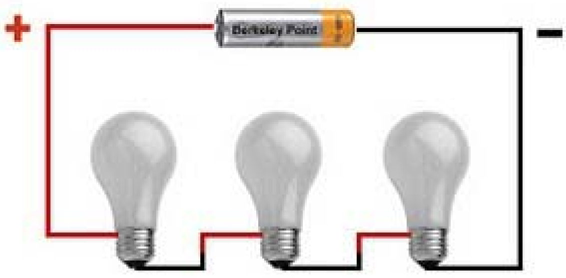
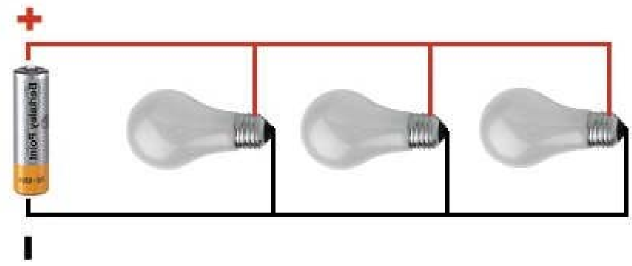
Basic Components[1]

Components may be connected in series or parallel. Examples are shown below using a battery (or voltage source) and three lamps that represent the basic components.

	
Series components share a common current.	Parallel components share a common voltage.

Since series components share a common current, $E_B = E_1 + E_2 + \ldots E_n = R_1 \times I + R_2 \times I + \ldots + R_n \times I$. If we group all the terms on *I* we get $E_B = (R_1 + R_2 + \ldots R_n) \times I$. Now divide both sides by *I*, $\frac{E_B}{I} = R_1 + R_2 + \ldots + R_n$. The equivalent resistance that would draw the same current would be, $R_{eq} = \frac{E_B}{I} = R_1 + R_2 + \ldots + R_n$. Thus the resistors in series add.

Since parallel components share a common voltage, each branch current is, $I_1 = \frac{E}{R_1}$, $I_2 = \frac{E}{R_2}$, through $I_n = \frac{E}{R_n}$. The battery current is, $I_B = I_1 + I_2 + \ldots + I_n = \frac{E}{R_1} + \frac{E}{R_2} + \ldots + \frac{E}{R_n}$. Now group on E, $I_B = (\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}) \times E$. Now divide each side by *E*, $\frac{I_B}{E} = (\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n})$. The reciprocal equivalent resistance that would draw the same current would be for the given voltage is, $\frac{I_B}{E} = \frac{1}{R_{eg}} = (\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n})$. The reciprocal of the equivalent resistance is the sum of the reciprocal of each branch resistance.

Now for some of the questions relating to parallel and series resistors.

Parallel and Series Resistance

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G5B02 (C)
How does the total current relate to the individual currents in each
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branch of a purely resistive 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

In a series resistance circuit the current is the same. In a parallel resistance circuit the total current is equal to the sum of the currents through each branch. Therefore for this question the answer is C.

G5C03 (B)
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

Only resistors may be combined into an equivalent resistance. Let's answer this question by example and assume 10 ohms in parallel with 5 ohms. Then $\frac{1}{R_{eq}}=\frac{1}{10}+\frac{1}{5}=\frac{3}{10}$ or $R_{eq}=\frac{10}{3}$ ohms which is less then both 10 ohms and 5 ohms. We are going the wrong way. This does not satisfy the need for an increased resistance. Now let's try resistors in series, $R_{eq}=10+5=15$ ohms which satisfies the problem. We may add 5 ohms to 10 ohms which increases the total resistance. Or we may add 10 ohms to 5 ohms which increases the resistance. Therefore B is the correct answer.

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

A. 0.30 ohms
B. 0.33 ohms
C. 33.3 ohms
D. 300 ohms

Since the three 100 ohm resistors are in parallel the equivalent resistance is,
$\frac{1}{R_{eq}}=\frac{1}{100}+\frac{1}{100}+\frac{1}{100}=\frac{3}{100}$ and $R_{eq}=\frac{100}{3}=33.3$ ohms and C is the correct answer.

G5C05 (C)
If three equal value 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 the three resistors in series add, $450=R+R+R=3\times R$. Now solve for R by dividing both sides by 3, $\frac{450}{3}=\frac{3\times R}{3}=R=150$ ohms. Therefore C is the correct answer.

