# General Licensing Class
# "G5"

Presented by the

Renton Emergency Communications Services

**May 23rd, 2011**

# General Class Element 3 Course Presentation

- **ELEMENT 3 SUB-ELEMENTS**

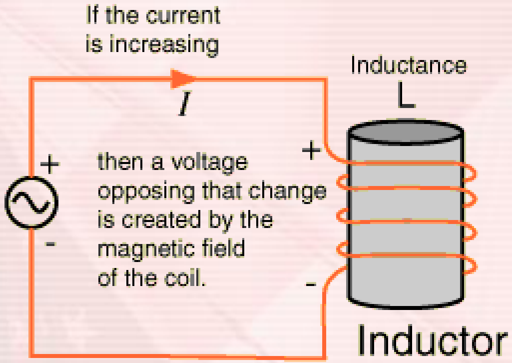
  **G1 – Commission's Rules**
  **G2 – Operating Procedures**
  **G3 – Radio Wave Propagation**
  **G4 – Amateur Radio Practices**
  **G5 – Electrical Principles**
  **G6 – Circuit Components**
  **G7 – Practical Circuits**
  **G8 – Signals and Emissions**
  **G9 – Antennas**
  **G0 – Electrical and RF Safety**

# G5 …Electrical Principles

G5A

## Resistance; Reactance

- Reactance is opposition to the flow of alternating current caused by capacitance or inductance.
- Reactance causes opposition to the flow of alternating current in a capacitor.
- Reactance causes opposition to the flow of alternating current in an inductor.




- The Ohm is the unit used to measure reactance.

# G5 …Electrical Principles

G5A

## Inductance

- A coil reacts to AC such that as the frequency of the applied AC increases, the reactance increases. [Directly proportional]

$$X_L = 2 * \pi * F * L$$

**Inductive Reactance = 2 * π * Frequency * Inductance**

$X_L$ is small at low frequencies and large at high frequencies
For steady DC (frequency zero), $X_L$ is zero (no opposition),
Hence the rule that **inductors pass DC but block high frequency AC**

# G5 …Electrical Principles

G5A

## Capacitance

- A capacitor reacts to AC such that as the frequency of the applied AC increases, the reactance decreases.
  [Inversely proportional]

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

**Capacitive Reactance = 1 divided by (2 * π * Frequency * Capacitance)**

$X_C$ is large at low frequencies and small at high frequencies.
For steady DC which is zero frequency, $X_C$ is infinite (total opposition),

Hence the rule that **capacitors pass AC but, block DC**.

# G5 …Electrical Principles

G5A

## Impedance

- Impedance is the opposition to the flow of current in an AC circuit.
- When the impedance of an electrical load is equal to the internal impedance of the power source the source can deliver maximum power to the load.
- The Ohm is the unit used to measure impedance.

# Resonance or Resonant Frequency

$$x_L = 2\pi FL \qquad X_C = \frac{1}{2\pi FC}$$

**Resonance occurs in a circuit when $X_L$ is equal to $X_C$.**

$$2\pi FL = \frac{1}{2\pi FC}$$

Therefore:

What we do to the left side of the equation, we must do to the right side, and what we do to the numerator we must do to the denominator, to maintain equality

$$f^2 = \frac{1}{(2\pi L)(2\pi C)}$$

$$f^2 = \frac{1}{(2\pi)^2 LC}$$

# Resonance or Resonant Frequency

$$f^2 = \frac{1}{(2\pi)^2 LC}$$

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

This is the resonant frequency formula.

# G5 …Electrical Principles

G5A

## Impedance matching

- Impedance matching is important so the source can deliver maximum power to the load.
- Core saturation of a conventional impedance matching transformer should be avoided because Harmonics and distortion could result.
- One method of impedance matching between two AC circuits is to insert an LC network between the two circuits.
- One reason to use an impedance matching transformer is to maximize the transfer of power.

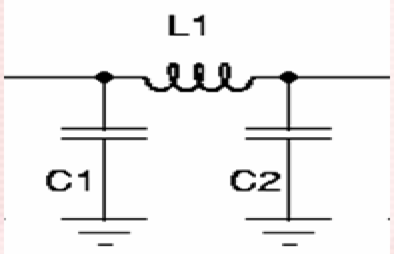
# G5 …Electrical Principles

G5A/B

## ➢ Impedance matching (cont)

- The following devices can be used for impedance matching at radio frequencies:
  - A transformer

  - A Pi-network




  - A length of transmission line

***[All of these choices are correct]***

# G5 …Electrical Principles

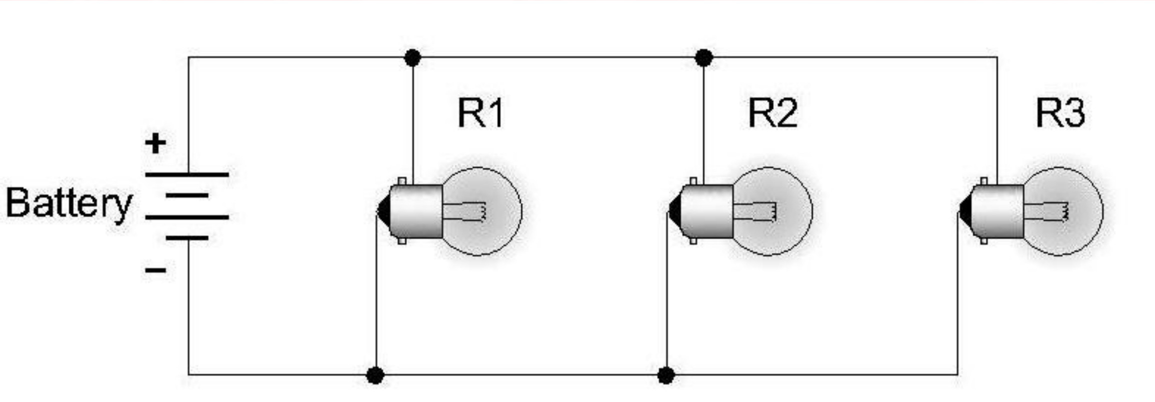
G5/B

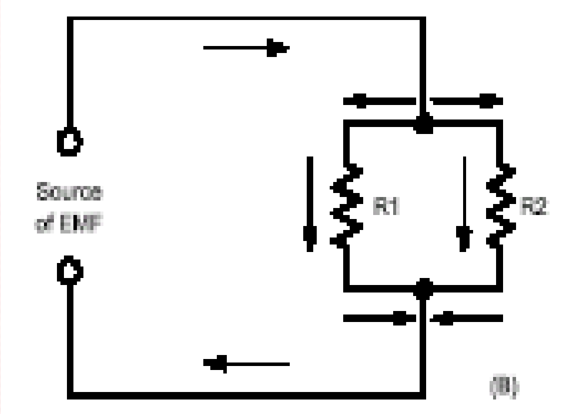
## ➢ The Decibel

- A two-times increase or decrease in power results in a change of 3 dB. (more Tech info.)
- A percentage of 20.5% power loss would result from a transmission line loss of 1 dB.

