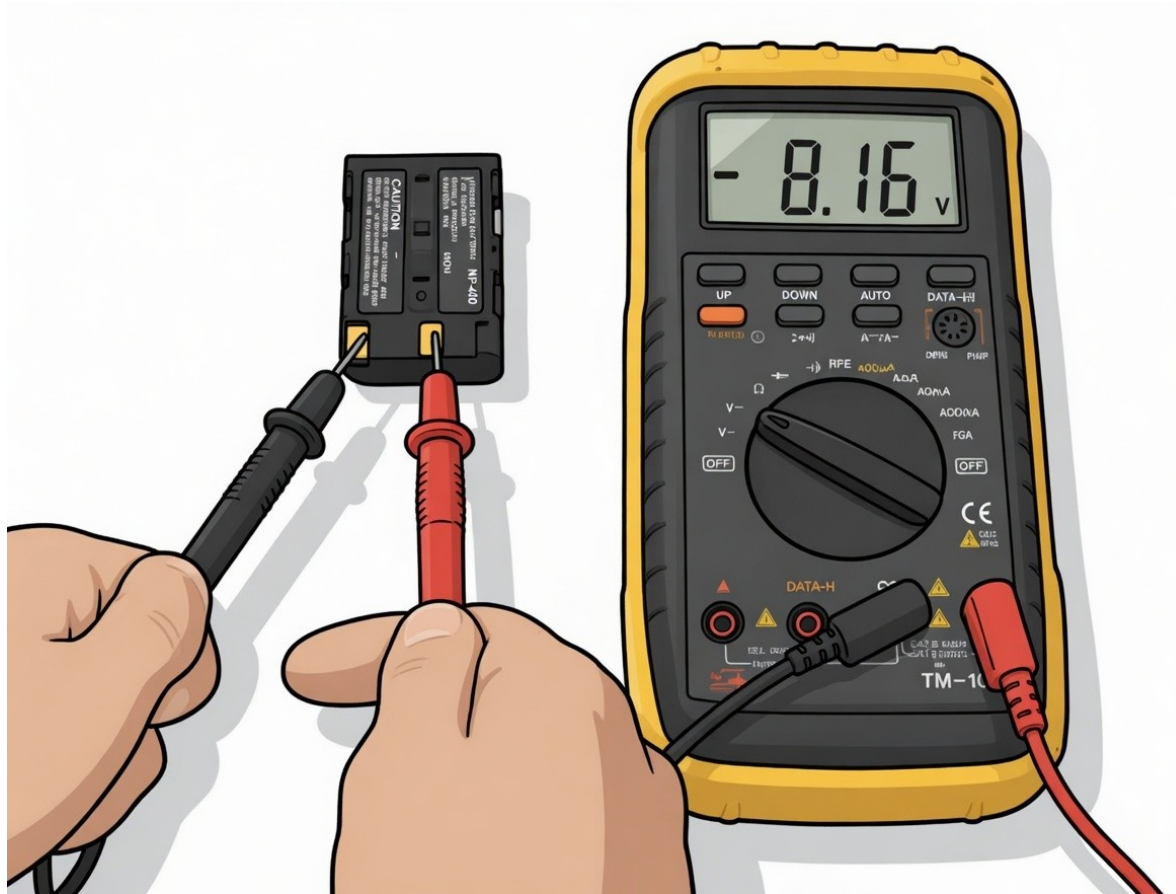


B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

ACCURATE MEASUREMENTS ARE ESSENTIAL IN HAM RADIO FOR:

- **THE TWO MOST COMMON INSTRUMENTS ARE THE MULTIMETER (DOES IT ALL) AND THE RF WATTMETER (FOR TRANSMITTER POWER).**
- **ALWAYS START WITH POWER OFF WHEN CONNECTING, AND CHOOSE THE CORRECT RANGE/SCALE TO AVOID DAMAGE.**

B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS



B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

BASIC CONNECTIONS – VOLTMETER VS. AMMETER

- **VOLTMETER** (MEASURES VOLTAGE/POTENTIAL DIFFERENCE): CONNECTED IN **PARALLEL** WITH THE COMPONENT OR CIRCUIT UNDER TEST.
- IT APPEARS AS A **HIGH VALUE RESISTANCE** TO THE CIRCUIT (SO IT DRAWS VERY LITTLE CURRENT AND DOESN'T AFFECT THE VOLTAGE MUCH).
- USED TO CHECK BATTERY VOLTAGE, SUPPLY RAILS, BIAS POINTS, ETC.

