

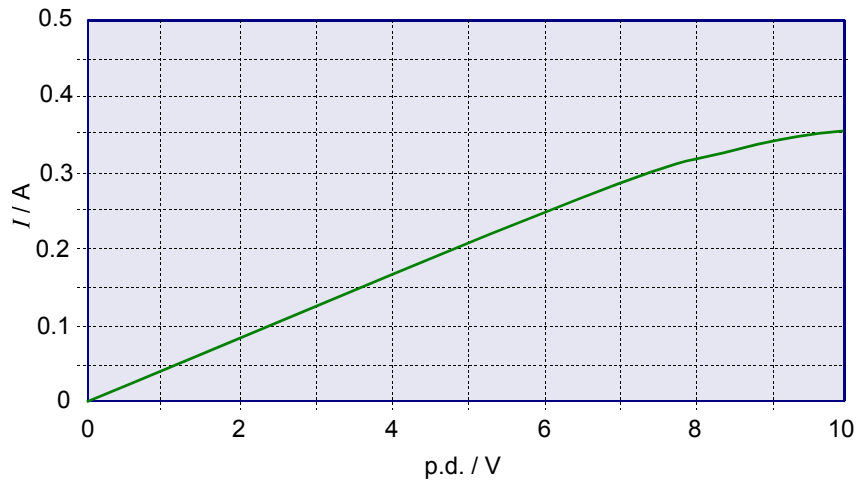
TAP 109- 4: Using non-ohmic behaviour

Instructions:

Using a diode for meter protection

The graphs show the characteristics of (i) a resistor made from a coiled wire and (ii) a commonly-used diode (forward bias).

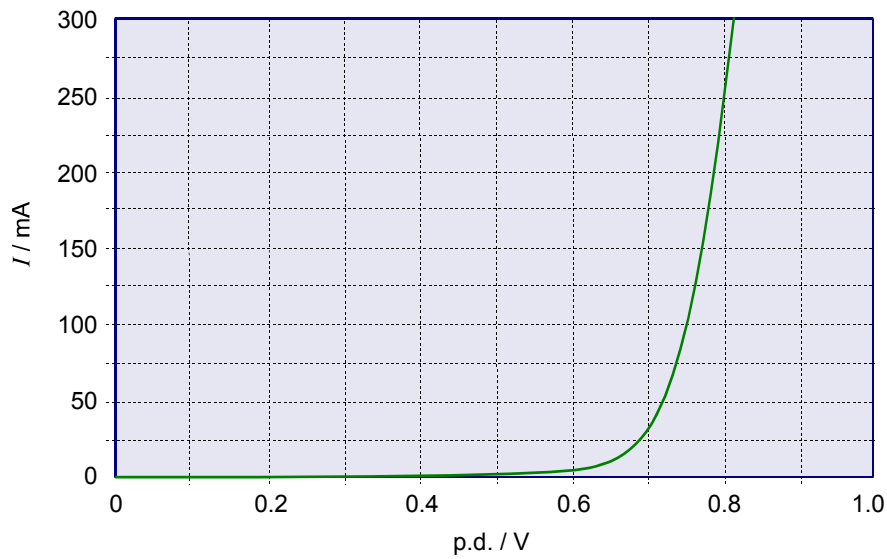
1. Current - p.d. characteristic for wire coil



Use the characteristic for a wire coil.

1. Describe and account for the shape of the graph.
2. What is the resistance of the coil in the ohmic region?
3. Estimate the maximum power rating of this resistance coil.

2. Current - p.d. characteristic for diode

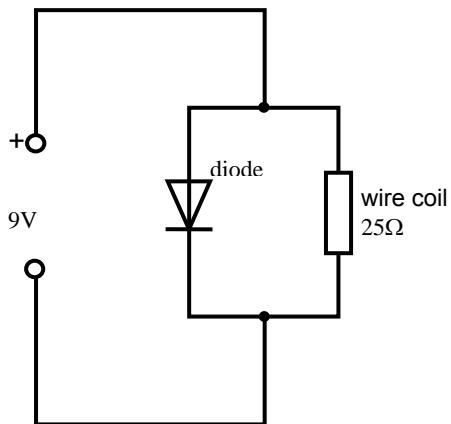


Use the characteristic for a diode

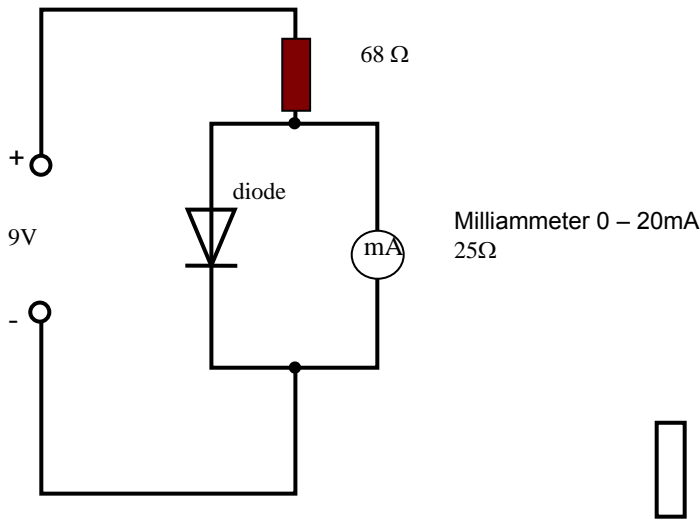
4. Describe and account for the shape of this graph.
5. Complete the table, using data from the graph to estimate the resistance of the diode in forward bias, at different values of the potential difference.

| Applied pd / V | 0.50 | 0.55 | 0.60 | 0.65 | 0.70 | 0.75 | 0.80 |
|-----------------------|------|------|------|------|------|------|------|
| Resistance / Ω | | | | | | | |

The diode and the coil are connected in parallel across a variable d.c. source.



