EASY(ER) ELECTRICAL PRINCIPLES FOR GENERAL CLASS HAM LICENSE

2011 - 2015

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FOREWORD

Taking an exam in order to get a ham license is quite stressful ordeal as it comes. To make things worse most people get extremely confused when dealing with calculations required. This guide will help you understand how to come to the answer as simply as possible and without calculator (which you will inevitably forget at home).

In order to make things easier to remember physics here is extremely simplified and takes full advantage of rounding numbers and moving decimal point around to get us into a ballpark of an answer. It is what engineers around the world do when they refer to "back of the envelope" calculations.

These simplifications work with General Class exam expiring on June 30, 2015. Most shortcuts will still apply for new exam but be warned that there might be some deviations.

Only Electrical Principles part of an exam is covered here and you will need to use other resources too. I recommend No-Nonsense Study Guides by KB6NU and do check for free classes at nearby Ham club. Ham radio is all about community – there is no reason to pass through all this alone.

SUBELEMENT G5 - ELECTRICAL PRINCIPLES

BASIC DEFINITIONS

There are only three components you need to understand here.

Resistor is a component that **resists flow** of electrical current and its property of resistance is expressed in units of **Ohm** (Ω).

Capacitor is component that resists signals at low frequencies but passes whatever comes at high frequency. I personally simply remember that **capacitor loves high frequencies** (as it passes them)**.**

Inductor is component that resists signals at high frequencies but passes whatever comes at low frequency. It is essentially quite the opposite of how capacitor behaves. That is, **inductor loves low frequencies**.

Impedance is opposition to the **flow of current** in AC circuit. When connecting two components (e.g. feed line and antenna) **closer their impedances are, less power is lost**.

Reactance is pretty much the same thing as **impedance** but narrowed for **capacitance and/or inductance** in circuit only. Both have Ohm as a unit.

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

As name says, something is impeded. In this case it is current.

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 de-energized

Impedance and reactance share quite a lot together. It is just that former is specific for capacitors and inductors.

G5A03

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

   A. Conductance
   B. Reluctance
   C. Admittance
   D. Reactance

Reactance applies to capacitor and inductor only.

G5A04

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

   A. Conductance
   B. Reluctance
   C. Reactance
   D. Admittance

Reactance applies to both capacitor and inductor.

G5A05

How does an inductor react to AC?

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

Inductor loves low frequencies. As reactance is opposition to current, we can deduce that any rise in frequency will not be appreciated. For inductor increase in frequency leads to reactance (opposition) increase.

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

Capacitor loves high frequencies and thus it won't oppose any increase. As reactance is a measure of opposition we can tell that capacitor will have it decrease as frequency increases.

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

Any mismatch in impedance will cause loss of power.

G5A09

What unit is used to measure reactance?

- A. Farad
- **B. Ohm**
- C. Ampere
- D. Siemens

Pretty much any opposition or resistance is measured in ohms. This goes for reactance too.

G5A10

What unit is used to measure impedance?

- A. Volt
- **B. Ohm**
- C. Ampere
- D. Watt

As impedance is a form of resistance, it is too measured in ohms.

G5A11

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

Inductor and capacitor are magical components when it comes to adjustment of impedance.

G5A12

What is one reason to use an impedance matching transformer?

A. To minimize transmitter power output
B. To maximize the transfer of power
C. To reduce power supply ripple
D. To minimize radiation resistance

If we match impedance we will reduce power loss and thus maximize power transfer.

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

Transformer is just special inductor, π network is "just" some inductors and capacitors thrown together. And any length of wire will exhibit inductance too. So all choices are correct here.

DECIBELS

Decibels look weird as they use logarithms. They become just an exercise in conversion once you understand that **every 3 dB is doubling of power**. Assuming you start with 1 W, 3 dB increase will be 2 W; 6 dB increase will be 4 W; and 9 dB increase will be 8 W. Conveniently 10 dB is same as tenfold increase.

A single dB is around 20% of a value.

