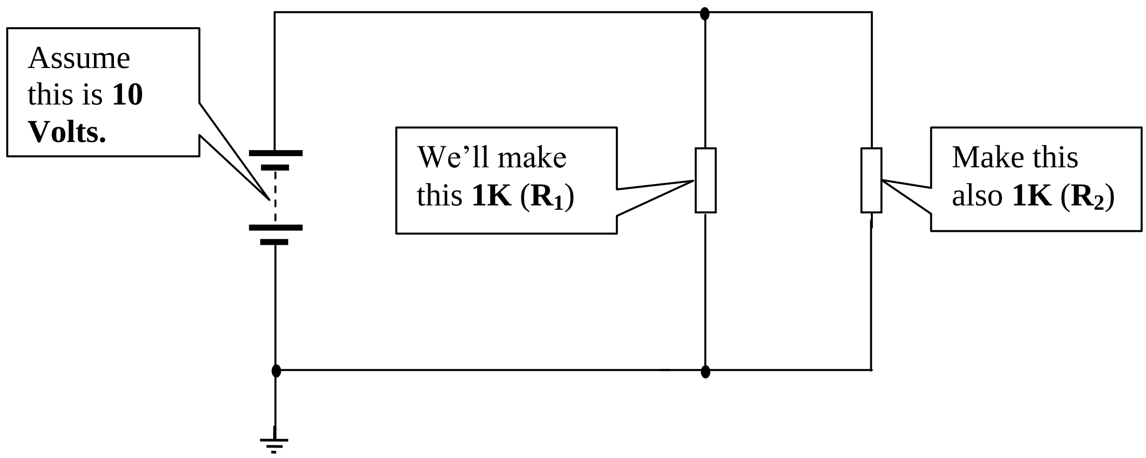
Diploma of Audio Production Name________________

Analogue Fundamentals (Audio Knowledge)

Module 9

Topic 2. Parallel resistive circuits

OK so now we know what happens in a series circuit but what happens in this circuit?



Now the current has 2 paths to flow through. So the current drawn from the battery doubles in this case with the addition of R2
Well if the current increases the resistance offered to the battery must have decreased..
An analogy is like having 2 lanes of traffic to ease the congestion.
In this case the total resistance must be half of what is with only 1 resistor across the battery.
Therefore R total is 500 ohms
And total battery current would be **twice** of that of just one resistor. **ie 4mA** And VR1 = VR2 = 10volts

This is known as a **parallel circuit.**

But what about power dissipation?

Well Power total **(P_T) = Vs x I_T**, and **P_{R1} = Vs x I_{R1}** also **P_{R2} = Vs x I_{R2}**.

Calculating R total (RT)

Determining the total resistance value of resistors in parallel is not quite as easy as in the series circuit although if all resistors are the same value we simply divide the value of 1 resistor by the number in parallel.

That is for 2 resistors = 1K / 2 = 500Ω
For 3 resistors = 4K7 / 3 = 1.566KΩ
And four resistors = 2K2 / 4 = 550Ω

Some problems for you to work out.

Find **RT** for the following;

4 x 8Ω in parallel = _______________
3 x 8Ω in parallel = _______________
2 x 4K7 in parallel = ______________

Now if the resistors are not the same value then it becomes slightly more difficult to determine the RT.
There are 2 basic methods we can use depending on how many resistors are in parallel.

1/. for only 2 resistors we can use the product divided by the sum method.