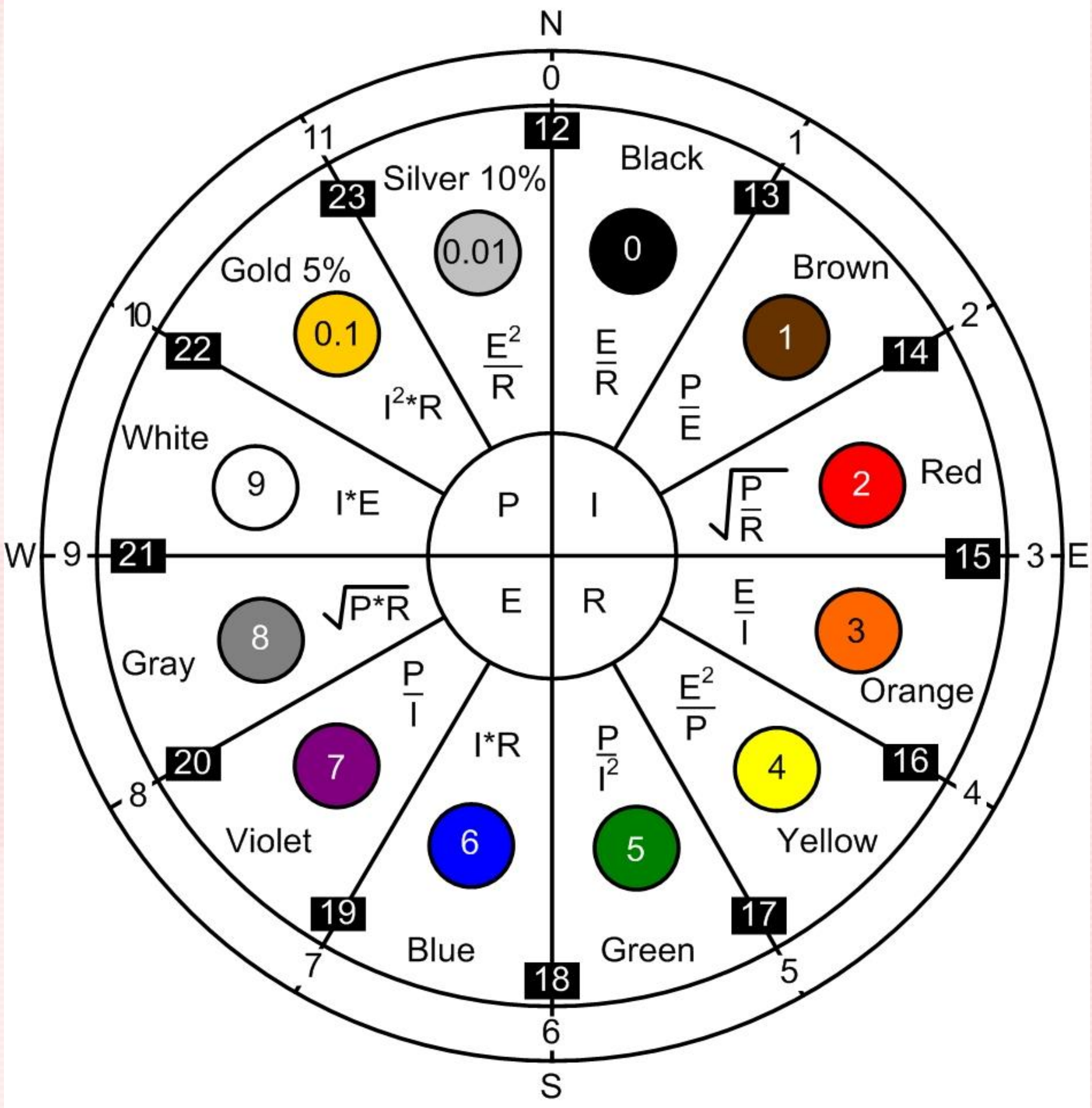
## ➢ Current and voltage dividers

- The total current equals the sum of the currents through each branch of a parallel circuit.



# Ohm's law formulas (circle chart)




Tnx to N5IUT

# G5 …Electrical Principles G5B

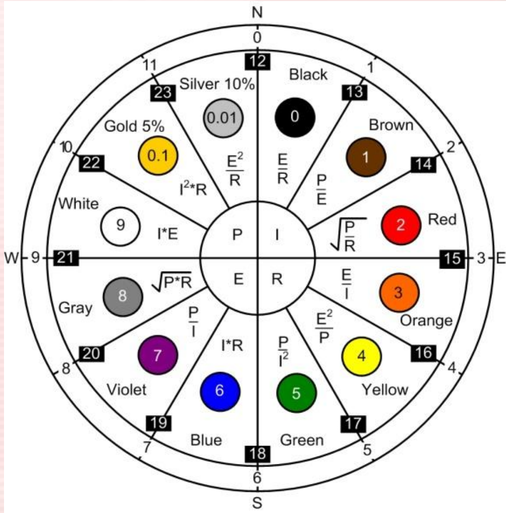
- **Electrical power calculations**
  - There are **200 watts** of electrical power used if 400 VDC is supplied to an 800-ohm load. …. **{Think Power Formula(s)}**

$$P = E^2/R$$

$$P = 400^2/800 \rightarrow$$

$$P = 160000/800 \rightarrow$$

**P= 200 watts**



# G5 …Electrical Principles

G5B

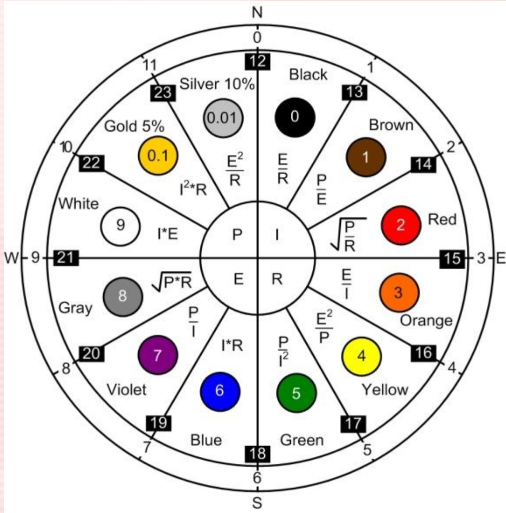
## ➢ Electrical power calculations (cont)

- There are **2.4 watts** of electrical power are used by a 12-VDC light bulb that draws 0.2 amperes.

