Welcome to 2023 Amateur Radio General Class License Training

Amateur Radio General License Training

These presentations are sponsored by:

Mendocino Auxiliary Communications Service (MACS)

Mendocino County Amateur Radio Communications Service (McARCS)

Willits Amateur Radio Society (WARS)

Topics on General Class Exam

Section	Contents	Questions on Exam	Questions in Pool	Covered in Session
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Sub-element G5 – electrical principles

Topics in G5:

- **Electrical principles**
  - Reactance; inductance; capacitance; impedance; impedance transformation; resonance
  - The decibel; current and voltage dividers; electrical power calculations; sine wave root-mean-square (RMS) values; PEP calculations
  - Resistors, capacitors, and inductors in series and parallel; transformers
- **One question from each of the three categories on exam**

Technician Electrical Review

- **Voltage (EMF) - force (pressure) that make electrons move**
  - Basic unit of EMF = volt, “E” in equations
- **Flow of electrons in an electrical circuit is current**
  - Basic unit of current = ampere, “I” in equations
- **Property opposing flow of electrons is electrical resistance**
  - Basic unit of resistance = ohm, “R” in equations

Technician Electrical Review

DC vs AC

- **Direct current (DC) flows in one direction**
- **Alternating current (AC) alternates between positive and negative directions**
    - Frequency (Hertz) = times per second that a cycle (+/-) is completed
    - Opposition to AC flow = impedance
    - Basic unit of impedance = ohm

Technician Electrical Review

Ohm’s Law

- **Defines relationship between current, voltage, resistance**
  - With fixed resistance, current increases as voltage increases
  - With fixed voltage, current decreases as resistance increases
  - *Voltage “E” equals current “I” multiplied by resistance “R” (**E = I X R**)*
  - *Current “I” equals voltage “E” divided by resistance “R” (**I = E/R**)*
  - *Resistance “R” equals voltage “E” divided by current “I” (**R = E /I**)*

Technician Electrical Review

Power

- **Rate at which electrical energy is used**
    - Basic unit of electrical power = Watt (P)

Power “P” equals current “I” multiplied by voltage “E” (**P = I x E**)

- **E = P / I**
- **I = P / E**

Technician Electrical Review

Power

Changes in power levels expressed in decibels (dB)

- Doubling power = +3 dB change *(from 5W to 10W = +3 dB)*
- Halving power = -3 dB change
- -1 dB = 20.6% loss of power
- Pages 4-2 through 4-5 in ARRL study guide

DC power calculations

Three questions in pool

- Need to apply Ohm's law for two

(E = I X R) = (I = E/R) = (R = E /I)

E = 12 V, I = 0.2 A, P = ? watts *P = IxE = 12 x 0.2 =* ***2.4 W***

E = 400 V, R = 800 Ω, P = ? watts $I = E/R$, $P=(E/R)xE = E^2/R = 160000/800 =$ ***200 W***

I = 7 mA, R = 1250 Ω, P = ? watts $E=IxR$, $P=Ix(IxR) = I^2xR = 0.007^2 \times 1250 = 0.061\ W =$ ***61 mW***

AC power calculations

How to calculate power with changing voltage?

- Reference peak voltage
- Reference peak-to-peak voltage (2X peak)
- "Average" for sine wave = root mean square (RMS) value
  - $V_{RMS} = 0.707 \times V_{PK}$ *$V_{RMS} = 0.707 \times 17\ V_{PK}$ =* ***$12\ V_{RMS}$***
  - $V_{RMS} = 0.707 \times (V_{P\text{-}P}/2)$
  - $V_{P\text{-}P} = 2 \times 1.414 \times V_{RMS}$ *$V_{P\text{-}P} = 2 \times 1.414 \times 120\ V_{RMS}$ =* ***$339.4\ V_{P\text{-}P}$***
- Power dissipated by resistor at V_{RMS} = power at equal DC voltage

AC power calculations

How to calculate peak envelope power (PEP)