$$R_{Total} = \frac{R1 \times R2}{R1 + R2}$$

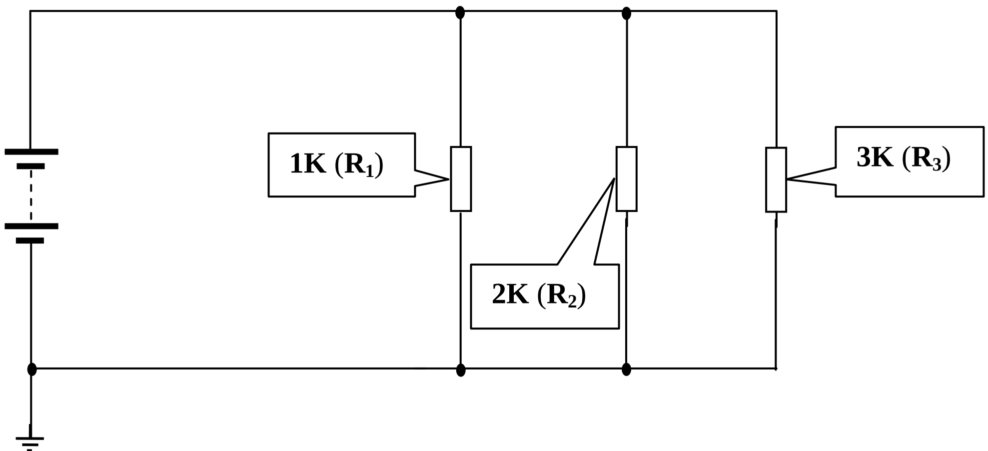
As an example lets see if it works for 2 x 1k's in parallel.

$$\frac{1K x 1K}{1K + 1K} = \frac{1000000}{2000} = 500\Omega$$

This seems to work but what if the resistors are different values? Well lets try it foot a 1K and a 2K

$$R_T = \frac{R1 x R2}{R1 + R2} = \frac{1K x 2K}{1K + 2K} = \frac{2000000}{3000} = 666\Omega$$

If we have more than 2 resistors however, the simple formula does not work.
eg.



Now we can do this problem 2 ways. We could get the RT for R2 & R3 then use this result with R1 using the product divided by the sum for both calculations.

So here goes

$$RT1_{(R2,R3)} = \frac{R2xR3}{R2+R3} = \frac{2Kx3K}{2K+3K} = \frac{6000000}{5000} = 1200\Omega$$

$$RT_{(R1,RT1)} = \frac{R1xRt1}{R1+Rt1} = \frac{1Kx1K2}{1K+1K2} = \frac{1200000}{2200} = 546\Omega \text{ Remember this figure.}$$

Method 2 , Using the Reciprocal method..

$$R^{total} = \frac{1}{1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 \quad etc}$$

Which method do you prefer?

Is there an easier way?

Yes there is.

How.. By using **Ohms Law** to calculate the individual currents and add up these currents.

Then find RT by again using ohms law with the same supply voltage you used to determine the individual currents..

eg. $R_{Total} = Vsupply / Itotal$ Or put this way: $R_T = \frac{V^{ss}}{I^T}$

Will it work? No point in wondering lets get onto it..

Using VS = 10 Volts calculate the individual currents.(Note we could use or assume any VS providing we use the same VS to calculate RT at the end)

IR1 = 10mA, IR2 = 5mA and IR3 = 3.3mA.

So I total = 18.3 mA

Therefore RT = $10Volts / 18.3mA$ = 546Ω Seem familiar??

So we can use any or all of these methods to determine R total in a parallel circuit.

And probably the last method was the easiest don't you think?

Power consumption in a parallel resistive circuit.