**P = I*E ➔**

**P = 0.2*12 ➔**

**P = 2.4 watts**



# G5 …Electrical Principles

**G5B**

➢ **Electrical power calculations (cont)**

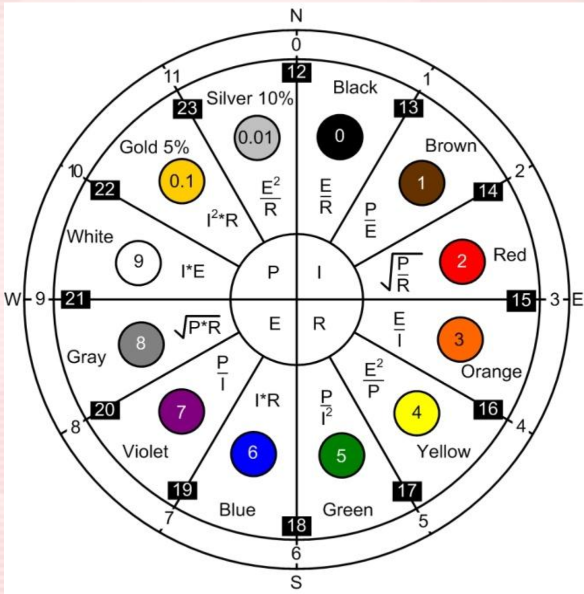
- **Approximately 61 milliwatts are being dissipated when a current of 7.0 milliamperes flows through 1.25 kilohms.**

$$P = I^2 * R \rightarrow$$

$$P = (0.007)^2 * 1250 \rightarrow$$

**P = 61 mW**

***or* 0.061 watts**



# G5 …Electrical Principles

G5B

- **Electrical power calculations** (cont)
  - **The voltage across a 50-ohm dummy load dissipating 1200 watts would be 245 volts.**

**P=I*E** ***and*** **E=I*R** ***therefore*** $E=\sqrt{(P*R)}$

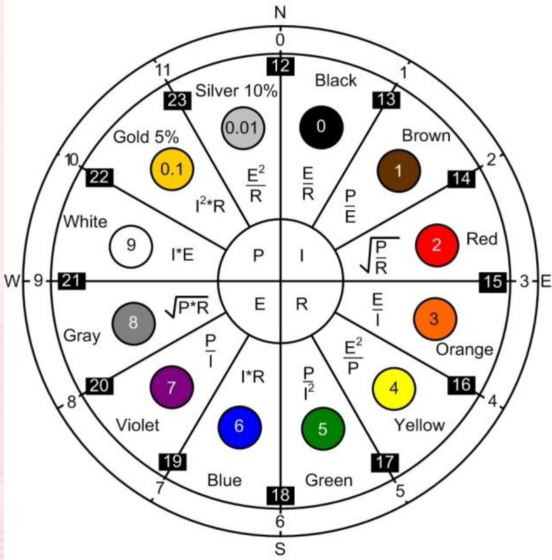
(E=P/I and I=E/R … Substitute I=E/R in E=P/I) to get:

$E=\sqrt{(P*R)}$ ➔

$E=\sqrt{(1200*50)}$ ➔

$E=\sqrt{60000}$ ➔

**E = 245 volts**



# G5 …Electrical Principles

- **Conversion Factors for AC Voltage or Current**

| *From* | *To* | *Multiply By* |
|---|---|---|
| Peak | Peak-to-Peak | 2 |
| Peak-to-Peak | Peak | 0.5 |
| Peak | RMS | $1 / \sqrt{2}$ or 0.707 |
| RMS | Peak | $\sqrt{2}$ or 1.414 |
| Peak-to-Peak | RMS | $1 / (2 \times \sqrt{2})$ or 0.35355 |
| RMS | Peak-to-Peak | $2 \times \sqrt{2}$ or 2.828 |
| Peak | Average | $2 / \pi$ or 0.6366 |
| Average | Peak | $\pi / 2$ or 1.5708 |
| RMS | Average | $(2 \times \sqrt{2}) / \pi$ or 0.90 |
| Average | RMS | $\pi / (2 \times \sqrt{2})$ or 1.11 |

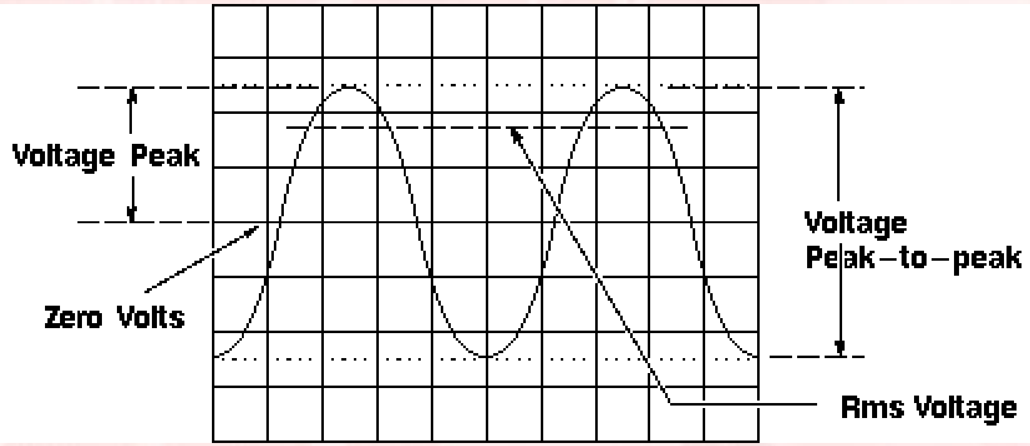
**Note: These conversion factors apply only to continuous pure sine waves.**