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G5C15 (A)
What is the total resistance of a 10 ohm, a 20 ohm, and a 50 ohm
resistor connected in parallel?
   A. 5.9 ohms
   B. 0.17 ohms
   C. 10000 ohms
   D. 80 ohms
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Since the three resistors are in parallel, $\frac{1}{R_{eq}}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}=\frac{1}{10}+\frac{1}{20}+\frac{1}{50}=\frac{10}{100}+\frac{5}{100}+\frac{2}{100}=\frac{17}{100}$,

and $R_{eq}=\frac{100}{17}=5.88$ or 5.9 ohms. Thus A is the correct answer.

Capacitors in Series and Capacitors in Parallel

The resistors in series could be more generally stated as $X_{eq}=X_{R1}+X_{R2}+...+X_{Rn}$ and in parallel $\frac{I}{X_{eq}}=\frac{1}{X_{R1}}+\frac{1}{X_{R2}}+...\frac{1}{X_{Rn}}$. For capacitors that becomes in series $X_{Ceq}=X_{C1}+X_{C2}+...+X_{Cn}$. Now $X_C=\frac{1}{2\pi\ f\ C}$. By substitution that becomes,

$\frac{1}{2\pi\ f\ C_{eq}}=\frac{1}{2\pi\ f\ C_1}+\frac{1}{2\pi\ f\ C_2}+...+\frac{1}{2\pi\ f\ C_n}$. Muliply both sides by $2\pi\ f$ and we get

$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2}+...+\frac{1}{C_n}$. Thus capacitors in series add as resistors in parallel.

In a similar manner, resistors in parallel can be stated as $\frac{1}{X_{Req}}=\frac{1}{X_{R1}}+\frac{1}{X_{R2}}+...+\frac{1}{X_{Rn}}$ and capacitors in parallel, $\frac{1}{X_{Ceq}}=\frac{1}{X_{C1}}+\frac{1}{X_{C2}}+...+\frac{1}{X_{Cn}}$. Substituting $X_C=\frac{1}{2\pi\ f\ C}$. Now

$\frac{1}{\frac{1}{2\pi\ f\ C_{eq}}}=\frac{1}{\frac{1}{2\pi\ f\ C_1}}+\frac{1}{\frac{1}{2\pi\ f\ C_2}}+...+\frac{1}{\frac{1}{2\pi\ f\ C_n}}$ and $2\pi\ f\ C_{eq}=2\pi\ f\ C_1+2\pi\ f\ C_2$ + $2\pi\ f\ C_n$. Divided both sides by $2\pi\ f$ and $C_{eq}=C_1+C_2+...+C_n$. Or capacitors in parallel add like resistors in series.

Series Capacitors and Parallel Capacitors

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G5C08 (D)
What is the equivalent capacitance of two 5.0 nanofarad capacitors
and one 750 picofarad capacitor connected in parallel?
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A. 576.9 nanofarads
B. 1733 picofaradsCapacitors in parallel like resistors in series
C. 3583 picofarads
D. 10.750 nanofarads

This is just a plug and chug problem, $C_{eq} = C_1 + C_2 + C_3 = 5\times10^{-9} + 5\times10^{-9} + 750\times10^{-12}$. Now convert the two 5 nanofarad capacitors to 5,000 picofarad and add, $C_{eq} = 10000\times10^{-9} + 750\times10^{-12}$ = $10{,}750^{-12} = 10.750^{-9}$ or 10.750 nanofarad. The correct answer is D.

G5C09 (C)
What is the capacitance of three 100 microfarad capacitors connected in series?
A. 0.30 microfarads
B. 0.33 microfarads
C. 33.3 microfarads
D. 300 microfarads

Again plug and chug as follows since the three equal capacitors are in series, $\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C}$.
Therefore $C_{eq} = \frac{C}{3} = \frac{100\times10^{-6}}{3} = 33.3\times10^{-6}$ or 33.3 microfarad. The correct answer is C.