Well P total is easy and is simply $\mathbf{P_T = V_S \times I_T}$

Calculating Pt for our circuit we have 10Volts x 18.3mA

= 183 milliWatts

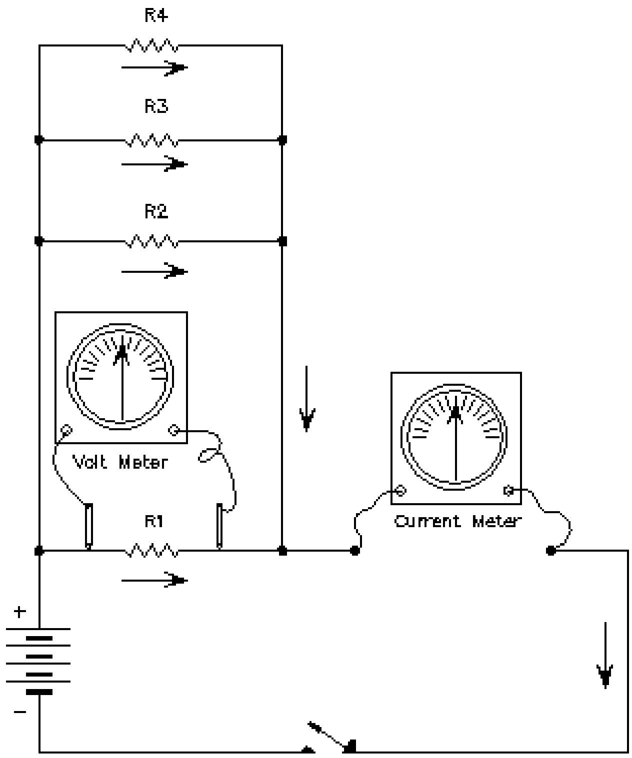
Individual Power consumptions

$\mathbf{P_{R1} = V_S \times I_{R1}}$	$\mathbf{P_{R2} = Vs \times I_{R2}}$	$\mathbf{P_{R3} = Vs \times I_{R3}}$
= 10v x 10mA	= 10v x 5mA	= 10v x 3.3mA
= 100mW	= 50mW	= 33mW

So Power total = PR1 + PR2 + PR3
= 100mW + 50mW + 33mW
= 183 milliWatts

Now which resistor in our parallel circuit has the highest power consumption?
If you answered the lowest value you are of course correct.. How does this compare to our series circuit??

Proof of the || R formula: In a parallel circuit there are multiple paths for the current to take. This means that in the circuit below, each resistance will have the same battery voltage over it, and the currents going through each resistance are not affected by each other. Therefore, the ***total*** current being drawn from the battery will be equal to the sum of currents drawn by R1, R2, R3 & R4.



We also know that:

$$\mathbf{R} = \frac{\mathbf{V}}{\mathbf{I}}$$

Therefore the total resistance of a parallel circuit must be related to the sum of the currents.

$$\mathbf{R} = \frac{\mathbf{V}}{\mathbf{I_1 + I_1 + I_3 + I_4 \quad etc}}$$ … and substituting

$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}}$$

We get $\mathbf{R_{Total}} = \dfrac{\mathbf{V}}{\mathbf{V/R_1 + V/R_2 + V/R_3 + V/R_4 \quad etc}}$ and the "**Vs**" cancel out to:

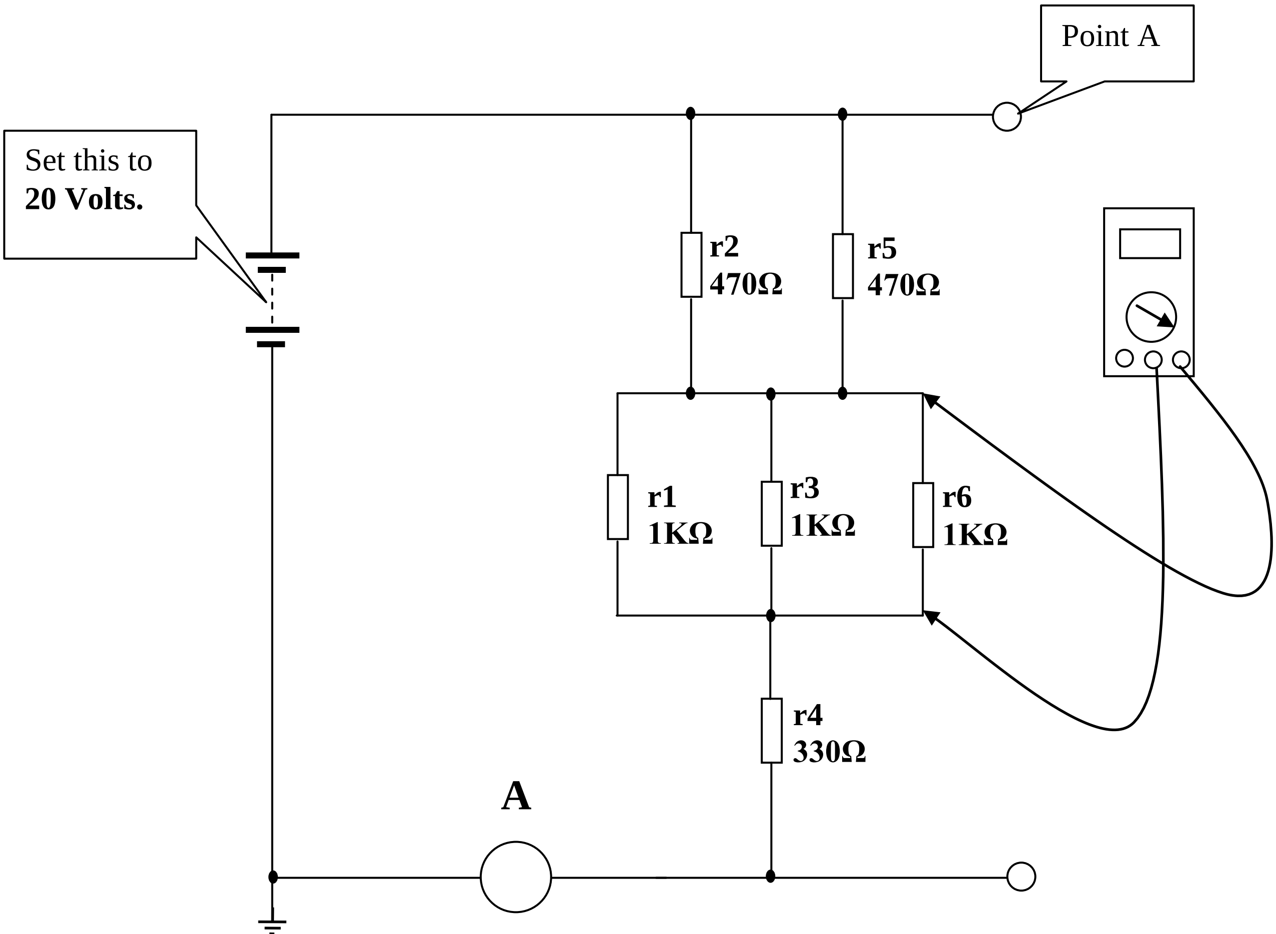
$$\therefore\ \mathbf{R^{\,total}} = \frac{\mathbf{1}}{\mathbf{1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 \quad etc}}$$