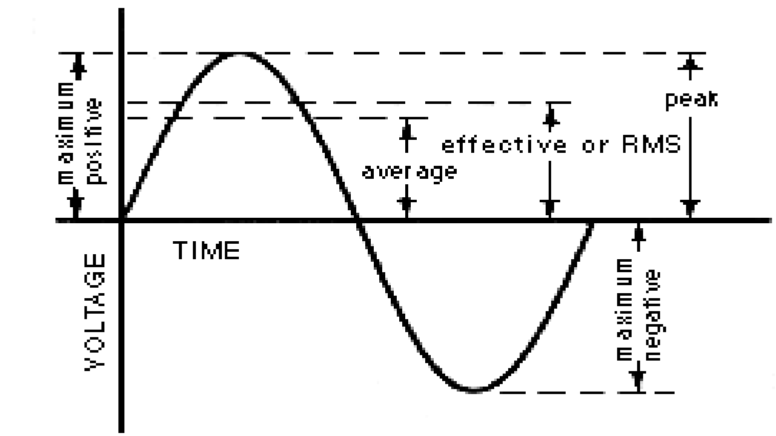
# G5 …Electrical Principles

G5B

## ➢ Sine wave root-mean-square (RMS) values

- **The RMS value measurement of an AC signal is equivalent to a DC voltage of the same value.**




- **If you combined two or more sine wave voltages, the RMS voltage would be the square root of the average of the sum of the squares of each voltage waveform.**

# G5 …Electrical Principles

G5B

- **Sine wave root-mean-square (RMS) values** (cont)
  - The RMS voltage of sine wave with a value of 17 volts peak is 12 volts RMS.
    - 1.0 volt peak = 0.707071 volts RMS

Or

1.0 volt RMS = 1.414 volts peak

$V_{RMS} = V_P * 0.707071$ →

$V_{RMS} = 17 * 0.707071 =$ 12 volts RMS

# G5 …Electrical Principles

G5B

## PEP calculation

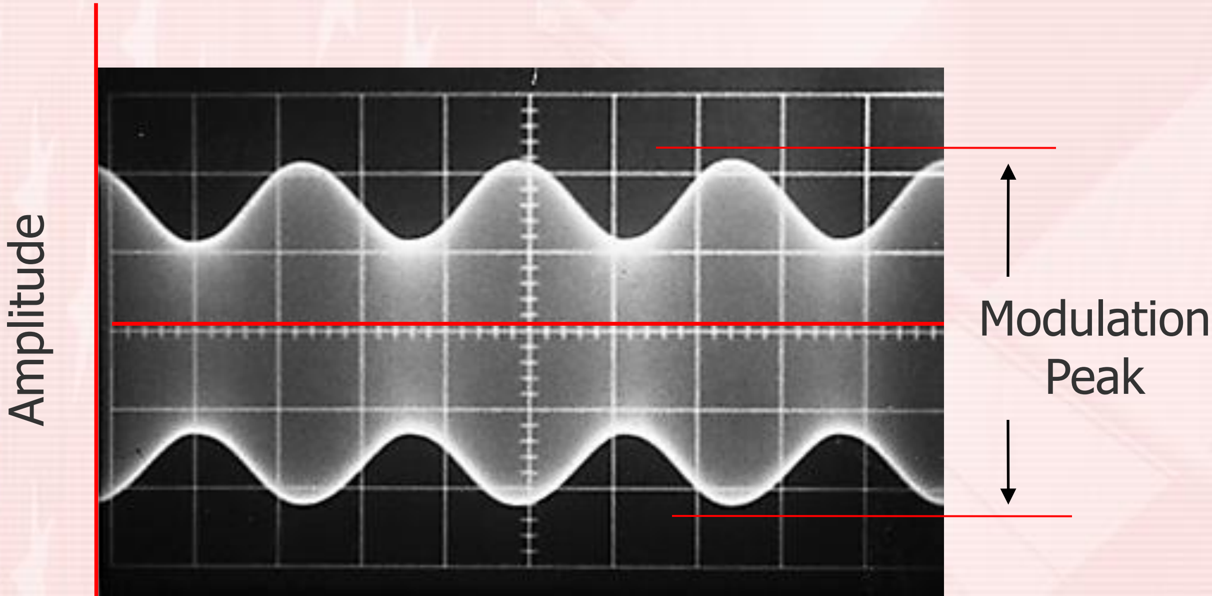
- The peak-to-peak (PEP) output power from a transmitter is 100 watts if an oscilloscope measures 200 volts peak-to-peak across a 50-ohm dummy load connected to the transmitter output. (think power formula)
  - Root Mean Square (RMS)
    - 2.0 volts peak-to-peak = 1.0 volt peak = 0.707071 volts RMS
    - 200 volts peak-to-peak = 100 volts peak = 70.7071 volts RMS

$P=E^2/R$ →

$P=(70.7071)^2/50$ →

$P=4999.5/50$ →

**P=100 Watts**



# G5 …Electrical Principles

G5B

- **PEP calculations** (cont)
  - **The peak-to-peak voltage of a sine wave that has an RMS voltage of 120 volts is 339.4 volts.**
    - **2.0 volts peak-to-peak = 1.0 volt peak = 0.707071 volts RM**

**Or**

- **1.0 volt RMS = 1.414 volts peak = 2.828 volts peak-to-peak**
  - $V_{p\text{-}p} = V_{rms} * 2.828$ →
  - $V_{p\text{-}p} = 120 * 2.828$ →
  - $V_{p\text{-}p} = 339.4$ volts

# G5 …Electrical Principles

G5B

## PEP calculations (cont)

- The output PEP from a transmitter if an oscilloscope measures 500 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output is 625 watts.
  - 2.0 volts peak-to-peak = 1.0 volt peak = 0.707071 volts RMS
  - 500 volts peak-to-peak = 250 volts peak = 176.77 volts RMS

$P = E^2/R$ ➔

$P = 176.77^2/50$ ➔

$P = 31247/50$ ➔

$P = 625$ watts

# G5 …Electrical Principles

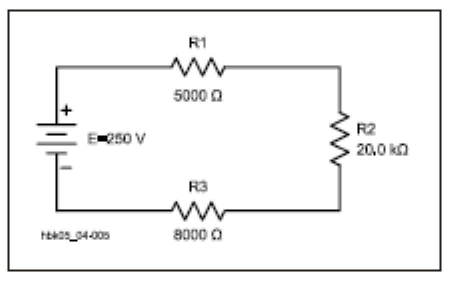
G5B/C

## PEP calculations (cont)

- If an average reading wattmeter, connected to the transmitter output indicates 1060 watts, the output PEP of an unmodulated carrier is 1060 watts.

## Resistors in series

- To increase the circuit resistance a resistor should be added in series in a circuit.




