Math for the General Class Ham Radio Operator

A prerequisite math refresher for the math phobic ham
What We Will Cover

Ohm’s Law

Power Circle

Write these down!
What We Will Cover

Write these down!

\[
P = EI \\
P = I^2R \\
P = \frac{E^2}{R}
\]
What We Will Cover

Write this down!

How to calculate RMS (root mean square) of an AC voltage

\[ \text{RMS} = 0.707 \times \text{Peak} \]
What We Will Cover

Write these down!

\[ V_{\text{Peak}} = 1.414 V_{\text{RMS}} \]

Peak Voltage to RMS

\[ V_{P-to-P} = 2 \times V_{\text{Peak}} \]

Peak-to-Peak Voltage to Peak Voltage

\[ PEP = \frac{(V_{\text{RMS}})^2}{R} \]

Peak Envelope Power
What We Won’t Cover

Power Measurement in dB

\[ dB = 10 \log_{10} \left( \frac{P_2}{P_1} \right) \]

\[ \log_{10} N = L \]

Why? Only 1 math question on test dealing with dB

Yes, this is important, but will take too much class time, sorry

Pages 4-3 thru 4-5
Teach to the Test

Not generally a good idea, but:

- Section 5 = 3 questions out of 3 groups
- Section 5 = 3 groups, 1 from each group
- Section 5B = 1 test question out of 13

Pages 11-42 thru 11-43
Math Vocabulary

• What are equations and formulas?
• What do variables mean?
• What does solving an equation mean?
• Getting the final answer!
Math Vocabulary
What are equations and formulas?

• Equations are relationships between things that are exactly equivalent (have the same overall value).

• Two equivalent sets of things are shown equal by using the equal sign (=).

• The left side of the = has the same value as the right side.
Math Vocabulary
What do variables mean?

It’s all about the cheese!
Math Vocabulary
What do variables mean?

50 x =

If 50 cheese-heads can fit into 1 bus…
Math Vocabulary
What do variables mean?

How many cheese-heads are there in 5 busses?
Math Vocabulary
What do variables mean?

5 x 50 = 250

That’s a lot of cheese-heads!
Math Vocabulary

What do variables mean?

E = Voltage (Volts)

The electromotive force it takes to push electrons

I = Current (Amps)

The flow of electrons

R = Resistance (Ohms)

Opposition of a material to current flow
Math Vocabulary
What do variables mean?

- **P** = Power (Watts)
  The product of voltage and current

- **I** = Current (Amps)
  The flow of electrons

- **E** = Voltage (Volts)
  The electromotive force it takes to push electrons
Math Vocabulary
Equations from Ohm’s Law

\[ E = I \times R \]
\[ I = \frac{E}{R} \]
\[ R = \frac{E}{I} \]
Math Vocabulary
Equations from Power Circle

\[ P = I \times E \]
\[ I = \frac{P}{E} \]
\[ E = \frac{P}{I} \]
Let’s Put Them Together

What is P if given I & R?

You need E, so use Ohm’s law, then you can solve for P

\[ P = I^2 \times R \]
Let’s Put Them Together

What is $P$ if given $E$ & $R$?

You need $I$, so use Ohm’s law, then you can solve for $P$

$$P = \frac{E^2}{R}$$

Page 4-2
G5B03

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

What do we want to find out and what do we know?

\[ P = ? \]
\[ E = 400 \]
\[ R = 800 \]
How many watts of electrical power are used if 400 VDC is supplied to an 800-ohm load?

\[ P = ? \]
\[ E = 400 \]
\[ R = 800 \]

You need I, so use Ohm’s law, then you can solve for P

\[ P = \frac{E^2}{R} \]

P = 200 Watts
G5B04

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

We know that we want to solve for \( P \) (watts), we have 12 volts (\( E \)) and .2 amps (\( I \))
How many watts of electrical power are used by a 12-VDC light bulb that draws 0.2 amperes?

\[ P = ? \]
\[ E = 12 \]
\[ I = .2 \]

\[ P = I \times E \]

\[ P = 2.4 \text{ Watts} \]
How many watts are being dissipated when a current of 7.0 milliampers flow through 1.25 kilohms?

\[ P = ? \]

I = 7.0 milliamps
R = 1.25 kilohms

Let’s first convert to amps and ohms!
G5B05
How many watts are being dissipated when a current of 7.0 milliamperes flow through 1.25 kilohms?

I = 7.0 milliamps (mA)

0.007 amps

1 amp = 1000 mA
G5B05
How many watts are being dissipated when a current of 7.0 milliampers flow through 1.25 kilohms?

R = 1.25 kilohms

1250 ohms

Kilo = 1,000
Meg = 1,000,000
How many watts are being dissipated when a current of 7.0 milliamperes flow through 1.25 kilohms?

