Physics II
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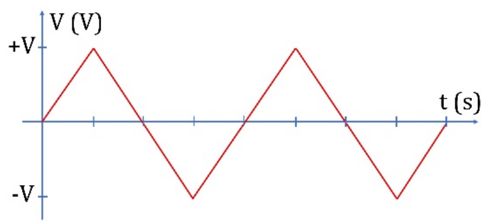
Resistance, Ohm's Law, and I vs. V Curves

The dependence of the current through the component on the voltage across a component will be studied for a resistor, a light bulb, and a diode to gain an understanding of resistance, Ohm's law, unmeasured variables, and functionality of devices.

I. Introduction

A resistor, light bulb from a flashlight (both "passive" devices), and a diode active device subjected to a voltage that varies between –V, +V, –V, +V in a smooth, ramplike, triangular manner as a function of time. The corresponding current through these devices varies with changing voltage. The current and voltage are studied graphically as a function of time for each device. Current vs. voltage is also graphed to convey the concepts of resistance, Ohm's law, unmeasured variables, and how a device function.



Data studio provides a convenient power source that varies the voltage in this triangular manner while automatically graphing the voltage across the device and the current through the device. This power supply is "current limited" to 300 mA. When the current reaches this value, the supply automatically limits the voltage, thus it no longer increases in the usual triangular fashion but becomes constant in value ("truncated") until once again the voltage value is such that the current is less than 300 mA.

For a resistor operated in the current range where the device does not heat up appreciably, there is a linear relationship between the voltage and the current called Ohm's law.

$$V = IR \tag{1}$$

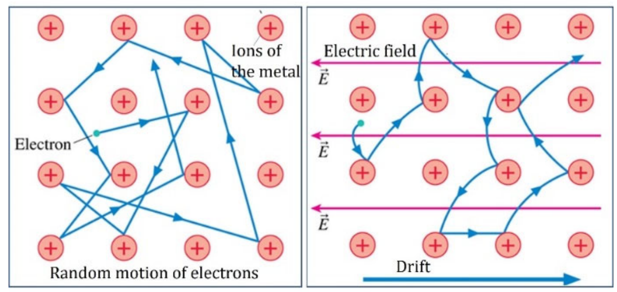
where V is the magnitude of the voltage drop across the resistor in volts (V).
I is the magnitude of the current through the resistor in amperes (A).
R resistance in ohm (Ω).

The temperature is an unmeasured variable that could affect the linearity of this relationship, Eq.1, which assumes a fixed temperature usually around the room temperature of 70^0F. To assure this is basically met, a resistor is given the power rating, e.g. 1 W (watt), 10 W, 100 W etc. and grows dimensionally in size to distribute the heating over a greater volume as a power value grows. All the power to resistor is dissipative and appears as the rate of heating.

$$P = IR = I^2R \qquad (2)$$

Where P is the power to the resistor or the rate of heating the resistor.

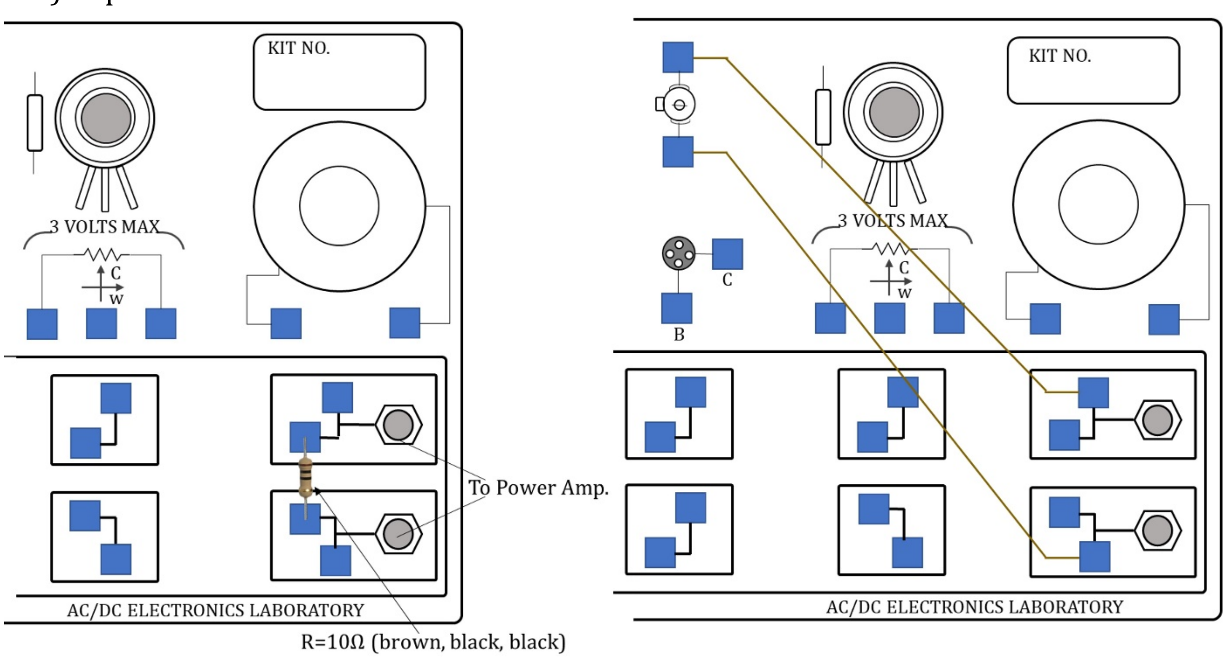
By knowing the wattage and the resistance values, the maximum current and can be calculated. If one exceeds this current, damage to the resistor can occur (the resistor can "burn up"). On the microscopic level, the heating is due to the electrons increasing their random speeds due to the impressed voltage causing movement (drift) of the "free" electrons. This "drift" speed translates into random motion increase through collisions among electrons.