Conclusion.

We should write conclusions about our findings of a parallel circuit.

Series / parallel combinations.

In the electronics and audio industry there are an infinite number of series and parallel resistive circuits in use as well combinations of series and parallel. We are not going to dwell over these circuits but we will include a sample one here that you can tackle if you get bored.



Problems:

Find Total resistance:

Total current:

Voltage across r2. (Vr2)

Voltage across r3 (Vr3)

Voltage r4 (Vr4)

Which resistor do you think is dissipating most power? ______________________________

Here's a bit of space to prove your answer.

Well let's apply all this knowledge to something more related to your industry.

Connecting up loudspeakers in series, parallel and a combination of both.

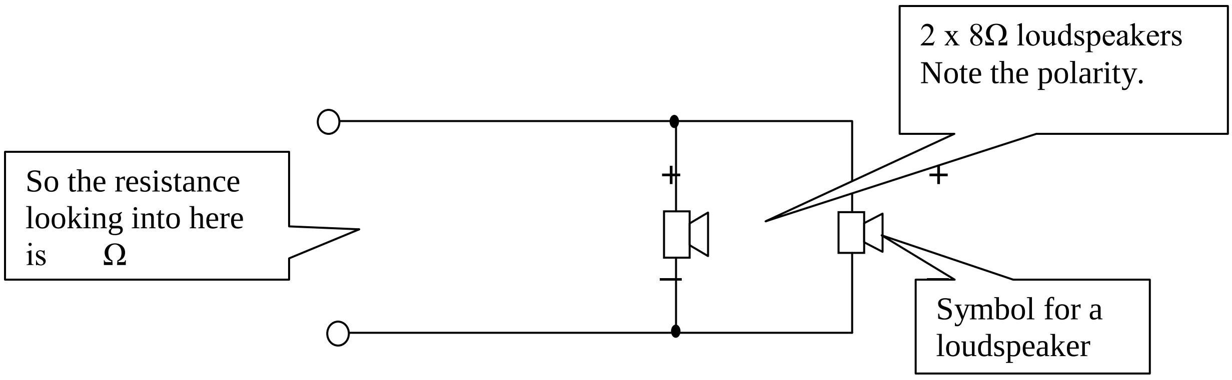
Now loudspeakers or speakers or drive units as they are sometimes referred to as are normally either 4 ohms or 8 ohms. The 4 ohms is normally the exclusive domain of the car audio industry and 8 ohms for the Hi-Fi and music industries.