$R_{total} = R1 + R2 + R3 + \ldots$

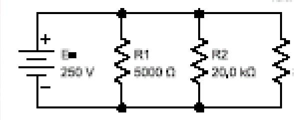
# G5 …Electrical Principles

G5C

## ➢ Resistors in parallel

- **The total resistance of three 100-ohm resistors in parallel is 33.3 ohms.**
- **Rt=1 /((1/100)+(1/100)+(1/100)) = 1 / 0.03 = 33.3 ohms**

$$R_{total} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\ldots}$$



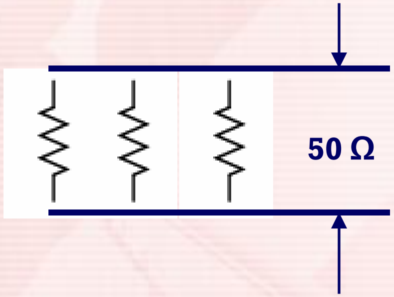

- **The total resistance of a 10 ohm, a 20 ohm, and a 50 ohm resistor in parallel is 5.9 ohms.**
- **Rt=1 /((1/10)+(1/20)+(1/50)) = 1 / 0.17 = 5.9 ohms**

# G5 …Electrical Principles

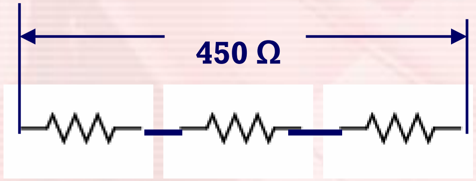
G5C

## Resistors in parallel and series

- **The value of each resistor is *150 ohms* if three equal value resistors in parallel produce 50 ohms of resistance, and the same three resistors in series produce 450 ohms**
- **$R_t$ = 1 /((1/150)+(1/150)+(1/150)) = 1 / 0.02 = 50 ohms**




- **Rt = 150+150+150 = 450 ohms**



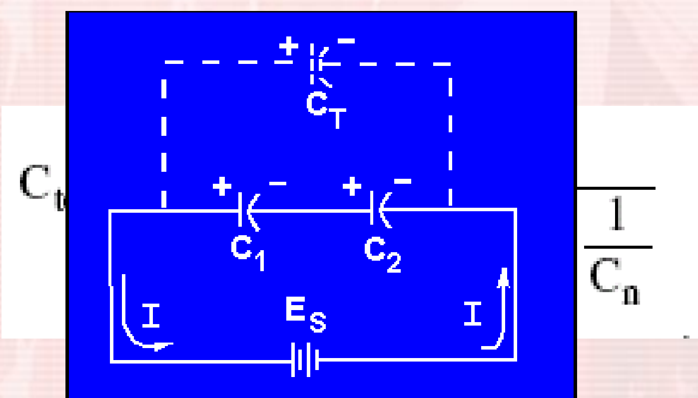
# G5 …Electrical Principles

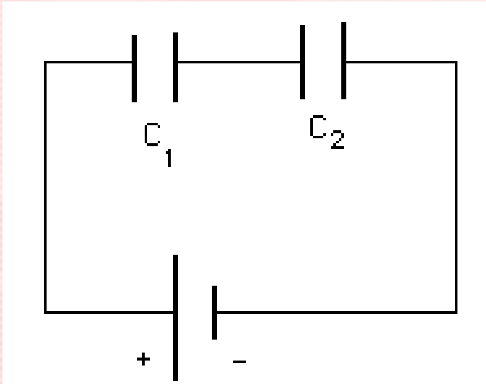
G5C

## Capacitors in series

- **The capacitance of three 100 microfarad capacitors connected in series is 33.3 microfarads.**
- **Ct = 1 /((1/100)+(1/100)+(1/100)) = 1 / 0.03 = 33.3 microfarads**

- **The capacitance of a 20 microfarad capacitor in series with a 50 microfarad capacitor is 14.3 microfarads.**
- **Ct = 1 /((1/20)+(1/50)) = 1 / 0.07 = 14.3 microfarads**




$$C_{total} = \frac{C1 \times C2}{C1 + C2}$$

**Just two caps in series.**

# G5 …Electrical Principles

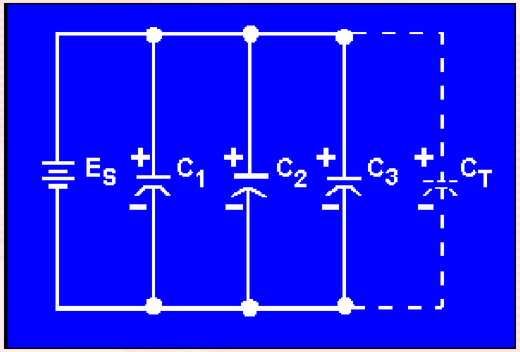
G5C

## Capacitors in parallel

- To increase the circuit capacitance a capacitor should be added in parallel in a circuit. **Ctotal** = C1 + C2 + C3 + …
- The equivalent capacitance of two 5000 picofarad capacitors and one 750 picofarad capacitor connected in parallel is 10750 picofarads.
- **Ctotal** = C1 + C2 + C3 = 5000+5000+750 = 10750 picofarads

Recapping:

$$C_{total} = C1 + C2 + C3 + C4 + \dots + C_n$$

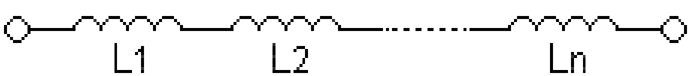


# G5 …Electrical Principles

**G5C**

## Inductors in series

- To increase the circuit inductance an inductor should be added in series in a circuit. $\mathbf{L_{total}} = L1 + L2 + L3 + \ldots$
- The inductance of a 20 millihenry inductor in series with a 50 millihenry inductor is 70 millihenrys.




$$L_{eq} = L_1 + L_2 + \cdots + L_n$$

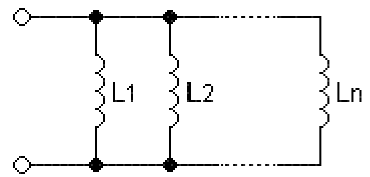
- $\mathbf{L_{total}} = L1 + L2 = 20+50 =$ 70 millihenrys

# G5 …Electrical Principles

G5C

## Inductors in parallel

- The inductance of three 10 millihenry inductors connected in parallel is 3.3 millihenrys.