B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

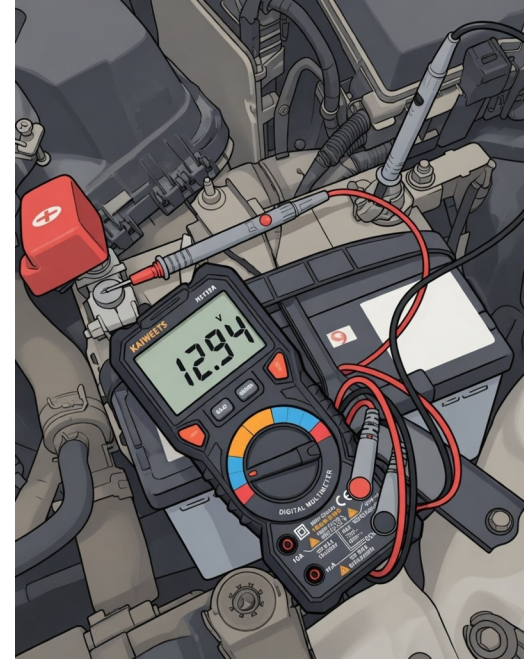
BASIC CONNECTIONS – VOLTMETER VS. AMMETER

- **AMMETER** (MEASURES CURRENT): CONNECTED **IN SERIES** WITH THE CIRCUIT (BREAK THE PATH AND INSERT THE METER). IT APPEARS AS **A LOW VALUE RESISTANCE** (IDEALLY NEAR ZERO OHMS SO IT DOESN'T DROP MUCH VOLTAGE OR LIMIT CURRENT).
- USED TO MEASURE CURRENT DRAW FROM A POWER SUPPLY, FINAL AMPLIFIER CURRENT, ETC.

B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

THE MULTIMETER – YOUR GO-TO TOOL

- A MULTIMETER (ANALOG OR DIGITAL) MEASURES THREE MAIN QUANTITIES:
- VOLTAGE (DC AND AC), CURRENT (DC AND AC), RESISTANCE (OHMS)
- MOST HAMS USE A DIGITAL MULTIMETER (DMM) FOR ITS EASE OF READING, AUTO-RANGING, AND EXTRA FEATURES (CONTINUITY BEEP, DIODE TEST, CAPACITANCE, ETC.).



B-005-013: MEASURING INSTRUMENTS IN ELECTRONICS

MEASURING TRANSMITTER OUTPUT POWER

- FOR RF POWER (TRANSMITTER OUTPUT TO ANTENNA OR DUMMY LOAD):
- USE AN **RF WATTMETER** (OR SWR/WATTMETER COMBO).
- IT PROVIDES A DIRECT MEASUREMENT OF FORWARD POWER, REFLECTED POWER, AND OFTEN SWR.
- ESSENTIAL FOR CHECKING IF YOUR RIG IS PUTTING OUT THE EXPECTED WATTS, TUNING ANTENNAS, AND STAYING WITHIN LEGAL LIMITS.

INSTRUMENT QUALITY – ACCURACY

- THE TERM THAT DESCRIBES HOW WELL AN INSTRUMENT DISPLAYS VALUES THAT ARE **TRUE TO REALITY** (CLOSE TO THE ACTUAL VALUE) IS **ACCURACY**.
- LOOK FOR $\pm 1\%$ OR BETTER ON A GOOD DIGITAL MULTIMETER.
- CALIBRATE PERIODICALLY OR COMPARE AGAINST A KNOWN REFERENCE.



73