Now we can build up a high power speaker system by using multiple speaker systems but we have to ensure that the impedance or resistance remains as per the requirement of the amplifying system.
Using our theory of series and parallel resistive circuits we can determine or design a speaker system to suit any power and resistance requirements. Now in loudspeaker terminology the resistance that we refer to the "Voice Coil" as in actually known as the

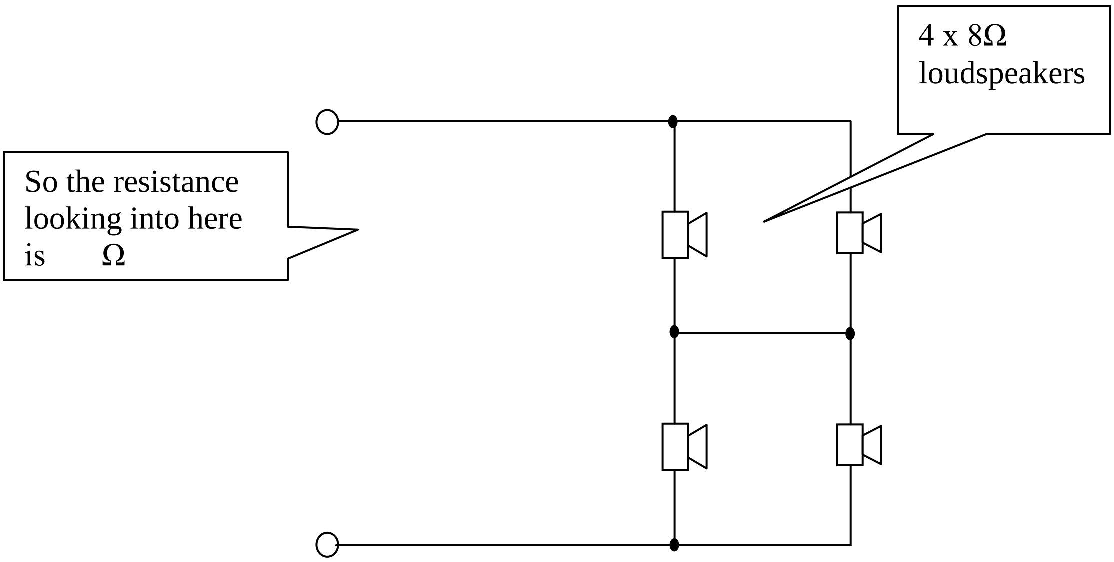
“Impedance” of the speaker. This impedance is the actual resistance offered to the audio signal in the 20Hz to the 20KHz region. We may like to refer to it as the “AC” resistance of the speaker. Either way it still can be considered to be a resistance and all our theory to date can be applied to it. And incidentally, if we measure the voice coil resistance on a DMM it will be approximately the stated impedance anyway. So there we have it, aren’t you glad you asked.

Examples.

1/. 2 by 8Ω speakers in parallel.

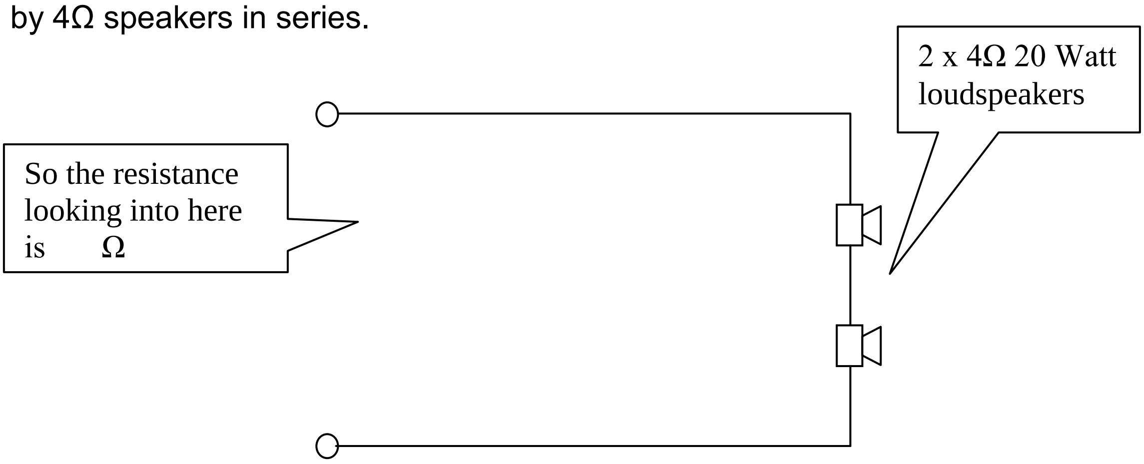


2/. 4 by 8Ω speakers in series / parallel.