G5C12 (B)
What is the capacitance of a 20 microfarad capacitor connected in series with a 50 microfarad capacitor?
A. 0.07 microfarads
B. 14.3 microfarads
C. 70 microfarads
D. 1000 microfarads

Yet again, a plug and chug as follows since the two capacitors are in series, $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$ = $\frac{1}{20\times10^{-6}} + \frac{1}{50\times10^{-6}} = \frac{5}{100\times10^{-6}} + \frac{2}{100\times10^{-6}} = \frac{7}{100\times10^{-6}}$ and $C_{eq} = \frac{100}{7}\times10^{-6} = 14.29\times10^{-6}$ or 14.4 microfarad. And B is the correct answer.

G5C13 (C)
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

Only capacitors may be combines with capacitors to come up with an increased capacitance. Let's try two capacitors of C in series. Then $\frac{1}{C_{eq}}=\frac{1}{C}+\frac{1}{C}=2\times\frac{1}{C}=\frac{2}{C}$ or $C_{eq}=\frac{C}{2}$. This reduces the total capacitance and is going the wrong way. Let's try the same two capacitors in parallel and , $C_{eq}=C+C=2\times C$ which is going the correct way. Therefore C is the correct answer.

Inductors in Series and Inductors in Parallel (Without Mutual Inductance)

The phrase, without mutual inductance, means that the magnetic field of each inductor does not couple to magnetic field of any other inductor. When the magnetic fields couple we call the component a transformer. Transformers are discussed in the next section.

To prevent the magnetic field from coupling, we magnetically shield the coils with mu-metal, place the coils on a torrid core, or place the cylindrical cores perpendicular to each other. All the inductor problems in this section are assumed to have no mutual inductance.

The reactance of an inductor is, $X_L=2\pi\ f\ L$ For inductors in series the equivalent inductance is, $X_L=X_1+X_2+...X_n=2\pi\ f\ L_{eq}=2\pi\ f\ L_1+2\pi\ f\ L_2+...+2\pi\ f\ L_n$. Divided both sides by $2\pi\ f$ which yields $L_{eq}=L_1+L_2+...+L_n$, much like resistors in series. And inductors in parallel the equivalent inductance is, n $\frac{1}{X_{eq}}=\frac{1}{X_1}+\frac{1}{X_2}+...+\frac{1}{X_n}=\frac{1}{2\pi\ f\ L_{eq}}=\frac{1}{2\pi\ f\ L_1}+\frac{1}{2\pi\ f\ L_2}+...+\frac{1}{2\pi\ f\ L_n}$. Now multiply both sides by $2\pi\ f$ and $\frac{1}{L_{eg}}=\frac{1}{L_1}+\frac{1}{L_2}+...+\frac{1}{L_n}$, much like resistors in parallel. Remember the two relationships given above are for the no mutual inductance case.

Series Inductors and Parallel Inductors

G5C10 (C)
What is the inductance of three 10 millihenry inductors connected in parallel?
A. 0.30 henrys
B. 3.3 henrys
C. 3.3 millihenrys
D. 30 millihenrys

Let's do the math. Since inductors in parallel add like resistors in parallel, $\frac{1}{L_{eq}}=\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}$ = $\frac{1}{L_{eq}}=\frac{1}{10\times10^{-3}}+\frac{1}{10\times10^{-3}}+\frac{1}{10\times10^{-3}}=\frac{3}{10\times10^{-3}}$, Thus $L_{eq}=\frac{10\times10^{-3}}{3}=3.3\times10^{-3}$ or 3.3 millihenrys. Therefore C is the correct answer. Note this assumes that the three magnetic field don't couple to each other. That is to say that there is no mutual inductance.

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

A. 0.07 millihenrys
B. 14.3 millihenrys
C. 70 millihenrys
D. 1000 millihenrys

Again let's do the math. Since inductors in series add like resistors in series, $L_{eq}=L_1+L_2$ = $20\times10^{-3}+50\times10^{-3}=70\times10^{-3}$ or 70 millihenrys. Therefore C is the correct answer. Again mote this assum3es that the two magnetic field don't couple to each other. That is to say that there is no mutual inductance.

G5C14 (D)
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

Only inductors may be combined with inductors. Let's try this by exampl using 2 henry and 3 henry inductors. In parallel the math yield, $\frac{1}{L_{eq}}=\frac{1}{2}+\frac{1}{3}=\frac{3}{6}+\frac{2}{6}=\frac{5}{6}$ and $L_{eq}=\frac{6}{5}=1.2$ which is less than either inductor. In series series the math yields, $L_{eq}=L_1+L_2=2+3=5$ henery. Therefore D is the correct answer.