P = ?
I = .007 amps
R = 1,250 ohms

Now we have converted our values, next we need E (volts)

E = .007 x 1250
G5B05

How many watts are being dissipated when a current of 7.0 milliampers flow through 1.25 kilohms?

\[ P = ? \]
\[ I = 0.007 \text{ amps} \]
\[ R = 1,250 \text{ ohms} \]

\[ 8.75 \text{ volts} = 0.007 \times 1250 \]
\[ P = 8.75 \times 0.007 \]
How many watts are being dissipated when a current of 7.0 milliampers flow through 1.25 kilohms?

0.06125 watts = 8.75 x .007

Now, convert to milliwatts

(1 watt = 1000 milliwatts)

0.06125 x 1000 = 61.25 milliwatts
A two-times increase or decrease in power results in a change of how many dB?

3 dB = twice the increase (or decrease) in power

3 dB increase = P x 2
3 dB decrease = P x .5
What percentage of power loss would result from a transmission line loss of 1 dB?

1 dB = .79 decrease
% = 100 – (100 x .79)
21% power loss

1 dB increase = P x 1.26
1 dB decrease = P x .79
To use the power circle or Ohm’s law for AC, we must first convert AC into a DC value.

\[ \text{RMS} = \text{Peak} \times 0.707 \]

\[ \text{RMS} = E \text{ (volts)} \text{ or } \text{RMS} = I \text{ (amps)} \]
G5B07

Which measurement of an AC signal is equivalent to a DC voltage of the same value?

The RMS value
Peak-to-Peak vs. Peak

$$\text{Peak-to-peak} = \text{Peak} \times 2$$

$$\text{Peak} = \text{RMS} \times 1.414$$

$$\text{RMS} = \text{Peak} \times .707$$

$$\text{Peak-to-peak} = \text{Peak} \times 2$$

$$\text{Peak} = \frac{\text{Peak-to-peak}}{2}$$
What is the peak-to-peak voltage of a sine wave that has an RMS voltage of 120 volts?

First, solve for the Peak voltage

120 x 1.414 = 168.68 volts (peak)

Then, solve for the Peak-to-Peak voltage

168.68 volts (peak) x 2 = 339.36 peak-to-peak
G5B09
What is the RMS voltage of sine wave with a value of 17 volts peak?
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?

What are we looking for?
Peak Envelope Power output in Watts

What do we know?
Peak-to-Peak = 200 Volts (AC)
Load Resistance = 50
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?

200 Peak-to-Peak Volts (AC) needs to be converted to RMS (DC) so we can use our Power Circle.

\[
\text{RMS} = \text{Peak} \times 0.707 \\
\text{Peak} = \frac{\text{PtoP}}{2} \\
\text{RMS} = \left(\frac{200}{2}\right) \times 0.707
\]
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?

RMS = 70.7 So that now gives us our E Voltage!

\[
E = 70.7 \\
R = 50 \\
I = 70.7 \div 50 \\
I = 1.414
\]
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?

Finally, let’s solve for P

\[ P = 1.414 \times 70.7 \]

\[ P = 99.9698 \text{ Watts} \]
G5B12

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

We are looking for the Voltage (E) at the load

Here is what we know:

\[ R = 50 \text{ ohms} \]
\[ P = 1200 \text{ watts} \]
What would be the voltage across a 50-ohm dummy load dissipating 1200 watts?

We are looking for the Voltage \( E \) at the load.

\[
P = \frac{E^2}{R}
\]

\[
P = \frac{1200}{50} = \frac{E^2}{50}
\]

\[
E = \sqrt{1200 \times 50}
\]
What would be the voltage across a 50-ohm dummy load dissipating 1200 watts?

\[ E \text{ (Voltage)} = 244.95 \]

\[ P = \frac{E^2}{R} \]

\[ 1200 = \frac{E^2}{50} \]

\[ E = \sqrt{1200 \times 50} \]
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?

We want to know the PEP (Watts) from the transmitter

Here’s what we know:
Volts peak-to-peak = 500
Resistance = 50
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?

Need to convert peak-to-peak voltage to RMS

\[ P = \frac{E^2}{R} \]

\[ \text{RMS} = \text{Peak} \times 0.707 \]

\[ \text{Peak} = \frac{\text{P2P}}{2} \]

\[ \text{RMS} = \left(\frac{500}{2}\right) \times 0.707 \]
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?

\[ \text{RMS} = 176.75 \text{ volts (E)} \]

\[ P = \frac{E^2}{R} \]

\[ \text{RMS} = \text{Peak} \times 0.707 \]

\[ \text{Peak} = \frac{\text{P2P}}{2} \]

\[ \text{RMS} = \left( \frac{500}{2} \right) \times 0.707 \]
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?

\[ P = \frac{E^2}{R} \]

\[ P = \frac{176.75^2}{50} \]

\[ P = 624.811 \]
What is the ratio of peak envelope power to average power for an unmodulated carrier?

Ratio = 1:1

Un-Modulated Carrier

100 watts PEP
100 watts Avg Pwr

Pages 4-7
G5B15

What is the output PEP of an unmodulated carrier if an average reading wattmeter connected to the transmitter output indicates 1060 watts??

Un-Modulated Carrier

1060 watts PEP

1060 watts Avg Pwr

Ratio = 1:1