- PEP = average power of one full RF cycle at envelope peak
- PEP (watts) = V_{RMS}^2 / impedance
- **PEP = average power** in absence of amplitude modulation (ratio = 1.0)
- To calculate PEP given $V_{P\text{-}P}$ first convert to V_{RMS}
  - ***(G5B14)*** $V_{RMS} = 0.707 \times (V_{P\text{-}P}/2) = 0.707 \times (500V_{P\text{-}P}/2) = 176.75\ V_{RMS}$
  - PEP = $V_{RMS}^2 / \Omega = (176.75)^2 / 50 =$ ***675 W_{PEP}***
  - ***(G5B06)*** $V_{RMS} = 0.707 \times (V_{P\text{-}P}/2) = 0.707 \times (200\ V_{P\text{-}P}/2) = 70.7\ V_{RMS}$
  - PEP = $V_{RMS}^2 / \Omega = (70.7)^2 / 50 =$ ***100 W_{PEP}***
- To calculate V_{RMS} given PEP and impedance $V_{RMS} = \sqrt{PEP \times R}$
  - ***(G5B12)*** $V_{RMS} = \sqrt{1200 \times 50} = \sqrt{60000} =$ ***245 V_{RMS}***

Section questions:

G5B03

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

A. 0.5 watts

B. 200 watts

C. 400 watts

D. 3200 watts

Section questions:

G5B01

What dB change represents a factor of two increase or decrease in power?

A. Approximately 2 dB
B. Approximately 3 dB
C. Approximately 6 dB
D. Approximately 9 dB

Section questions:

G5B08

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

A. 84.8 volts
B. 169.7 volts
C. 240.0 volts
D. 339.4 volts

Section questions:

G5B11

What is the ratio of PEP to average power for an unmodulated carrier?

A. 0.707
B. 1.00
C. 1.414
D. 2.00

Impedance and Reactance

Impedance

- Opposition to AC current flow in a circuit is impedance
- Defined the ratio of voltage to current, measured in ohms
- Inverse of impedance is admittance

Reactance

- Inductors and capacitors respond differently to AC vs DC
- Both oppose flow of AC
- Property known as reactance, measured in ohms, “X” in formulas
- Inductive reactance X_L increases as frequency increases
- Capacitive reactance X_C decreases as frequency increases

Resonance

LC circuits

- Inductors and capacitors can be combined in “LC” circuits
- May be in parallel or series
- Resonance occurs at frequency where $X_L = X_C$ and they cancel
- Impedance is very low at resonance in series LC circuit

Transformers

Transformers

- Two inductors with over-lapping magnetic field (mutual inductance)
- Used to “transform” AC voltage or impedance, up or down
- Change in voltage/impedance proportional to ratio of primary to secondary windings
- Voltage appearing across secondary winding = primary voltage x turns ratio
- 1:4 step-up transformer 10 VAC on primary yields 40 VAC across secondary
- Power equal on both sides, higher current in primary of step-up vs secondary
- Function even if connected “backwards”
- 500 turn primary/1500 turn secondary = 1:3 120 VAC primary = 360 VAC secondary

Transformers

Impedance transformation

- Turns ratio $N_P / N_S = \sqrt{Zp / Zs}$
- Match 600 Ω feed point to 50 Ω coax $N_P / N_S = \sqrt{(600/50)} = \sqrt{12} = 3.5:1$
- RF impedance match with transformer, Pi-network, length of transmission line

Section questions:

G5A08

What is impedance?

A. The ratio of current to voltage
B. The product of current and voltage
C. The ratio of voltage to current
D. The product of current and reactance

Section questions:

G5A12

What occurs in an LC circuit at resonance?

A. Current and voltage are equal

B. Resistance is cancelled

C. The circuit radiates all its energy in the form of radio waves

D. Inductive reactance and capacitive reactance cancel

Section questions:

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

Section questions:

G5C06

What is the voltage output of a transformer with a 500-turn primary and a 1500-turn secondary when 120 VAC is applied to the primary?

A. 360 volts
B. 120 volts
C. 40 volts
D. 25.5 volts

Section questions:

G5A11

What letter is used to represent reactance?

