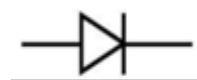
Rectification

Rectification: the process of converting an AC supply into DC

Reason: many electronic devices run on DC (computer, TV, phone charger)

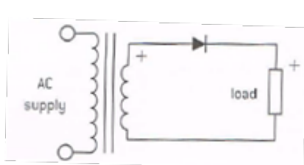
Rectifier: a device that converts AC into DC
Diode: a semiconductor device that only allows current to flow in one direction



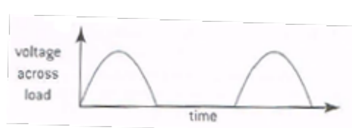
An ideal diode allows current to flow in the forward direction (negligible resistance with forward bias) but does not allow current to flow in the reverse direction (infinite resistance with reverse bias).

Types of rectification circuits (rectifiers)

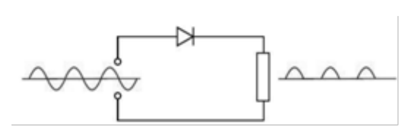
a) Half-wave rectification: uses one diode - allows only the positive half of the AC wave to pass
A single diode converts AC into pulsating DC.



Circuit

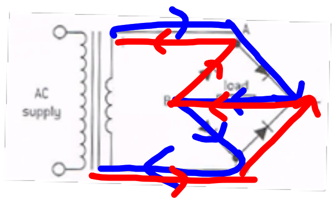


Voltage Output

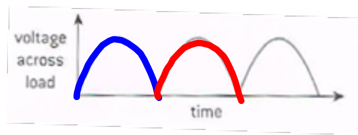


Another example

b) Full-wave rectification: uses a diode bridge (with four diodes) – allows both halves of the AC wave to pass but the negative half is inverted



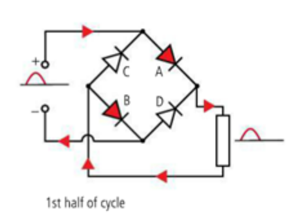
Circuit

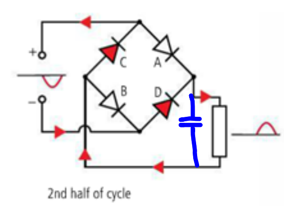


Voltage Output

Diodes point at positive end of output

How does the full wave rectification circuit work?





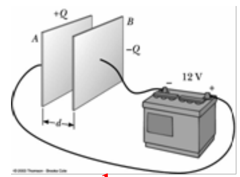
Note: alternate placement of resistor

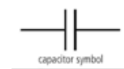
a) Diode bridge is formed from two sets of parallel diodes. Diodes on parallel sides of the bridge point in the same directions.
b) During each half-cycle of AC, one set of parallel-side diodes conducts.
c) Output current always flows through the load resistor in the same direction (DC).
d) The output voltage and current are not constant or smooth. A capacitor may be used to “smooth” the output.

January 10, 2020

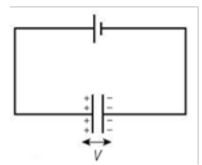
Capacitance

Two identical metal plates, each with area A, are set a distance d apart. They are each charged by connecting them to a source of potential difference V like a battery, as shown in the diagram.





Capacitor: a device that stores charge and energy



Schematic

Capacitance: the ability to store charge and energy

Definition - the ratio of charge to potential difference

Formula: $C = q/V$

Units: C/V or farad (F)

1. What physical properties does the capacitance of a capacitor depend on?

Quantity	Variable	Unit
Area of a plate	A	m^2
Distance between plates	d	m
Material between plates (permittivity)	ε	$C^2/N\,m^2$

$K = \frac{1}{4\pi\varepsilon_0}$

Permittivity of free space (vacuum): $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N\,m^2$ (use for air)

General Formula:

$$C = \varepsilon \frac{A}{d}$$

Formula for vacuum(air):

$$C = \varepsilon_o \frac{A}{d}$$

2. The square plates in the capacitor shown above are 32 mm apart and are 5.0 cm on each side.
a) What is the capacitance?

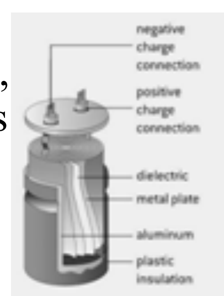
$$C = \varepsilon_0 A/d = 8.85\times10^{-12}\frac{C^2}{Nm^2}\cdot\frac{(.05m)^2}{(.032m)} = .69pF$$

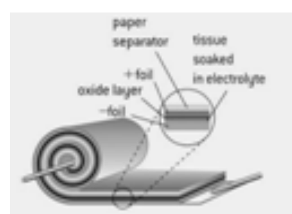
b) What is the amount of charge stored in the capacitor?

$$C = Q/V \qquad Q = CV = 8.3pC$$
$$V = 12v$$

Dielectric material: an electrical insulator that is polarized when placed in an electric field

Examples: paper, mica, Teflon, plastics, ceramics, metal oxides



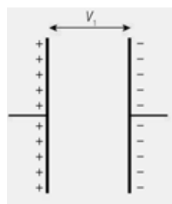


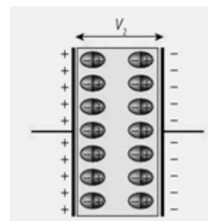
3. What is the effect of different dielectric materials on capacitance when the dielectric is placed between the parallel plates?

