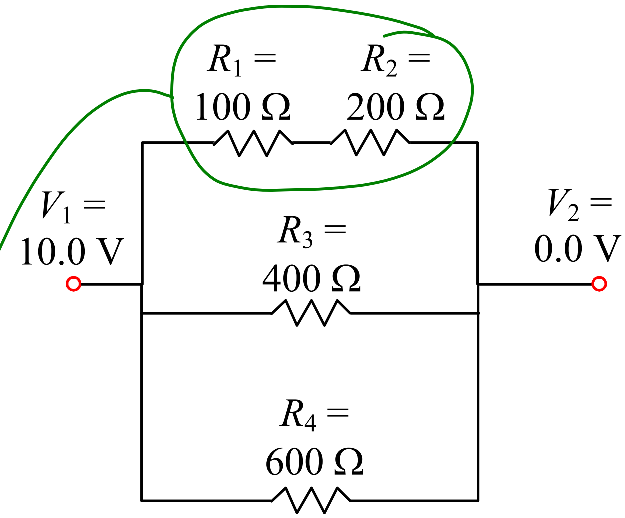
Today, we will: Reminder: Always text Cimbala before class (37607) or log into PE

- Do some example problems – basic electronics and dimensional analysis
- Review the pdf module: **Errors and Calibration** and do some example problems
- Review the pdf module: **Basic Statistics** and do some example problems

Example: Basic electronics

Given: The circuit shown.



To do:

(***a***) Calculate the equivalent resistance of this circuit.

(***b***) Calculate the total current through this circuit.

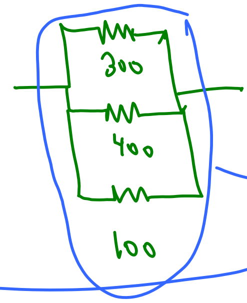
(***c***) Calculate the power used by this circuit.

Solution:

(a) • First do the top 2 in series

$R_{top} = 100 + 200 = 300\ \Omega$

• Now have



= 3 resistors in parallel

$$R_{eq} = \frac{1}{\frac{1}{300} + \frac{1}{400} + \frac{1}{100}} = 133.33..\ \Omega$$

So, $\boxed{R_{equivalent} = 133.33...\ \Omega}$

The equivalent circuit is

(b) OHM's LAW: $\Delta V = IR \rightarrow I = \frac{\Delta V}{R_{eq}}$ here, so

[Note: 3 sig. digits in answer since 10.0 = 3 digits]

$$I = \frac{\Delta V}{R_{eq}} = \frac{(10.0 - 0.0)\ \cancel{V}}{133.333..\ \cancel{\Omega}}\left(\frac{A \cdot \cancel{\Omega}}{\cancel{V}}\right) = \boxed{0.0750\ A \text{ or } I = 75.0\ mA}$$

(Ohm's law) [Unity conversion factors]

(c) $\dot{W} = (\Delta V) I = (IR) I = I^2 R$

OR, $\dot{W} = \Delta V (I) = \Delta V \left(\frac{\Delta V}{R}\right) = \frac{\Delta V^2}{R}$

$$\dot{W} = \frac{(10.0\ V)^2}{133.33..\ \Omega}\left(\frac{W}{V \cdot A}\right)\left(\frac{A \cdot \Omega}{V}\right)$$

$$\boxed{\dot{W} = 0.0750\ W}$$

Example: Basic electronics

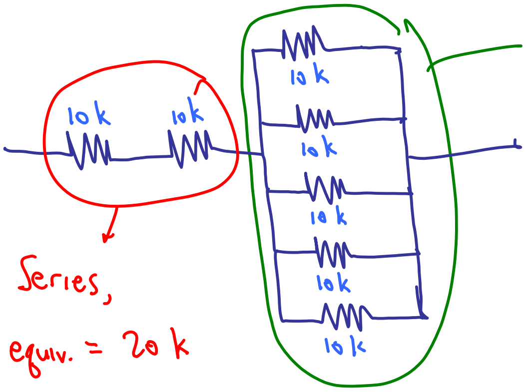
Given: A bunch of 10 kΩ resistors is available in the lab. We have need for a resistance of 22 kΩ for a circuit we are building on a breadboard.