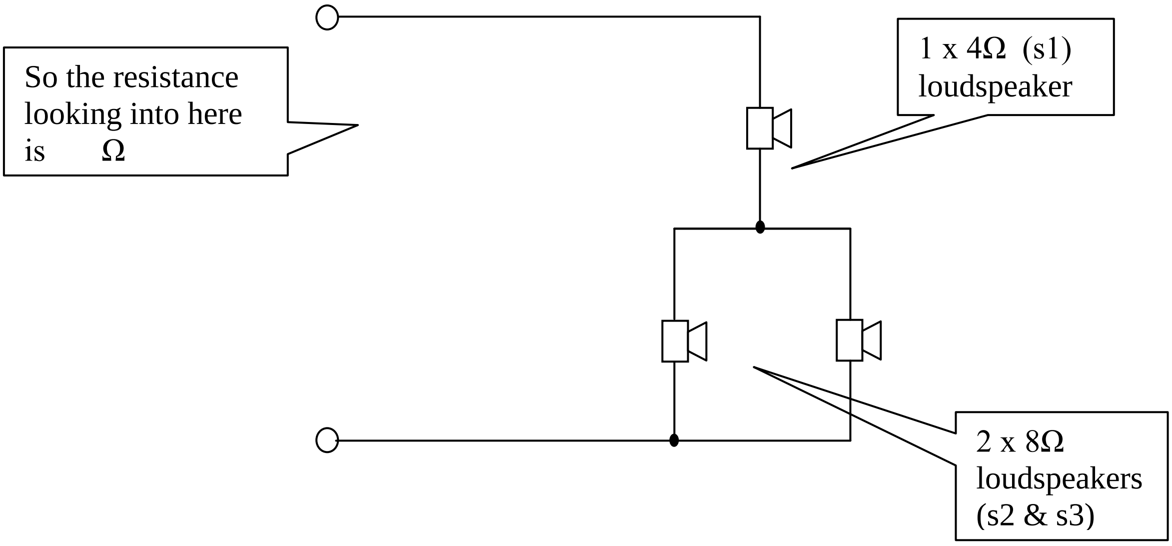
Mark in the polarity of the speakers.
What would the system be rated at if each speaker is rated at 100 Watts?__________

3/. 2 by 4Ω speakers in series.



Power rating of this system would be ______________________
Mark in the polarities of the speakers

4/. 1 by 4Ω speakers in series with 2 by 8Ω speakers in parallel.



Question What would be the power distribution in this system given that the driving amplifier is rated at 100 Watts into 8Ω?______________

Mark in the polarities of the speakers.

Topic 2: Ohm's Law as applied to Loudspeakers.

Loudspeakers act as resistors when placed across the output of an amplifier and the amplifier becomes the source of EMF that drives the speaker. EMF = Electro-Motive Force. Therefore the amplifier drives a current through the loudspeaker “voice Coil” And just like in ohms law, the product of the voltage and current will give us the power dissipated in the speaker coil.
Note: This power that is dissipated is not really a measure of how loud the speaker will sound but merely how much power the voice coil can dissipate without damage. (ie burning out). The loudness is to do with the efficiency of the speaker or drive unit and this is measured in dB_{spl} for a given input power.
It is possible for a speaker rated at 10 Watts to sound louder than a speaker rated at 100 Watts but more of this later in the lesson.

When calculating the power in a speaker we use the RMS value of the audio signal. Remember the RMS value is the equivalent DC voltage or has the same heating effect as the same DC voltage. This is the voltage as measured on a DMM on AC volts not as viewed on the oscilloscope. (∿Volts)

Example.

Lets say that an amplifier is outputting 20 volts of audio, how much current will flow into an 8Ω speaker and how much power is being dissipated? Note all signal voltages are RMS unless otherwise advised. So a signal voltage with nothing written next to it is an RMS voltage as distinct from 20 volts p-p etc.

