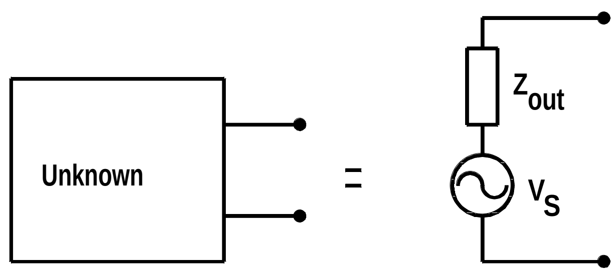
Any linear electronic system, having two output terminals, can be fully modelled by a voltage source, V_S, in series with an impedance, called the output impedance, Z_{out} .

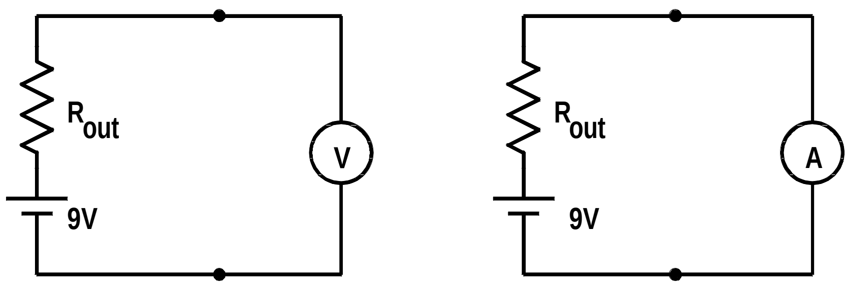
A voltage source gives a constant output voltage which does not depend on the current drawn from the voltage source.



Two good examples which approximate to the ideal voltage source are:—

- The mains AC power supply. The RMS voltage at the wall socket remains at a constant 240V and is independent of the current drawn.

- A lead acid car battery. The voltage at the battery terminals in a car remains constant at 12V whether we operate the clock which draws 10 mA, the radio which draws 3A, the headlights which draw 14A or the starter motor which draws 120A.



(a) Open circuit output voltage (b) Short circuit current

We can then model these two measurements of the open circuit output voltage and the short circuit current with these circuits

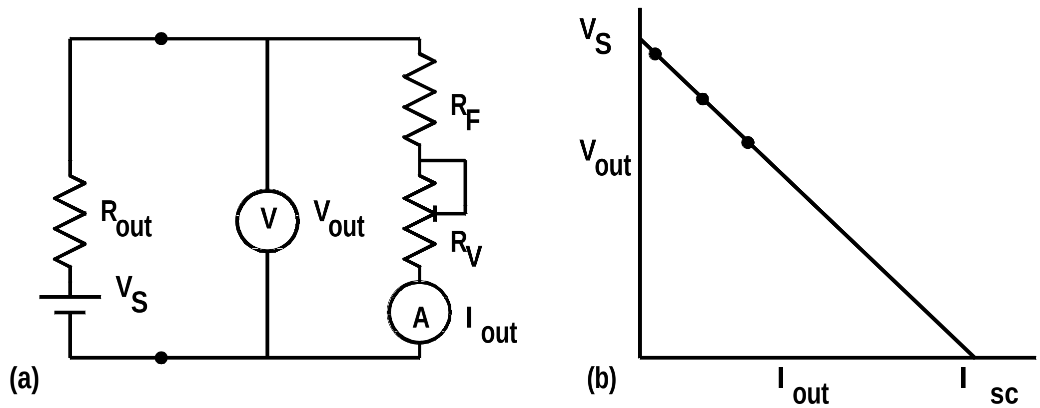
$$R_{\text{out}} = \frac{V_{\text{out open circuit}}}{I_{\text{out short circuit}}}$$

For a PP9 battery
Open circuit output voltage = 9V
Short circuit current = 3A
The current is limited by the internal resistance of the electrolyte and electrodes of the battery.

Model the PP9 battery by a 9V voltage source and a resistance internal to the battery called the Output Resistance, R_{out}
R_{out} is physically equivalent to the resistance of the internal electrolytes and electrodes.