G5B01

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

A. Approximately 2 dB
B. Approximately 3 dB
C. Approximately 6 dB
D. Approximately 12 dB

Every 3 dB we double the power.

G5B10

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%

Single dB will increase/decrease value by around 20%.

PARALLEL CIRCUIT

Currents in parallel are always added while voltage in parallel stays the same.

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

Currents in parallel can be summed.

POWER

Main formula for power is **$P = V \times I$** (in units that is W = V × A). This simply means we need to multiply voltage with current to get total power. And we are interested only in RMS voltage when it comes to power – not peak to peak. Another useful ways to get power is by using **$P = V^2 / R$** or **$P = I^2 \times R$**.

Peak-to-peak voltage is exactly **two times peak voltage**. In formula this would be $V_{peak-to-peak} = 2 \times V_{peak}$.

Whenever there is a question of power we need to calculate with **RMS voltage** and that one is $V_{RMS} = V_{peak} \times 0.7$ (or **about 3/4th**).

Peak envelope power is just another name for **average power** (of an unmodulated carrier).

Calculator is usually not necessary for any calculation here – you can just abuse the heck out of metric system and move decimal place around at will. That is, result will start with same numbers if you square number 4 (**16**), 40 (**16**00), or 400 (**16**0,000).

Similarly you can move decimal point to make numbers arbitrarily smaller (or bigger). Formula will return **same starting digits** whether you divide/multiply by **2**, **2**0, or **2**00.

Do notice that we can completely ignore units in most cases and there is a good reason for this. Those preparing questions want to see it you understand the principle, not whether you can do basic algebra. When you need these formulas in real life, you will have a calculator next to you and you can do it properly.

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

As we have voltage and resistance handy we can fetch $P = V^2 / R$ from our memory. This would make power equal to $400^2 / 800$. Abusing decimal point brings us to have this simplified to $4^2 / 8$. This gives handy result of 2.

As we moved decimal point around, we just see what begins with number in that ballpark and here the single answer is 200 W.

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

From our memory we fetch $P = V \times I$. Thus power is equal to 12×0.2. Those annoyed by decimal point can just calculate $12 \times 2 = 24$ and see what matches.

Unfortunately this brings us to two matching results: 2.4 W and 24 W. Since one of numbers we multiplied was lower than 1, we can deduce result cannot be 24 W and that leaves 2.4 W as a correct answer.

G5B05

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

   A.   Approximately 61 milliwatts
   B.   Approximately 61 watts
   C.   Approximately 11 milliwatts
   D.   Approximately 11 watts

Question will force us to remember another power formula $P = I^2 \times R$. Here we can simplify this as 7^2 x ~1 (about 1/4th above 1). This gives us result 1/4th higher than 49. Two results do match this description but we can see that question deals with really small currents. Thus power cannot be large and we can select 61 mW.

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

Formula for power that fits having voltage and resistance is $P = V^2 / R$. As voltage is peak-to-peak we need to convert it to peak voltage by dividing it by two and thus our peak voltage is 100V. V_{RMS} is then around 70 V ($3/4^{th}$ of a value). Abusing decimal point will tell us result will be starting with same numbers as $7^2 / 5$. Again rounding that is 50 / 5 = 10 and correct answer is only one starting with 10 – 100 W.

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

Same calculation applies. 500 volts peak-to-peak is 250 volts in peak and about 180 volts RMS. Further rounding gives $2^2 / 5$ which is same as 40 / 5 giving us 8. As we always rounded up, we know that first number must be smaller than 8 and 626 W fits that nicely.

Notice that values here are quite close (as far as first digit goes) and that we need to always remember whether we rounded up or down. We could have gotten much closer if we used 18^2 instead of rounding to 2 but calculating 18^2 is pain-in-the butt.

G5B07

Which value of an AC signal results in the same power dissipation as 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

When dealing with power dissipation, RMS is the way to go.

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

Instead of calculating peak-to-peak we can solve this by removing what isn't correct result. First thing we know is that peak voltage is always larger than RMS. As we are speaking about peak-to-peak values we need to divide all results by 2 and single (half) result that is larger than 120 V is 339.4 V.