$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}$$

- Lt = 1 /((1/10)+(1/10)+(1/10)) = 1 / 0.3 = 3.3 millihenrys

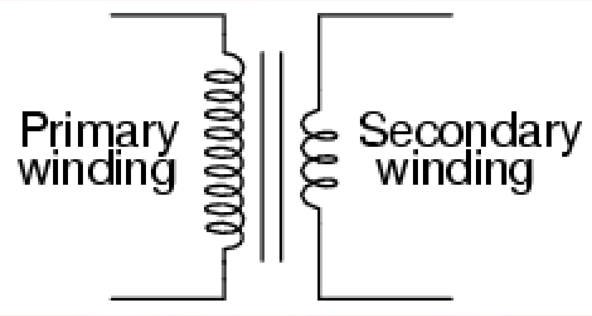
# G5 …Electrical Principles

G5C

- **Transformers**

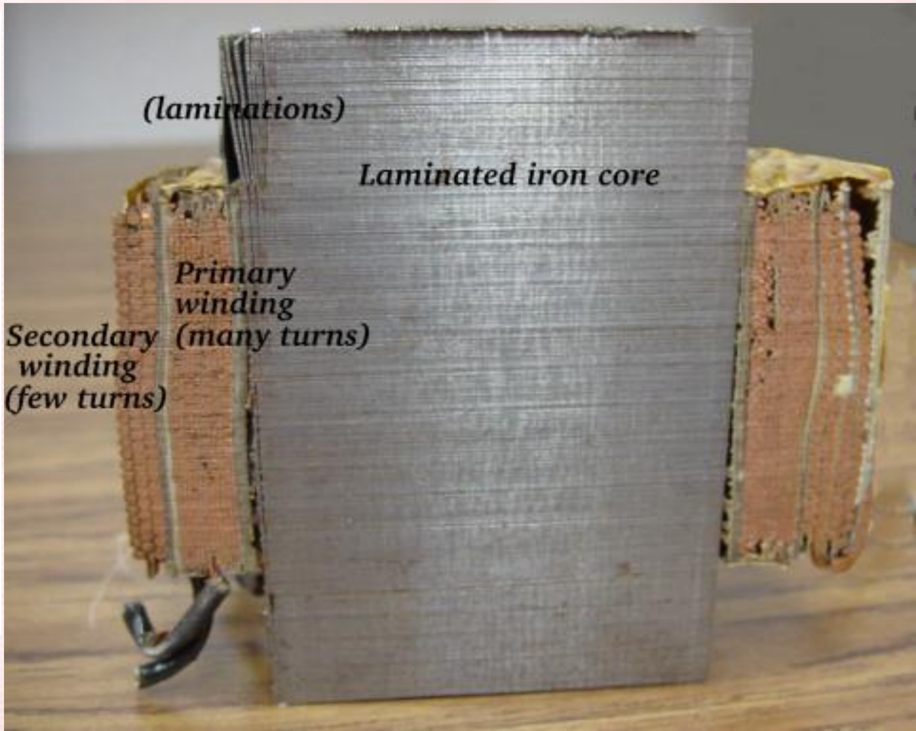
**Various types**

**Schematic diagram**



# G5 …Electrical Principles

- **Transformers** **(cont)**

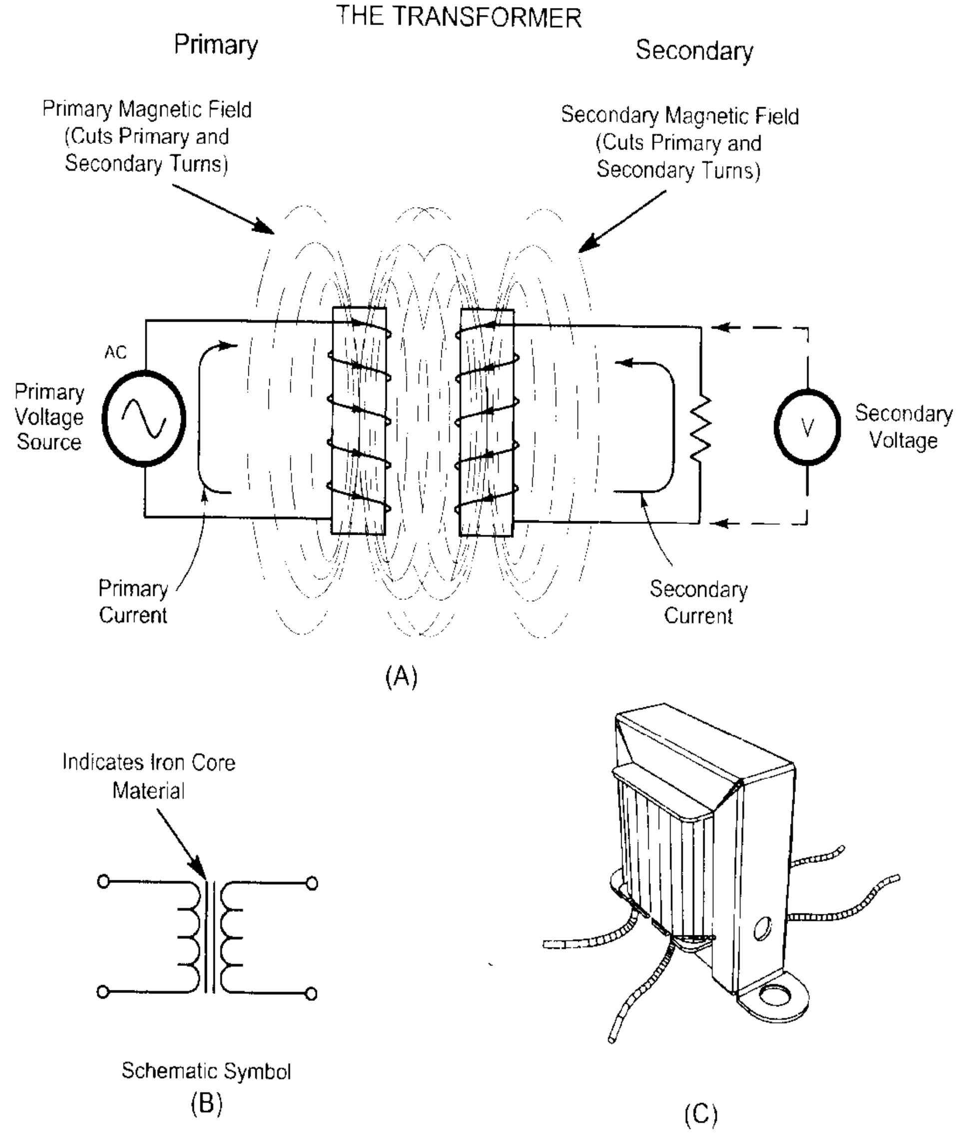



# G5 …Electrical Principles

G5C

## ➢ Transformers (cont)

- Mutual inductance causes a voltage to appear across the secondary winding of a transformer when an AC voltage source is connected across its primary winding.