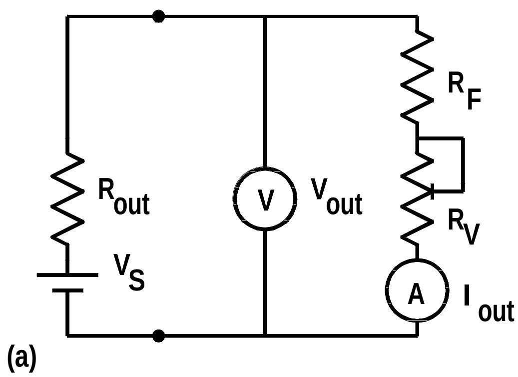
For the PP9 battery we therefore have
$R_{\text{out}} = \frac{9V}{3A} = 3\Omega$.

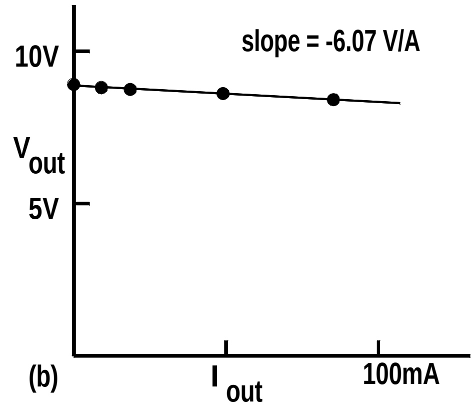
We do not normally short the output of a circuit with an ammeter in order to measure the short circuit current.
The concept of short circuit current is, however, very useful for defining the output resistance.



Take a less drastic approach

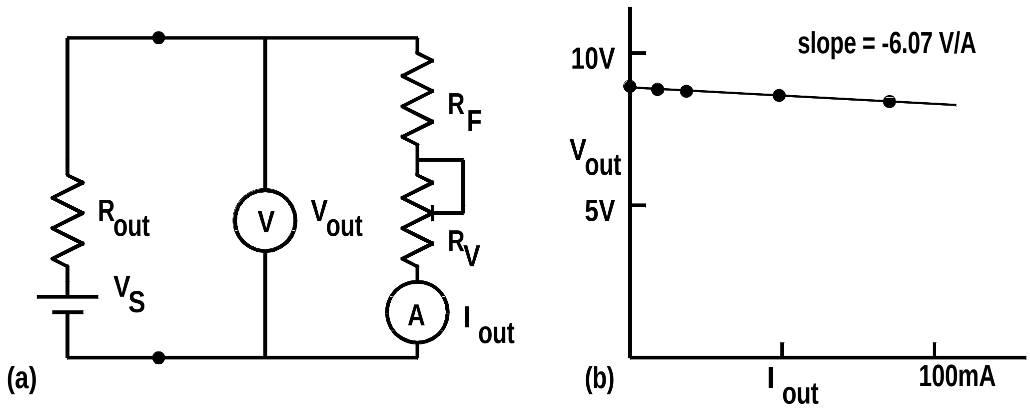
To measure the output resistance of an electronic system:–
Measure the voltage at the output terminals as a function of the current drawn from the terminals.
The short circuit current can then be obtained by extrapolation.





The table below shows the terminal voltages and currents which were measured when the specified resistance was connected across a PP3 battery.
Calculate the Thévenin equivalent circuit for the PP3 battery.

R Ohms	V_{out}	I_{out} mA
500kΩ	8.91	0.00
1kΩ	8.82	9.18
470Ω	8.75	18.70
180Ω	8.56	49.10
100Ω	8.39	85.70

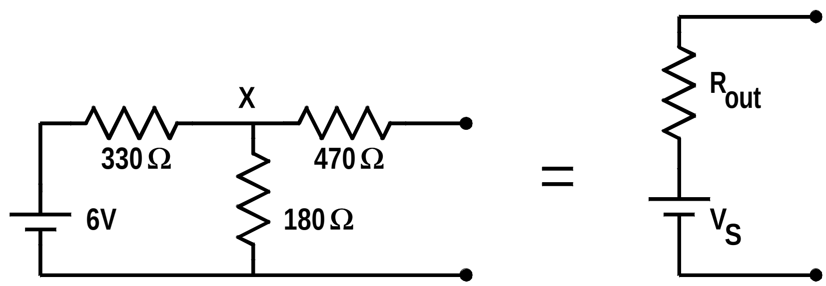


The output voltage is plotted against current The slope of the curve is $-6.07VA^{-1}$ which, when extrapolated, gives an intercept at