Well the current is still determined by the voltage divided by the resistance.

ie $I = \frac{V}{R} = {}^{20}\!/_{8} = 2.5$ **Amps and power =V x I = 20 x 2.5 = 50 Watts.**

How much **current** flows into a **4Ω** car audio speaker that is delivering **400watts** of power?
To solve this problem we need to use one of the derivations of the power formula as we are not told the voltage..

So from the basic formula for power (P = V x I) we can substitute V for I x R,

Therefore power **(P) = I x R x I**, which gives: $P = I^2 R$

So to find I we divide both sides by R which gives us: $I^2 = \frac{P}{R}$
Get the square root of both sides and we have:

$$I = \sqrt{\frac{P}{R}}$$

Finding the Current $\mathbf{I} = \sqrt{400/4} = \sqrt{100} = \mathbf{10\ Amps}$

To find the RMS Voltage we can again use one of the derivations of the basic power formula.

So again we have **P = V x I & s**ubstituting V/R for **I** we have;

$$P = V \times V/R \text{ and this gives us } \quad P = \frac{V^2}{R}$$

Dividing both sides by R we obtain **P x R = V²** Now find the square root of both sides and we have

$$V = \sqrt{PR}$$

So the RMS voltage will be V = $\sqrt{400x4} = \sqrt{1600} = \mathbf{40\ Volts}$

We can prove all this by putting these figures back into the original formula..

So Power = V x I = 40 x 10 = 400 Watts

And all of this is just using Ohms Law that we learnt in the previous lessons.

Note:
This signal that is applied to a loudspeaker is a steady “sine wave” with a frequency of either 400Hz or 1KHz not a music signal as this is always varying in amplitude and frequency. It would not be possible to listen to a signal of this magnitude at this frequency for very long as we would quickly finish up with a severe headache..

Now if we are testing the amplifier for maximum power output we would substitute the speaker for a “Dummy Load” which is really just a high power wire wound resister with the same impedance.
Some problems for you to do...

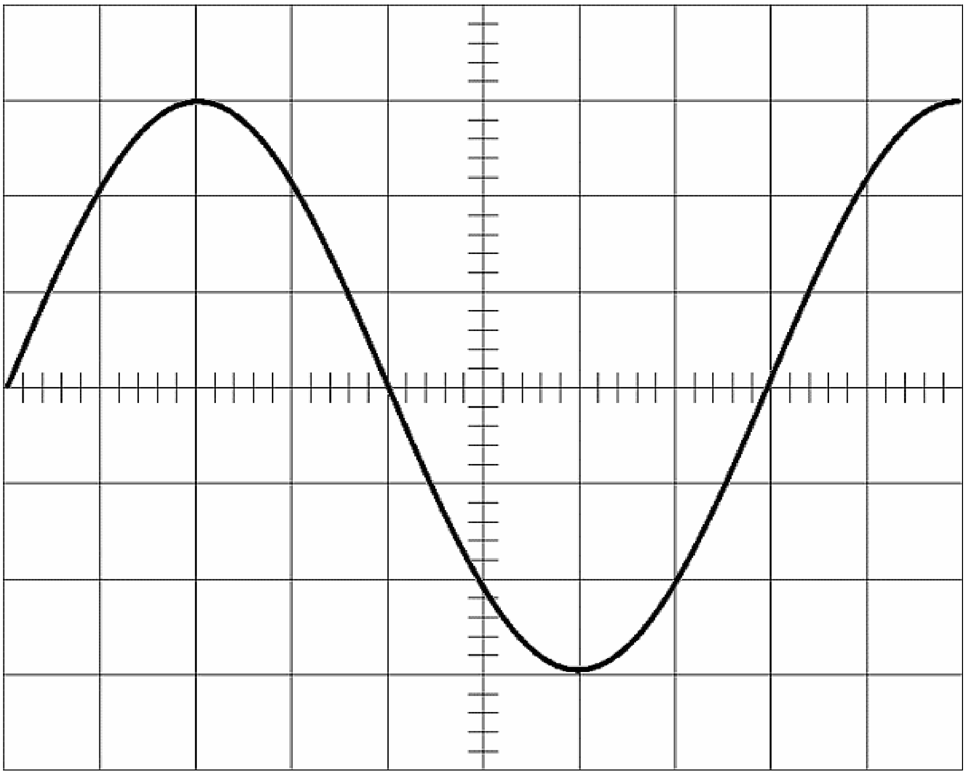
1/. Given that an 8Ω loudspeaker has 40 volts of signal across it, how much power is the speaker dissipating? (Is this 40 volts RMS? yes it is. Why?)