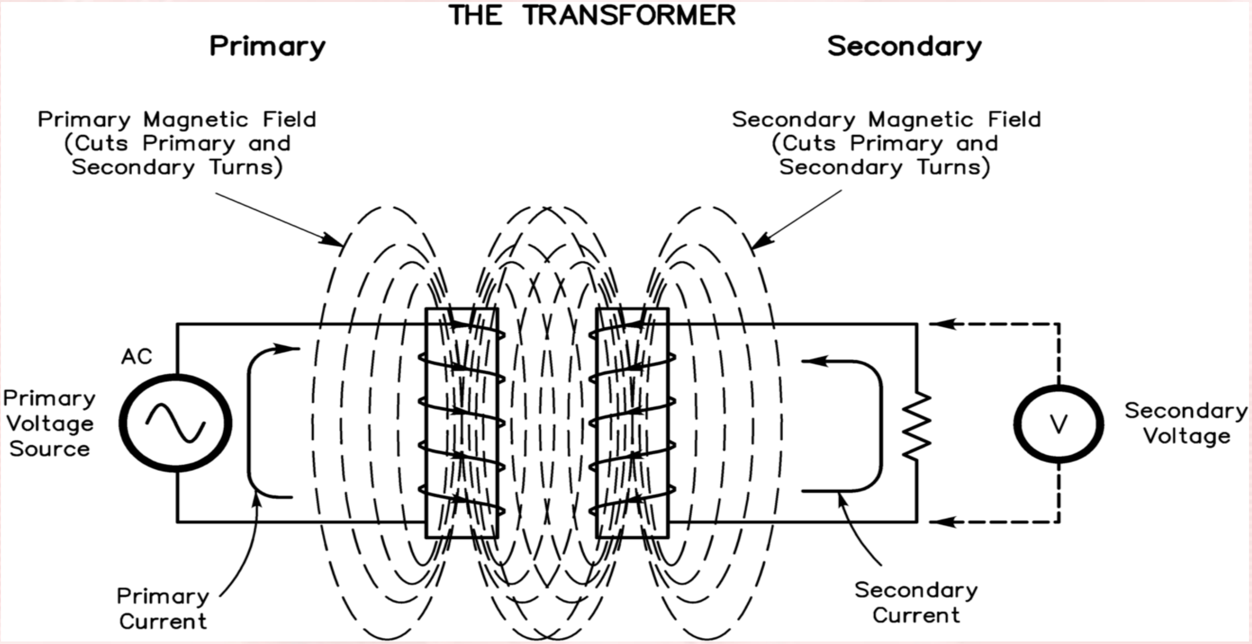


# G5 …Electrical Principles

G5C

## ➢ Transformers (cont)

- The source of energy is normally connected to the primary winding in a transformer.




- The current in the primary winding of a transformer if no load is attached to the secondary is called the Magnetizing current.

# G5 …Electrical Principles

G5C

## Transformers (cont)

- The voltage across a **500-turn secondary** winding in a transformer is **26.7 volts** if the **2250-turn primary** is connected to **120 VAC**.

$$\frac{V_{primary}}{V_{secondary}} = \frac{\text{\# of turns of primary}}{\text{\# of turns in secondary}}$$

**(Solve for Voltage of Secondary)**

➔ **VS = VP * NS / NP**

**VS = 120 * 500 / 2250 = 26.7 volts**

# G5 …Electrical Principles

G5C

## Transformers (cont)

- The turns ratio of a transformer used to match an audio amplifier having a 600-ohm output impedance to a speaker having a 4-ohm impedance is 12.2 to 1.

$$\frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s} = \frac{600}{4}}$$

$$= \sqrt{150} = 12.2 \text{ to } 1$$

# Sub-element G5

Valid July 1, 2007

Through

June 30, 2011

# G5A01 What is impedance?

A. The electric charge stored by a capacitor

B. The inverse of resistance

C. The opposition to the flow of current in an AC circuit

D. The force of repulsion between two similar electric fields

# G5A02 What is reactance?

A. Opposition to the flow of direct current caused by resistance

B. Opposition to the flow of alternating current caused by capacitance or inductance

C. A property of ideal resistors in AC circuits

D. A large spark produced at switch contacts when an inductor is deenergized

## G5A03 Which of the following causes opposition to the flow of alternating current in an inductor?

A. Conductance

B. Reluctance

C. Admittance

D. Reactance

## G5A04 Which of the following causes opposition to the flow of alternating current in a capacitor?

A. Conductance

B. Reluctance

C. Reactance

D. Admittance

# G5A05 How does a coil react to AC?

A. As the frequency of the applied AC increases, the reactance decrease

B. As the amplitude of the applied AC increases, the reactance increases

C. As the amplitude of the applied AC increases, the reactance decreases

D. As the frequency of the applied AC increases, the reactance increases

# G5A06 How does a capacitor react to AC?

A. As the frequency of the applied AC increases, the reactance decreases

B. As the frequency of the applied AC increases, the reactance increases

C. As the amplitude of the applied AC increases, the reactance increases

D. As the amplitude of the applied AC increases, the reactance decreases

## G5A07 What happens when the impedance of an electrical load is equal to the internal impedance of the power source?

A. The source delivers minimum power to the load

B. The electrical load is shorted

C. No current can flow through the circuit

D. The source can deliver maximum power to the load

# G5A08 Why is impedance matching important?

A. So the source can deliver maximum power to the load

B. So the load will draw minimum power from the source

C. To ensure that there is less resistance than reactance in the circuit

D. To ensure that the resistance and reactance in the circuit are equal

# G5A09 What unit is used to measure reactance?

A. Farad

B. Ohm

C. Ampere

D. Siemens

# G5A10 What unit is used to measure impedance?

A. Volt

B. Ohm

C. Ampere

D. Watt

G5A11 Why should core saturation of a conventional impedance matching transformer be avoided?