G5B09

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

    A. 8.5 volts
    B. 12 volts
    C. 24 volts
    D. 34 volts

If you take peak value of 17 V and multiply it by $3/4^{th}$ result will be around 13 V. Closest value is thus 12 volts.

G5B11

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

    A. .707
    B. 1.00
    C. 1.414
    D. 2.00

Peak envelope power is average power of an unmodulated carrier. Thus ratio is 1:1.

G5B12

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

    A. 173 volts
    B. 245 volts
    C. 346 volts
    D. 692 volts

Formula for this is good old $P = V^2 / R$. One can either swap variables around and deal with square roots or you can simply put each answer through formula to determine which one gives result closest to 1200 W. In our case $245^2 / 50$ is similar to $25^2 / 50$ which is close enough to 60 / 5 and gives us 12. That is close to starting digits in our question.

G5B13

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

Peak envelope power is average power of an unmodulated carrier.

RESISTORS, CAPACITORS, AND INDUCTORS; OH MY!

Transformer is just a weird inductors. Part that receives energy on primary and energy is "converted" on secondary windings.

More resistors you have in line (series), the more resisting they will cause. If they are connected in **parallel, total value will always be smaller than smallest individual resistor value**. If resistors are the same in size (e.g. three parallel resistors of 100 Ω) final value will be individual value divided by number (100 Ω / 3).

Inductors follow the same parallel/serial values principle as resistors do.

Capacitors on other hand have their total value **increase when in parallel** and it is lower when in series.

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

If you look at transformer as a weird inductor and you remember that inductors love voltage, you'll find the answer.

G5C02

Which part of a transformer is normally connected to the incoming source of energy?

    A. The secondary
    B. The primary
    C. The core
    D. The plates

Energy source is always on primary side.

G5C03

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

    A. A resistor in parallel
    B. A resistor in series
    C. A capacitor in series
    D. A capacitor in parallel

Resistors resist more when they are one after another.

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

Resistors in parallel will have their total always smaller than any individual one. And since they are all the same value, you only need to divide them by 3.

G5C05

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

    A. 1500 ohms
    B. 90 ohms
    C. 150 ohms
    D. 175 ohms

Since resistors are the same and we know their parallel value is $1/3^{rd}$ of value each has, we can see that 150 Ω is only one that fits the bill.

Alternatively we know that resistance is added if they are in series. So we can also divide 450 Ω by 3 and get the same result.

G5C06

What is the RMS 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

This is just a matter of ratios. The more the turns, the higher the voltage. Since primary has around 2000 (rounded down) turns and secondary has 500 turns we know their ratio is 4:1. If we then apply the same ratio to 120 V from question we get 30 V. Closest value to 30 volts is 26.7 V.

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

Reflex answer here would be 150 to 1 and it would be true if we were dealing with voltages. However impedance has square relation with turn ratio. Square root of 150 is slightly more than 12 so that one is correct answer. This question is kind of an oddball.

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 picofarads
    C. 3583 picofarads
    D. 10750 picofarads

Capacitors in parallel add their values.

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

Capacitors behave opposite of resistors when placed in series. So values for three serial capacitors will behave same as for three parallel resistors.

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

Same formula as for parallel resistors applies – just divide by 3.

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

Resistors and inductors both add their values when connected in series.

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

Values of capacitors in series will behave as for resistors in parallel. That is, their value together will be just a smidge smaller than any one of them.

G5C13

Which of the following components should be added to a capacitor to increase the capacitance?

    A. An inductor in series
    B. A resistor in series
    C. A capacitor in parallel
    D. A capacitor in series

Capacitors in parallel behave as resistors and inductors in series, that is they increase their value.

G5C14

Which of the following components should be added to an inductor to increase the inductance?

    A. A capacitor in series
    B. A resistor in parallel
    C. An inductor in parallel
    D. An inductor in series

Both inductors and resistors increase their value when placed 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

Total resistance of resistors in parallel will always be just a smidge below value lowest of them has.