

General License Class

Math Review

Decibels

Ohm's Law & Joule's Law

Basic Components in Parallel

Basic Components in Serial

Impedance Matching

AC Power

Amplitude and Frequency Modulation

Antenna Wave Length

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This is a review of the math topics that related to the General Class license examination (element 3).

How Much Math?

- Six groups of question in the general pool have math related questions.
- The maximum number of math questions is 6 but typically is only 2 to 3 questions.
- If you answer all math questions wrong and all other non-math question right you will still pass the test.
- See [How Much Math is on the Amateur Radio Exams](#)

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The six groups with math questions are G4D, G5B, G5C, G8B, G9A and G9B. But these section also have non-math questions. On average one only has 3 to 2 math questions to answer on the element 3 exam.

Group	Math Questions	Non-Math Questions
G4D	1	10
G5B	8	5
G5C	12	6
G8B	2	8
G9A	5	10
G9B	3	9

Calculator Rules

- No Cell Phone Apps
- No Programmable Calculators
- Scientific Calculator Preferred



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No wireless devices may be used during the exams. Therefore cell phone calculator applications are not allowed. If your calculator is programmable you must demonstrate that all memory has been cleared. If you can't and won't demonstrate that memory is cleared, you cannot use it during the exam. The provided scientific calculator is preferred, but you may bring your own.

Decibel

$$Power_{gain} = \frac{Power_{output}}{Power_{input}} = 10^{\frac{dB}{10}}$$

$$dB = 10 \times \log(Power_{gain}) = 10 \times \log\left(\frac{Power_{out}}{Power_{input}}\right)$$

- Given dB want Power Gain, use exponentiation
- Given Power Gain want dB, use logarithm

The top equation converts decibel values to power gain by taking the anti-log. The bottom equation converts from power gain to decibels using the common logarithm. Both of these equations can be evaluated using a scientific calculator. A four function calculator will not have logarithm or anti-logarithm keys.

G4D05 How does a signal that reads 20 dB over S9 compare to one that reads S9 on a receiver, assuming a properly calibrated S meter?

- Given dB and want Power Gain thus use exponentiation equation.
- $10^{\frac{20}{10}} = 10^2 = 10 \times 10 = 100$
- It is 100 times more powerful
- EL-501X: $20 \div 10 = 2^{\text{nd F } 10^x}$

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To convert from 20 dB to the power gain ratio one must evaluate anti-logarithm. Convert decibels to Bels by dividing by 10. Then use the result as a power of ten and you have the answer.

G5B01 What dB change represents a two-times increase or decrease in power?

- Given power gain/attenuation and want dB, use logarithm equation
- $dB = 10 \times \log\left(\frac{2}{1}\right) = 10 \times 0.301 \approx 3 \text{ dB}$
- $dB = 10 \times \log\left(\frac{1}{2}\right) = 10 \times (-0.301) \approx -3 \text{ dB}$
- Approximately 3 dB
- EL-501X: $2 \div 1 = \log x \times 10 =$
- EL-501X: $1 \div 2 = \log x \times 10 =$

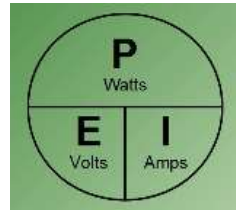
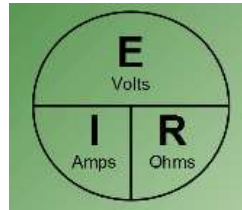
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A two-times increase is 2 to 1 or 2 over 1.

But a two-times decrease is 1 to 2 or 1 over 2. As shown above the result is +3 dB and -3 dB respectively.

Approximately 3 dB is the answer. Note the approximate is because the result is slightly larger than 3.

Ohm's Law & Joule's Law



- Use Ohm's Law when given two parameters, ohms, volts, or amps and want to find the third.
- Use Joule's Law when given two parameters, watts, volts, or amps and want to find the third. ⁷

Ohm's Law and Joule's Law relate voltage, current, resistance and power. Sometimes you must solve for either voltage or current in Joule's law and then substitute that value into Ohm's Law, or vice versa.

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

- Given volts and ohms, want power.
- Must use both Ohm's Law and Joule's Law
- $I = \frac{E}{R} = \frac{400}{800} = 0.5$ amps
- $P = 400 \times 0.5 = 200$ watts
- 200 watts
- EL-501X: $400 \times .5 =$

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The problem wants power which requires Joule's Law, but both voltage and current are not know. We will use Ohm's Law to find the current and make the necessary substitution into Joule's Law.