To do: Figure out how to create the required resistance from the available resistors.

Solution:

We use trial & error, playing with series & parallel combinations.

Here is one option (there may be more):



parallel, equiv. = $\dfrac{1}{\frac{1}{10}+\frac{1}{10}+\frac{1}{10}+\frac{1}{10}+\frac{1}{10}}$

Example: Basic electronics

Given: A voltage signal has a DC offset. We want to remove the DC offset so that the frequency content of the AC (fluctuating) component can be analyzed.

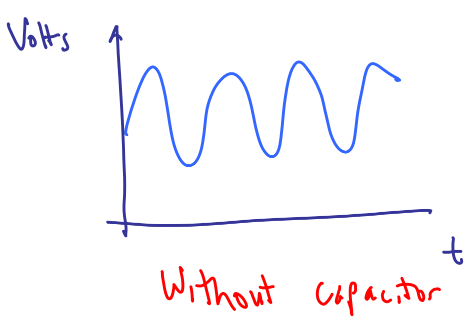
To do: Figure out how to remove the DC offset with a *single* electronic component (i.e., one resistor *only*, or one capacitor *only*, or one inductor *only*, etc.).

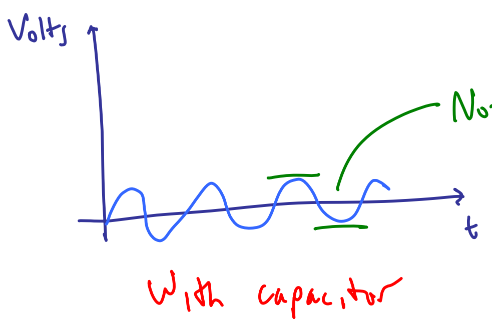
Solution:

See the Electronics Review notes on the course website.

A capacitor impedes DC signals. Basically, a DC voltage will build up a charge on the capacitor, but current does not flow through.

AC (fluctuating) voltages pass through, but are impeded slightly.





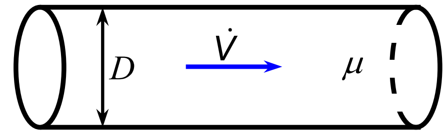
Notice – the amplitude also decreases, but we removed the DC component!

Answer: $\boxed{\text{Capacitor}}$

This is a crude high-pass filter!

Example: Dimensional analysis – pipe flow

Given: Consider fully developed laminar flow through a very long round tube. Volume flow rate $\dot{V}$ is a function of the tube's inner diameter D, fluid viscosity μ, and axial pressure gradient dP/dx. (we treat dP/dx as one variable here)



Pressure gradient = dP/dx

To do: If D is doubled, holding μ and dP/dx fixed, by what factor does $\dot{V}$ change?

Solution: Use dimensional analysis to generate a nondimensional functional relationship.

Step 1: $\dot{V} = \text{fnc}\left(D, \ \mu, \ dP/dx\right)$ $\quad \left\{\frac{F/A}{L}\right\} = \left\{\frac{m\cancel{L}}{t^2}\frac{1}{L^2}\frac{1}{\cancel{L}}\right\}$

Step 2: $\left\{\frac{L^3}{t}\right\} \quad \{L\} \quad \left\{\frac{m}{Lt}\right\} \quad \left\{\frac{m}{L^2t^2}\right\}$ $\quad \boxed{n=4}$

Step 3: Pick $\boxed{j=3}$ since m, L, & t appear in dimensions. $\boxed{\text{Expect } k = n - j = 4 - 3 = 1 \ \Pi\text{'s}}$

Step 4: Pick 3 repeating variables since $j=3$ → only choice is D, μ, dP/dx.