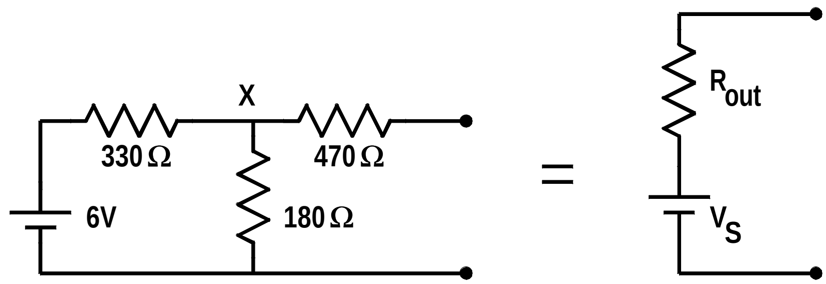
$$I_{\text{short circuit}} = \frac{8.91}{6.07} = 1.47A$$

hence $$R_{\text{out}} = \frac{V_{\text{open circuit}}}{I_{\text{short circuit}}} = \frac{8.91}{1.47} = 6.07\Omega$$

which is the slope of the V–I characteristic! So this PP3 can be modelled by an 8.91V voltage source in series with 6.07Ω.



Calculate the Thévenin equivalent of this circuit

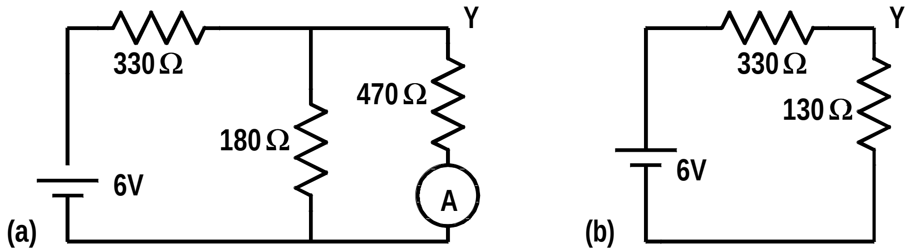


A voltmeter draws very little current

$$\begin{aligned} V_S &= V_{\text{open circuit}} \\ &= \frac{180}{330+180} \times 6V \\ &= 2.12V \end{aligned}$$

Connect an ammeter across the output

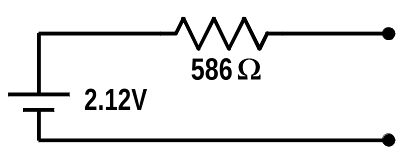
R ammeter $\approx 0\Omega$

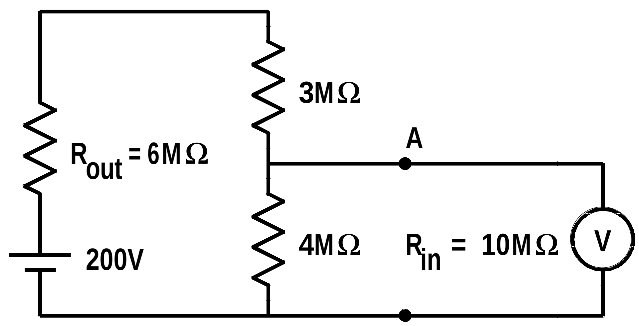


$$V_Y = \frac{130}{330+130} \times 6V = 1.7V$$

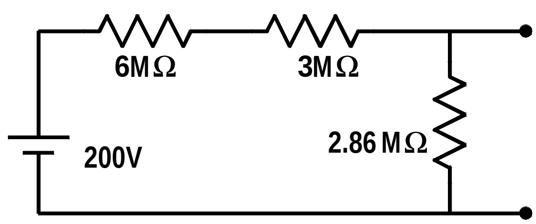
Therefore $\quad I_{\text{SC}} = \frac{1.7}{470} = 3.61mA$

Giving $R_{\text{out}} = \frac{V_{\text{open circuit}}}{I_{\text{short circuit}}} = \frac{2.12V}{3.61mA} = 586\Omega$





Calculate the voltage which would be measured by a $10M\Omega$ input impedance voltmeter connected, as shown, between ground and point A



$$V = \frac{2.86}{2.86 + 6 + 3} \times 200V = 48.2V$$