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

- Given volts and amps and find power, use Joule's Law
- $P = E \times I = 12 \times 0.2 = 2.4$ watts
- 2.4 watts
- EL-501X: $12 \times .2 =$

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Power is wanted and we have both voltage and current. Therefore we only need use Joule's Law.

Basic Components

- Resistors in series share current
- $R_{eq} = R_1 + R_2 + \dots + R_n$
- Resistors in parallel share voltage
- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$

	Series	Parallel
Inductor	As R in series	R in parallel
Capacitor	As R in parallel	As R in series

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Resistors may be connected in series (end-to-end) or in parallel (side-by-side). They may also be connected in parallel and series combinations but not on this exam. Just add the values when in series to find the equivalent resistance. And add the reciprocals (1 over values) to find the reciprocal of the resistance when resistors are in parallel. Then take the reciprocal of the results to find the equivalent resistance.

G5C03 Which of the following components should be added to an existing resistor to increase the resistance?

- Only same type components combine to equivalent
- $\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{5} = \frac{3}{10}$ $R_{eq} = \frac{10}{3} = 3.33$ ohms
- $R_{eq} = 10 + 5 = 15$ ohms
- A resistor in series
- EL-501X: $10 + 5 =$
- EL-501X: $10 \text{ 2nd F } 1/x = + 5 = \text{2nd F } 1/x$
- Pick largest of the two which is resistors in series

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Adding a resistor in parallel will always reduce the equivalent resistance. Adding a resistance will always increase the equivalent resistance. Therefore for this problem you must add the resistance in series with the existing resistance.

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

- Use parallel resistors equation
- $\frac{1}{R_{eq}} = \frac{1}{100} + \frac{1}{100} + \frac{1}{100} = \frac{3}{100}$
- $R_{eq} = \frac{100}{3} = 33.3 \text{ ohms}$
- 33.3 ohms
- EL-501X: $100 \text{ 2nd F } 1/x = + 100 \text{ 2nd F } 1/x$
 $100 \text{ 2nd F } 1/x = 2nd F 1/x$

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You can use the equation and run the numbers. Or you can note that three identical resistors in parallel result in the intermediate term of $R/3$.

Capacitors

- Capacitors in series add like resistors in parallel
- $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}$
- Capacitors in parallel add like resistors in series
- $C_{eq} = C_1 + C_2 + \dots + C_n$

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Capacitors act different than resistors. The relationships are “capacitors in series add as resistors in parallel” and “capacitors in parallel add as resistors in series”. This is derived from the fact that $C = \frac{\text{Area}}{\epsilon \times \text{distance}}$ for a physical capacitor. When in series you are effectively increase the distance between plates and the reciprocal relationship holds. When placing the capacitors in parallel you are effectively increasing the area.

G5C08 What is the equivalent capacitance of two 5.0 nanofarad capacitors and one 750 picofarad capacitor connected in parallel?

- Capacitors in parallel add like resistors in series
- $C_{eq} = C_1 + C_2 + C_3 = 5 \times 10^{-9} + 5 \times 10^{-9} + 750 \times 10^{-12}$
- $10,750^{-12} = 10.750^{-9}$
- 10.75 nanofarads
- EL-501X: 5 Exp 9 +/- + 5 Exp 9 +/- + 750 Exp 12 +/- F \leftrightarrow E

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The answers are all in nanofarads. Therefore convert all quantities to nanofarads and apply the correct formula. 1 nanofarad = 1,000 picofarads or 0.750 (three-quarters) nanofarads = 750 picofarads.

Now apply the the formula for capacitors in parallel (resistors in series).

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

- Capacitors in series add like resistor in parallel

- $\frac{1}{C_{eq}} = \frac{1}{20 \times 10^{-6}} + \frac{1}{50 \times 10^{-6}} = \frac{5}{100 \times 10^{-6}} + \frac{2}{100 \times 10^{-6}} = \frac{7}{100 \times 10^{-6}}$

- $C_{eq} = \frac{100}{7} \times 10^{-6} = 14.29 \times 10^{-6} = 14.29 \text{ microfarads}$

- 14.3 microfarads

- EL-501X: 20 Exp 6 +/- 2nd F 1/X + 50 Exp 6 +/- 2nd F 1/X = 2nd F 1/X F↔E

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The answers are in microfarads and the values in the problem are also in microfarads. Therefore no magnitude conversions must be made.

Use the relationship for capacitors in series (resistors in parallel) which is the reciprocal relationship. Don't to invert the answer to find the equivalent capacitance. Electrical elastance is the inverse of capacitance.