One must note that the ratio of the voltage and current is not always the resistance. For example, capacitors and inductors are non-dissipative components which store energy in electric and magnetic fields, respectively, and therefore can absorb or supply this energy in a circuit by changing their fields. Capacitors and inductors conserve energy in a circuit whereas resistors remove energy from a circuit and give it up to the environment as heat.

Experimental part.
Initial Setup:

a) Connect the two outputs from the interface box to two banana jacks on patchboard.
b) Open the "E&M" folder (electricity and magnetism experiments).
c) Open the "Ohm's law1.ds" file.



Procedures: The interface box will act as a function generator and supply a repeating triangular voltage to each component under study in section i) - iv). Section v) uses a constant voltage.

i) The resistor

a) Place a 10 Ω resistor across the banana plug connections.
b) Click the Start button and observe how the voltage and current track with time. Note also how the current vs. voltage plot out in a repetitive straight-line fashion.
c) Click the Stop button and print out the voltage and current vs. time graphs (both on the same plot) in landscape and label it "10-ohm Resistor".
d) On the current vs. voltage graph, highlight the data and do a linear fit. The reciprocal of the slope (1/slope) is the resistance value.
e) Print out this I vs. V graph in landscape, label it "10 Ω Resistor", and compare 1/slope to the value R=10 Ω.
f) Choose the maximum value of the current from this graph and calculate the maximum power to the resistor. Does it exceed the 0.5 W rating of the resistor?

ii) Resistors in series and in parallel

a) Place two 100 Ω resistors in series on the patchboard and wire to the banana jacks.
b) Click Start and then after a short while click Stop.
c) Highlight the data set on the I vs. V graph and perform a linear fit to get the resistance (1/slope).
d) Print out this graph in landscape and label "Two 100 Ω Resistors in Series".
e) Calculate the equivalent series resistance and compare to 1/slope value.
f) Now place the two 100 Ω resistors in parallel and wire to the banana plug leads.
g) Click Start then after a short while click Stop.
h) Highlight the data set on the I vs. V graph and perform a linear fit to get the resistance (1/ slope).
i) Print out this graph in landscape and label "Two 100 Ω Resistors in Parallel"
j) Calculate the equivalent parallel resistance and compared to this slope value.

iii) The light bulb

a) Replace the resistor with a light bulb on the patchboard by running two wires between the bulb and the connections at the banana jacks.
b) Click the Start button and observe how the voltage and current track with time. Observe also the I vs. V graph.
c) You and your partner should coordinate so as to watch both these graphs and the light bulb itself. What happens to the bulb when the behavior begins to deviate markedly from linearity? What is happening to the resistance of the filament in the bulb?
d) Click the Stop button and print out the voltage and current vs. time graphs (both on the same plot) in landscape.

e) On the I vs. V graph, highlight the approximately "straight line" region near the origin, and perform a fit getting an approximate value for the filaments resistance in this region by taking 1/slope.
f) Print out all graphs in landscape and label them "Light bulb".
g) Take the voltage/current ratio where current is maximum to get the maximum resistance value.
h) Calculate a maximum power for the light bulb. How does this compare to the 0.75 W rating of the light bulb?

iv) The diode

a) On the patchboard replace the light bulb with the diode.
b) Click the Start button and observe how the voltage and current track with time. Observe also the voltage vs. current graph. What effect does the current limitation of 300 mA from the interface box have on triangular voltage function.
c) Click the Stop button and print out the voltage and current vs. time graph (both on the same plot) in landscape and label "Diode".
d) Calculate the ratio voltage/current from the "flat", current limited, region to get a resistance value for the diode "forward current" mode.
e) Calculate the power, V_i, in this "flat" region. How does this compare with the diode's 3 W power dissipation rating?
f) Print out I vs. V graph in landscape and label it "Diode".

v) Varying the resistance

a) Exit the present experiment by clicking on File and then Quit, choosing No when prompted to save activity.
b) Connect the two outputs from the interface box to the two banana jacks on patchboard.
c) Open the "E & M" folder.
d) Open the "Ohm's Law2.ds" file.
e) A constant 5 V is supplied across the two connections to the jacks and the current supplied to the jacks is displayed. Resistors of known value (10, 33, 100, 330, 560, 1000 Ω) are connected successively across these terminals and V(5v), R, and I are recorded in a table.
f) Graph I vs. R in pencil. Circle the data points. Use drawing curve to run a smooth fit through the data set.

Questions:

1) Consider two circuits, both being connected to a constant 3-volt source. Circuit A has two light bulbs connected in series and circuit B has the same two light bulbs connected in parallel. Describe the relative brightness of the bulbs in one circuit in comparison to the other. Explain your answer using circuit analysis.

2) For ease of installation, a cabin that is used occasionally is supplied with baseboard electric heating. These are 30-amp circuits powered with 220 volts. To supply the power of 20 kW,
   a) how many circuits are needed, and
   b) what is the resistance of each baseboard strip in a single circuit?