6. Copy the characteristic of the coil in the range 0 to 0.8 V onto this diode characteristic. Using a different colour draw a new curve to show how the total current supplied to the coil increases as the applied pd increases from 0 to 0.8 V.



Some meters can be damaged if the current through them far exceeds the full scale current. A school physics technician is worried that the students may damage the milliammeters which they have been given to use in a circuit with a $68\ \Omega$ resistor. These meters have a full scale deflection of 20 mA; they have a resistance of $25\ \Omega$, and similar characteristics to those in the graph above. The technician solders a diode in parallel with each meter.

7. Explain how this modification will protect the milliammeter.

Practical advice

This question can follow activities on electrical characteristics. It gives practice at graph reading and graph plotting.

If students have only used digital meters it would be good to show them a moving coil meter, to see how it could be damaged by excessive current.

Hints

1. When the applied pd exceeds 8 V, the coil starts to get hot.
6. You will need to calculate or estimate the equivalent resistance of the parallel combination for some applied pds.

Worked solutions

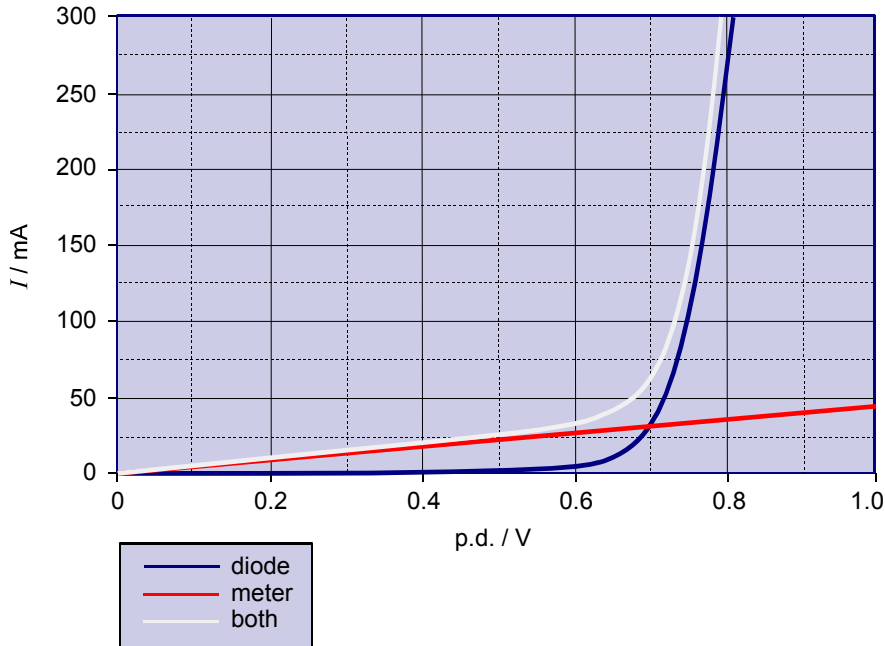
1. Current proportional to pd up to about 7 V – metals follow Ohm's law. Above 8 V the resistance is increasing because the current is heating up the coil.
2. 2.5 Ω
3. 2.5 W approx.
4. The diode does not conduct until the applied pd exceeds 0.6 V (the threshold). It is not an ohmic device. The current increases faster than the applied pd (because the number of charge carriers increases).

5.

| | | | | | | | |
|----------------|-------|------|------|------|------|------|------|
| Applied pd / V | 0.50 | 0.55 | 0.60 | 0.65 | 0.70 | 0.75 | 0.80 |
| Resistance / W | >1000 | 550 | 200 | 65 | 23 | 7.5 | 2.8 |

6.

3. Currents in the meter and the diode



7. When the unprotected milliammeter reads 20 mA, the pd across it ($V = I R$) must be 0.5 V. When the milliammeter is protected, the resistance of the diode is too large in comparison with the coil's resistance to affect the circuit and carry any significant current. If the circuit current rises to about 25 mA, the pd across the meter exceeds 0.6 V. The diode in parallel will become conducting at that applied pd and divert some of the current away from the coil. The student's graph shows that if the current through the combination rises much higher, most of the current flows through the diode; the meter will not be damaged by high current. However, the current cannot rise indefinitely since the 68 W resistor limits the circuit current to 175 mA.

External references

This activity is taken from Advancing Physics, Chapter 2, 270D