Inductors

- Inductors in series add like resistors in series
- $L_{eq} = L_1 + L_2 + \dots + L_n$
- Inductors in parallel add like resistors in parallel
- $\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n}$

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Inductors in series or parallel act as resistors in series and parallel. Therefore inductors in series add and inductors in parallel add as the reciprocal to yield reciprocal of the equivalent inductance. The reciprocal of inductance is called electrical reluctance (deprecated).

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

- Inductors in parallel add like resistor in parallel

- $$\frac{1}{L_{eq}} = \frac{1}{10 \times 10^{-3}} + \frac{1}{10 \times 10^{-3}} + \frac{1}{10 \times 10^{-3}} = \frac{3}{10 \times 10^{-3}}$$

- $$L_{eq} = \frac{10 \times 10^{-3}}{3} = 3.3 \times 10^{-3} = 3.3 \text{ millihenrys}$$

- 3.3 millihenrys

- EL-501X: 10 Exp 3 +/- 2nd F 1/X + 10 Exp 3 +/- 2nd F 1/X + 10 Exp 3 +/- 2nd F 1/X = 2nd F 1/X F↔E

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All three inductors are in units of millihenry so no scaling is required. Now take the reciprocal of all three and add. Then take the reciprocal of the result to find the equivalent inductance. Or use the concept of three resistors in parallel have the equivalent resistance of 1/3. Therefore since resistors and inductors have the same relationships, 10 millihenry inductors in parallel are 10/3 or 3.33 millihenry.

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

- Inductors in series add like resistors in series
- $L_{eq} = 20 \times 10^{-3} + 50 \times 10^{-3} = 70 \times 10^{-3} = 70$ millihenrys '
- 70 millihenrys
- EL-501X: 20 Exp 3 +/- + 50 Exp 3 +/- =
F↔E

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Inductors in series act as resistors in series. Since both inductances are in the units of millihenry, just add the values.

Transformers

- On exam used for impedance matching
- $Z_2 = \left(\frac{N_2}{N_1}\right)^2 \times Z_1$
- Also used for step-up or step-down transformer in real life
- $E_2 = \frac{N_2}{N_1} \times E_1$

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

- From Maximum Power Transfer Theorem we want the 600 ohm output of amplifier to match 600 ohm input to transformer with 4 ohm load

- $Z_{in} = \left(\frac{N_2}{N_1}\right)^2 \times Z_{spkr}$

- $600 = \left(\frac{N_2}{N_1}\right)^2 \times 4$

- $\frac{N_2}{N_1} = \sqrt{\frac{600}{4}} = 12.2$

- 12.2 to 1

- EL-501X: $600 \div 4 = \sqrt{\quad}$

AC Power

- Parameters can be measured in peak-to-peak, peak or root-mean-squared
- $V_{\text{peak}} = \frac{V_{\text{peak-to-peak}}}{2}$
- $V_{\text{RMS}} = 0.707 \times V_{\text{peak}}$
- All problems are without modulation
- Peak-Envelope-Power is Power RMS

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AC power is related to DC power by the effective value relationship or RMS (root-mean-squared). That is to say an RMS current in a resistor duces the same power loss as the DC current of the same magnitude. 1 amp RMS of AC current in a 2 ohm resistor dissipates 2 watts of power. In a similar manner 1 amp DC current in a 2 ohm resistor also dissipates 2 watts. $V_{\text{RMS}} = V_{\text{peak}} / \text{square-root of } 2 \text{ or } 0.707 \times V_{\text{peak}}$.

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

- $I = \frac{E}{R}$
- $P = E \times I = \frac{E \times E}{R} = \frac{E^2}{R}$
- $E = \sqrt{R \times P}$
- $E_{RMS} = \sqrt{50 \times 1200} = 244.9$ or 245 volts_{RMS}
- EL-501X: $50 \times 1200 = \sqrt{\quad}$

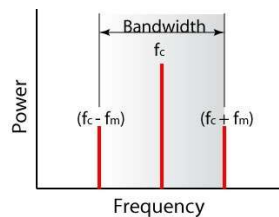
22

We have ohms (think Ohm's Law) and power (think Joule's Law). $P = I \times E$ and we want volts given power.

Symbolically solve for the current, I , in Ohm's Law and substitute into Joule's Law. The result is $P = E^2/R$. Make the substitutions and solve for E .