Step 5: $\Pi_1 = \dot{V} D^a \mu^b \left(\frac{dP}{dx}\right)^c$ → Force this Π to be dimensionless by solving for the exponents as follows:

Dimensionless

$$\{m^0 L^0 t^0\} = \left\{\frac{L^3}{t}\right\}\{L\}^a \left\{\frac{m}{Lt}\right\}^b \left\{\frac{m}{L^2t^2}\right\}^c$$

Algebra:

$$\left.\begin{aligned} m&: \ 0 = b + c \\ L&: \ 0 = 3 + a - b - 2c \\ t&: \ 0 = -1 - b - 2c \end{aligned}\right\}$$

Solve simultaneously any way you can.

Result: $\boxed{a = -4, \ b = 1, \ c = -1}$

So, $\Pi_1 = \dot{V} D^{-4} \mu^1 \left(\frac{dP}{dx}\right)^{-1}$ → $\boxed{\Pi_1 = \frac{\dot{V}\mu}{D^4 (dP/dx)}}$

Note: The constant cannot be found by dimensional analysis

Step 6: $\Pi_1 = \text{fnc(nothing)}$. $\therefore \Pi_1 = \text{constant}$ → $\boxed{\dot{V} = \text{constant}\ \frac{D^4 (dP/dx)}{\mu}}$

Since there is only one Pi in this problem

ANSWER →

Answer: If D is doubled, holding μ and dP/dx fixed, $\dot{V}$ goes up by a factor of $\boxed{16}$.

If D doubled, $\dot{V}$ ↑ by factor of $2^4 = 16$

We got this without knowing any fluid mechanics!

Example: Errors and calibration

Given:

- The actual (true) voltage is 4.6020 V.
- 256 voltage readings are taken, and the average voltage reading is 4.6015 V.

To do: (***a***) Calculate the systematic (bias) error and the mean bias error for this set of measurements. (***b***) Calculate the random (precision) error of a reading that is 4.6010 V.

Solution:

(***a***) Bias error = Systematic error = Avg. − true value = 4.6015 − 4.6020 V = $\boxed{-0.0005\text{ V}}$

MBE = Bias error/true value = −0.0005/4.6020 = −0.0001086 ≈ $\boxed{-0.011\%}$

(***b***) Random error of this one reading = reading − average of all readings = 4.6010 − 4.6015 = $\boxed{-0.0005\text{ V}}$

Example: Errors and calibration

Given:

- The actual (true) temperature is 22.100°C.
- Six thermometer readings are taken: 22.15, 22.22, 22.09, 22.21, 22.18, and 22.24°C.

To do: Calculate the mean, systematic error, and mean bias error for this set of data, and calculate the accuracy error (inaccuracy) and the precision error for each measurement.

T_i (°C)	Inaccuracy = $T_i - T_{true}$ (°C)	Precision error = $T_i - \overline{T}$ (°C)
22.15	= 22.15 − 22.100 = 0.05	= 22.15 − 22.182 = −0.0317 ≈ −0.03
22.22	0.12	0.04
22.09	−0.01	THIS DECIMAL PLACE −0.09
22.21	0.11	IS THE PLACE FOR THE 0.03
22.18	0.08	LEAST SIGNIFICANT −0.00
22.24	0.14	DIGIT IN THE ANSWERS −0.06

Solution:

- Average of all readings = Sample mean = 22.181666 ≈ 22.182 °C

- Systematic error = Avg − true Value = 22.181667 − 22.100 = 0.08167

Keeping significant digits in mind,

$\boxed{\text{Systematic error} = 0.082\ ^\circ\text{C}}$

- Precision error → See table. Precision error = reading − avg. of all readings

- MBE = $\frac{\text{Systematic error}}{\text{true value}} = \frac{0.081667}{22.110} = 0.003695$

$\boxed{\text{MBE} = 0.37\%}$ (to 2 sig. digits = best we can do)

[See also Excel spreadsheet on the website for this same problem]

☆ ↗ STUDY THE EXCEL AND/OR MATLAB FILES