A. Z

B. X

C. B

D. Y

Unit Conversion

Unit multipliers and conversion

- The actual value of a component or unit of measure may be several times greater, or only a small fraction of the base unit
- Frequencies may be in the millions of Hertz
- Capacitance may be in millionths of a Farad
- Unit multipliers used to simplify measurement

pico =	*1 trillionth*	*multiplier 10-12*
micro =	*1 millionth*	*multiplier 10-6*
milli =	*1 thousandth*	*multiplier 10-3*
kilo =	*thousand*	*multiplier 103*
mega =	*million*	*multiplier 106*
giga =	*billion*	*multiplier 109*

Like Components in Series/Parallel

Series circuits

- Components connected end to end
- Same DC current flows through all components

Parallel circuits

- Components connected side by side
- Same voltage appears across all components

Like Components in Series/Parallel

Resistors in parallel

- Total current is equal to the sum of the current through each resistor
- 10Ω, 20Ω, and 50Ω resistors in parallel, with 10V applied
- Current = 1.0A + 0.5A + 0.2A = 1.7A, effective R = E/I = 10/1.7 = **5.9Ω**
- Note effective resistance lower than any individual resistor
- Two resistors in parallel $R_{EQU} = (R_1 \times R_2)/(R_1 + R_2)$
- *100Ω + 200Ω resistors in parallel R_{EQU} = (100 x 200)/(100+200) = 20000/300 =* ***66.6Ω***
- Three resistors in parallel $R_{EQU} = 1/(1/R_1 + 1/R_2 + 1/R_3)$
- 10Ω, 20Ω, and 50Ω resistors in parallel
- *R_{EQU} = 1/(1/10 + 1/20 + 1/50) = 1/(0.1 + 0.05 + 0.02) = 1/0.17 =* ***5.9Ω***

Like Components in Series/Parallel

Resistors in series

- Much simpler, series resistance is additive
- 10Ω, 20Ω, and 50Ω resistors in series, $R_{EQU} = R_1 + R_2 + R_3 = 10 + 20 + 50 = \mathbf{80\Omega}$

Inductors

- Same as resistors, two inductors in series $L_{EQU} = L_1 + L_2$
- *20 mH in series with a 50 mH = 20 + 50 =* ***70 mH***
- Three inductors in parallel $L_{EQU} = 1/(1/L_1 + 1/L_2 + 1/L_3)$
- Three 10 mH inductors in parallel
- $L_{EQU} = 1/(1/10 + 1/10 + 1/10) = 1/(0.3) =$ ***3.3 mH***

Like Components in Series/Parallel

Capacitors

Opposite from resistors and inductors

Additive when connected in parallel

- Three capacitors in parallel $C_{EQU} = C_1 + C_2 + C_3 = $ *5 + 5 + 0.75 =* ***10.750 nF***

Reduced when connected in series

- Two capacitors in series $C_{EQU} = (C_1 \text{ x } C_2)/(C_1 + C_2)$
- $C_{EQU} = (20 \text{ x } 50)/(20+50) = 1000/70 =$ ***14.8 µF***
- Three capacitors in series $C_{EQU} = 1/(1/C_1 + 1/C_2 + 1/C_3)$
- $C_{EQU} = 1/(1/100 + 1/100 + 1/100) = 1/(0.003) =$ ***33.3 µF***

Like Components in Series/Parallel

Shortcuts to remember:

Resistors/inductors in parallel or capacitors in series

- If all components are <u>equal value</u>, divide value of one component by the total number of components
- Four 100Ω in parallel R_{EQU} = 100/4 = 25Ω
- Three 100 µF capacitors in series C_{EQU} = 100/3 = 33.3 µF

To add inductance to a circuit, add inductor in series

To add capacitance to a circuit, add a capacitor in parallel

Section questions:

G5C10

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

A. 0.30 henries

B. 3.3 henries

C. 3.3 millihenries

D. 30 millihenries

Section questions:

G5C03

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

A. 5.9 ohms

B. 0.17 ohms

C. 17 ohms

D. 80 ohms

Section questions:

G5C05

Why is the primary winding wire of a voltage step-up transformer usually a larger size than that of the secondary winding?

A. To improve the coupling between the primary and secondary
B. To accommodate the higher current of the primary
C. To prevent parasitic oscillations due to resistive losses in the primary
D. To ensure that the volume of the primary winding is equal to the volume of the secondary winding

Section questions:

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

End of G5 Electrical Principles