Transformers or Coupled Inductors

A transformer is formed by placing two or more coils (inductors) on a common magnetic core. The question in the General Class license pool assume only two coils are magnetically coupled. Therefore we will derive the equation for this situation. The magnetic field intensity, H_1, is given by $N_1\times I_1$ and measured in ampere-turns. If a second coil completely couple this magnetic field intensity then, $H_2=N_2\times I_2=H_1=N_1\times I_1$. Now solve for I_2 , $I_2=\frac{N_1}{N_2}\times I_1$. Note 1 can be the primary winding or secondary winding and 2 can be the remaining secondary winding or primary winding.

From Faraday's law we know, $E_1=N_1\times\frac{d\phi}{dt}$ and for a second coil $E_2=N_2\times\frac{d\phi}{dt}$. Solve for the time change in flux, $\frac{d\phi}{dt}$, and since the flux is assumed to completely couple the two are equal, $\frac{d\phi}{dt}=\frac{E_1}{N_1}=\frac{E_2}{N_2}$. The result is, $E_2=\frac{N_2}{N_1}\times E_1$. This yields the second equation for a two coil transformer. To find the last relationship divide the voltage relationship by the current relationship and manipulate, $\frac{E_2}{I_2}=\frac{\frac{N_2}{N_1}\times E_1}{\frac{N_1}{N_2}\times I_1}=Z_2=(\frac{N_2}{N_1})^2\times Z_1$. This yields the last relationship, $Z_2=(\frac{N_2}{N_1})^2\times Z_1$.

This shows that transformers can increase the impedance when $\frac{N_2}{N_1}>1$, or decrease the impedance when $\frac{N_2}{N_1}<1$. Since the turns is a cardinal number $\frac{N_2}{N_1}>0$. The transformer can't make an inductor look like a capacitor or the other way around.

You may not know what magnetic field intensisty, the derivative or Faraday's law. They were only mentioned here to derive the relationships.

Transformers

G5C02 (A)
What happens if you reverse the primary and secondary windings of a 4:1 voltage step down transformer?

A. The secondary voltage becomes 4 times the primary voltage
B. The transformer no longer functions as it is a unidirectional device
C. Additional resistance must be added in series with the primary to prevent overload
D. Additional resistance must be added in parallel with the secondary to prevent overload

The relationship goes from $E_S=\frac{N_S}{N_P}\times E_P=\frac{1}{4}\times E_P$ to $E_S=\frac{N_S}{N_P}\times E_P=\frac{4}{1}\times E_P=4\times E_P$. In the stated problem the primary winding becomes the secondary winding and the secondary winding becomes the primary winding, but the coils number of turns does not change. Therefore the answer is A.

G5C07 (A)
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?

A. 12.2 to 1
B. 24.4 to 1
C. 150 to 1
D. 300 to 1

To get maximum power transformer the 600 output impedance of the amplifier must be match to the 4 ohm speaker impedance. That is to say, $Z_{in}=(\frac{N_2}{N_1})^2\times Z_{spkr}$ or $600=(\frac{N_2}{N_1})^2\times 4$. Solving for the turns ratio $\frac{N_2}{N_1}=\sqrt{\frac{600}{4}}=12.2$ and A is the correct answer.

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G5C16 (B)
Why is the conductor of the primary winding of many voltage step up
transformers larger in diameter than the conductor 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 insure that the volume of the primary winding is equal to the
     volume of the secondary winding
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To answer this question look at the current relationship for transformers, . $E_S=\frac{N_S}{N_P}\times E_P$ For a step up transformer , $E_S=\frac{N_S}{N_P}\times E_P$ we note $\frac{E_S}{E_P}>1$ and therefore $\frac{N_S}{N_P}>1$. That means that $I_P=\frac{N_S}{N_P}\times I_S$ and since $\frac{N_S}{N_P}>1$ that means $I_P>I_S$. One would make the diameter of the primary wire larger to handle the increased current flow. Therefore B is the correct answer.

The bottom line...

The bottom line is you can memorize the answers and pass the exam or learn the concepts and use a calculator to pass the exam. Learning the concepts will apply during your amateur radio career and help you in the future. Also it will help you prepare for the more advanced concept on the Extra Class license exam.