2/. Find the speaker current if the voice coil was dissipating 100 Watts and its impedance is 4Ω.

3/.What signal voltage is required across an 8Ω speaker if we require it to dissipate 50 Watts.

4/. What will the RMS and P-P voltage across an 8Ω loudspeaker if it is to consume 1 Watt of Power.

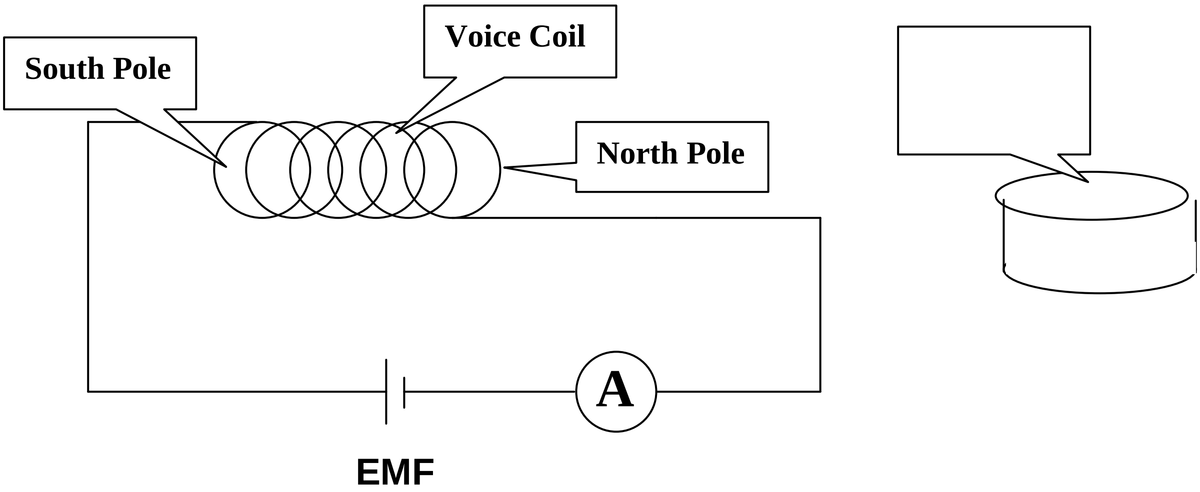
5/. Calculate the power being dissipated across a 4Ω loudspeaker if the following sine wave was across the voice coil terminals. This signal is how we would view the signal on the oscilloscope. (Volts per division settings = 5 Volts)



Now what about the current produced in the “voice coil” as a result of the voltage applied to it. And what effect does the current produce when flowing in the voice coil.

If you said it produces a magnet and in particular an “Electromagnet” you are 100% correct. Any time we have a current flowing in a coil of wire we will produce a magnet with its own north and south poles.

Example.



Now if the electromagnet is placed near a permanent magnet it will either be attracted to or repelled away from this fixed magnet. Now in a loudspeaker system the electromagnet is the actual voice coil and this is wound on a “former” attached to the cone or diaphragm. Therefore as the electromagnet is attracted to or repelled from the Fixed Permanent magnet it will move the cone in and out.
By convention, if we place a positive voltage on the positive terminal WRT the negative terminal a magnetic field will be produced that will move the cone forwards or outwards.

How much current will be produced in an 8Ω Voice coil if the input signal voltage is 2.8 Volts RMS?

We will need to use the formula $\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}}$ (Ohms Law Again)

Remember that this voltage produced 1 Watt of power in an 8Ω voice coil of the speaker. (Q4 on previous page)

Calculations:

Why is this important anyway? Well when they test or state the “Efficiency” of a loudspeaker in dB spl it uses an input power of one watt @ 400 Hertz to determine this.. We will look at specifications and testing of loudspeakers in the next lesson.