Amplitude Modulation

- With a carrier wave of frequency f_c and a modulating sine-wave of frequency f_m the output of the modulator is carrier wave of the original amplitude and frequency, an upper side band signal of up to $\frac{1}{2}$ the carrier amplitude and a frequency of $f_c + f_m$, and a lower side band signal of up to $\frac{1}{2}$ the carrier amplitude and a frequency of $f_c - f_m$



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AM or amplitude modulation has the lower-sideband, carrier and upper-sideband. The carrier or f_c comes from the local oscillator. The modulation frequency or f_m comes from the audio source. When f_c and f_m are passed through a multiplier (AM mixer) trigonometry tells us that we get the sum ($f_c + f_m$) or upper-sideband and the difference ($f_c - f_m$) or lower-sideband.

G4D08 What frequency range is occupied by a 3 kHz LSB signal when the displayed carrier frequency is set to 7.178 MHz?

- The displayed frequency is the virtual carrier frequency, f_c .
- $f_{lsb} = 3 \text{ kHz} = 0.003 \text{ MHz}$
- Since lower side band $f_c - f_{lsb} = 7.175 \text{ MHz}$ to $f_c = 7.178 \text{ MHz}$
- EL-501X: $7.178 \text{ Exp } 6 - 3 \text{ Exp } 3 = F \leftrightarrow E$

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Lower-sideband if $f_c - f_m$. The $f_m = 3 \text{ kHz}$ or 0.003 MHz . Therefore $f_c - f_m = 7.178 - 0.003 = 7.175 \text{ MHz}$. The frequency range is 7.175 MHz to 7.178 MHz .

Frequency Modulation

- Mathematics of FM much more complex than AM
- Carson's Rule states 98% of the power in FM signal is within the bandwidth B_T where

$$B_T = 2x(f_{\text{deviation}} + f_m)$$

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AM analysis only requires trigonometry, FM analysis requires an understanding of Bessel functions at a minimum. Therefore FM analysis is often done using rules of thumb and approximations. One approximation is Carson's Bandwidth Rule. This rule should only be used with rather smooth wave forms such as voice and not square waves such as some digital modes.

G8B06 What is the total bandwidth of an FM phone transmission having 5 kHz deviation and 3 kHz modulating frequency?

- Use Cramer's Rule for 98% of the power
- $B_T = 2 \times (5 + 3) = 2 \times 8 = 16 \text{ kHz}$
- EL-501X: $2 \times (5 \text{ Exp } 3 + 3 \text{ Exp } 3) = F \leftrightarrow E$

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Use Carson's Bandwidth Rule of add and double.

Standing Wave Ratio

- Defined as:
$$SWR = \frac{1 + \sqrt{\frac{P_r}{P_f}}}{1 - \sqrt{\frac{P_r}{P_f}}}$$
- For problems on exam use
$$SWR = \frac{Z_{\text{Largest}}}{Z_{\text{Smallest}}}$$

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The top formula is the defining formula

The bottom formula only applies for a purely resistive load. Since the ratio is always a positive number greater or equal to 1 to 1 use the larger number over the smaller number. Such as 1 to 1 or 4 to 1 etc. In the element 3 question pool all problems have a purely resistive load and none require the top formula.

G9A09 What standing wave ratio will result when connecting a 50 ohm feed line to a non-reactive load having 200 ohm impedance?

- $SWR = Z_{\text{Largest}} / Z_{\text{Smallest}} = 200 / 50 = 4$
- SWR is 4:1
- EL-501X: $200 \div 50 =$

Antenna Wave Length

- Wave length, λ , velocity of wave, v , and frequency f
- All waves $\lambda = \frac{v}{f}$
- Radio wave is metric units $\lambda = \frac{300}{f}$
- Radio wave in feet $\lambda = \frac{984}{f}$
- $\frac{1}{2}$ wave dipole in feet $\lambda = \frac{492}{f}$

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For US hams we design antenna in feet.

Therefore the equation changes from $\lambda = \frac{300}{f}$
to $\lambda = \frac{948}{f}$ or for a $\frac{1}{2}$ -wave antenna $\lambda = \frac{492}{f}$
since $948/2 = 492$. What would be the
formula for a $\frac{5}{8}$ wave antenna?

G9B10 What is the approximate length for a 1/2 wave dipole antenna cut for 14.250 MHz?

- $\lambda = (2 \times 246) / f = 492 / 14.250 = 34.5$ feet
- Closest answer is 32 feet
- EL-501X: $2 \times 246 \div 14.250 =$
- 2-4-6-8 who do we appreciate

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Either remember the number 492 or convert 300 million meters per second to 984 million feet per second using 2.54 cm per inch or some other ratio you remember. Not for a quarter wave the number 246 so some remember 2468 who do we appreciate. You drop the 8 and multiply by 2 for half wave antenna elements.