A. Harmonics and distortion could result

B. Magnetic flux would increase with frequency

C. RF susceptance would increase

D. Temporary changes of the core permeability could result

# G5A12 What is one reason to use an impedance matching transformer?

A. To reduce power dissipation in the transmitter

B. To maximize the transfer of power

C. To minimize SWR at the antenna

D. To minimize SWR in the transmission line

## G5A13 Which of the following devices can be used for impedance matching at radio frequencies?

A. A transformer

B. A Pi-network

C. A length of transmission line

D. All of these choices are correct

## G5A14 Which of the following describes one method of impedance matching between two AC circuits?

A. Insert an LC network between the two circuits

B. Reduce the power output of the first circuit

C. Increase the power output of the first circuit

D. Insert a circulator between the two circuits

G5B01 A two-times increase or decrease in power results in a change of how many dB?

A. 2 dB

B. 3 dB

C. 6 dB

D. 12 dB

## G5B02 How does the total current relate to the individual currents in each branch of a parallel circuit?

A. It equals the average of each branch current

B. It decreases as more parallel branches are added to the circuit

C. It equals the sum of the currents through each branch

D. It is the sum of the reciprocal of each individual voltage drop

## G5B03 How many watts of electrical power are used if 400 VDC is supplied to an 800-ohm load?

A. 0.5 watts

B. 200 watts

C. 400 watts

D. 3200 watts

## G5B04 How many watts of electrical power are used by a 12-VDC light bulb that draws 0.2 amperes?

A. 2.4 watts

B. 24 watts

C. 6 watts

D. 60 watts

G5B05 How many watts are being dissipated when a current of 7.0 milliamperes flows through 1.25 kilohms?

A. Approximately 61 milliwatts

B. Approximately 39 milliwatts

C. Approximately 11 milliwatts

D. Approximately 9 milliwatts

G5B06 What is the output PEP from a transmitter if an oscilloscope measures 200 volts peak-to-peak across a 50-ohm dummy load connected to the transmitter output?

A. 1.4 watts

B. 100 watts

C. 353.5 watts

D. 400 watts

G5B07 Which measurement of an AC signal is equivalent to a DC voltage of the same value?

A. The peak-to-peak value

B. The peak value

C. The RMS value

D. The reciprocal of the RMS value

G5B08 What is the peak-to-peak voltage of a sine wave that has an RMS voltage of 120 volts?

A. 84.8 volts

B. 169.7 volts

C. 240.0 volts

D. 339.4 volts

## G5B09 What is the RMS voltage of sine wave with a value of 17 volts peak?

A. 8.5 volts

B. 12 volts

C. 24 volts

D. 34 volts

## G5B11 What is the ratio of peak envelope power to average power for an unmodulated carrier?

A. 0.707

B. 1.00

C. 1.414

D. 2.00

G5B12 What would be the voltage across a 50-ohm dummy load dissipating 1200 watts?

A. 173 volts

B. 245 volts

C. 346 volts

D. 692 volts

G5B13 What percentage of power loss would result from a transmission line loss of 1 dB?

A. 10.9 %

B. 12.2 %

C. 20.5 %

D. 25.9 %

G5B14 What is the output PEP from a transmitter if an oscilloscope measures 500 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output?

A. 8.75 watts

B. 625 watts

C. 2500 watts

D. 5000 watts

G5B15 What is the output PEP of an unmodulated carrier if an average reading wattmeter connected to the transmitter output indicates 1060 watts?

A. 530 watts

B. 1060 watts

C. 1500 watts

D. 2120 watts

G5C01 What causes a voltage to appear across the secondary winding of a transformer when an AC voltage source is connected across its primary winding?

A. Capacitive coupling

B. Displacement current coupling

C. Mutual inductance

D. Mutual capacitance

## G5C02 Where is the source of energy normally connected in a transformer?

A. To the secondary winding

B. To the primary winding

C. To the core

D. To the plates

## G5C03 What is current in the primary winding of a transformer called if no load is attached to the secondary?

A. Magnetizing current

B. Direct current

C. Excitation current

D. Stabilizing current

## G5C04 What is the total resistance of three 100-ohm resistors in parallel?

A. .30 ohms

B. .33 ohms

C. 33.3 ohms

D. 300 ohms

G5C05 What is the value of each resistor if three equal value resistors in parallel produce 50 ohms of resistance, and the same three resistors in series produce 450 ohms?

A. 1500 ohms

B. 90 ohms

C. 150 ohms

D. 175 ohms

G5C06 What is the voltage across a 500-turn secondary winding in a transformer if the 2250-turn primary is connected to 120 VAC?

A. 2370 volts

B. 540 volts

C. 26.7 volts

D. 5.9 volts

## G5C07 What is the turns ratio of a transformer used to match an audio amplifier having a 600-ohm output impedance to a speaker having a 4-ohm impedance?

A. 12.2 to 1

B. 24.4 to 1

C. 150 to 1

D. 300 to 1

G5C08 What is the equivalent capacitance of two 5000 picofarad capacitors and one 750 picofarad capacitor connected in parallel?

A. 576.9 picofarads

B. 1733 picofdarads

C. 3583 picofarads

D. 10750 picofarads

## G5C09 What is the capacitance of three 100 microfarad capacitors connected in series?

A. .30 microfarads

B. .33 microfarads

C. 33.3 microfarads

D. 300 microfarads

## G5C10 What is the inductance of three 10 millihenry inductors connected in parallel?

A. .30 Henrys

B. 3.3 Henrys

C. 3.3 millihenrys

D. 30 millihenrys

G5C11 What is the inductance of a 20 millihenry inductor in series with a 50 millihenry inductor?

A. .07 millihenrys

B. 14.3 millihenrys

C. 70 millihenrys

D. 1000 millihenrys

G5C12 What is the capacitance of a 20 microfarad capacitor in series with a 50 microfarad capacitor?

A. .07 microfarads

B. 14.3 microfarads

C. 70 microfarads

D. 1000 microfarads

## G5C13 What component should be added to a capacitor in a circuit to increase the circuit capacitance?

A. An inductor in series

B. A resistor in series

C. A capacitor in parallel

D. A capacitor in series

G5C14 What component should be added to an inductor in a circuit to increase the circuit inductance?

A. A capacitor in series

B. A resistor in parallel

C. An inductor in parallel

D. An inductor in series

G5C15 What is the total resistance of a 10 ohm, a 20 ohm, and a 50 ohm resistor in parallel?

A. 5.9 ohms

B. 0.17 ohms

C. 10000 ohms

D. 80 ohms

## G5C16 What component should be added to an existing resistor in a circuit to increase circuit resistance?

A. A resistor in parallel

B. A resistor in series

C. A capacitor in series

D. A capacitor in parallel