The insertion of the dielectric reduces the potential difference between the plates ($V_2 < V_1$) because some of the stored energy of the capacitor has been used to align the dielectric molecules. Because the overall charge stored is unchanged, the net effect is that the capacitance has increased.

Therefore, dielectrics increase the capacitance of a capacitor.

$$C = q/V$$





4. How much energy is stored in a capacitor, that is, how much work is required to charge capacitor to a final charge of q?

The plates are initially uncharged and their potential difference is zero. As charge builds up on the plates, the potential difference between them increases and more work is required to move additional charge onto the plates.

Derivation:

$W = \Delta E_c$

$q\ \Delta V = \Delta E_c$

$q\ V = E_c$ if initial values are zero

$q\ \bar{V} = E_c$ since V is not constant

$q\ (1/2\ V) = E_c$

$E_C = \frac{1}{2}(CV)V$

$E_C = \frac{1}{2}CV^2$

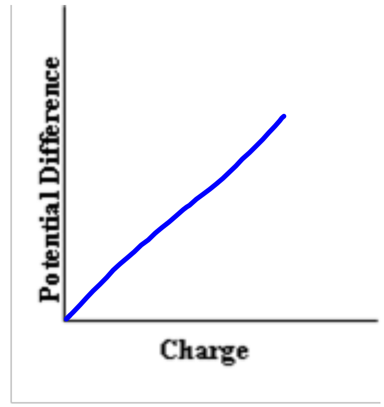
Formula:

$$E_c = \frac{1}{2}CV^2 = \frac{1}{2}qV$$

5. What do the slope and area of the graph represent?

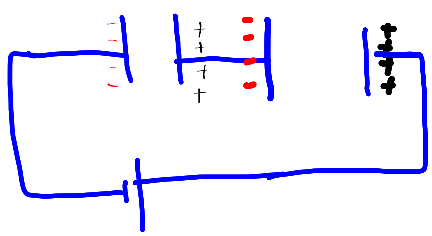
slope = V/q = C^{-1}

area = energy



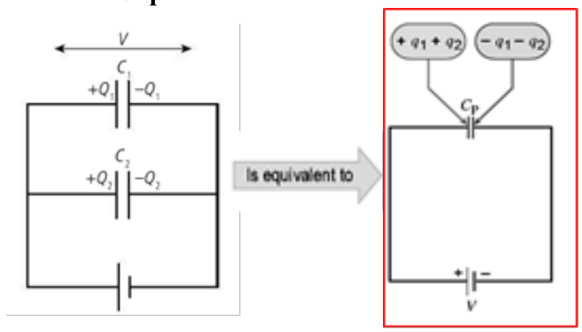
Slope = 1/C

Work= energy =area under graph



Capacitors in Series and Parallel

Parallel Capacitors



Control variable: voltage

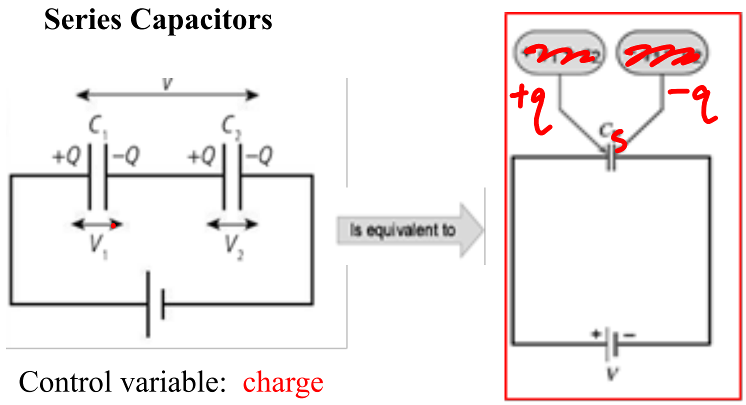
Conservation of . . . charge

Derivations:

$$q_T = q_1 + q_2$$
$$C_T V_T = C_1 V_1 + C_2 V_2$$
$$\text{but } V_T = V_1 = V_2$$
$$C_P = C_1 + C_2$$

$$\frac{C_1}{C_2} = \frac{\frac{q_1}{V_1}}{\frac{q_2}{V_2}} = \frac{q_1}{q_2}$$

Series Capacitors



Control variable: charge

Conservation of . . . energy

Derivations:

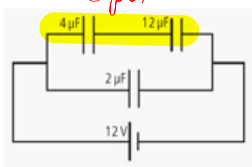
$$V_T = V_1 + V_2$$
$$\frac{q_T}{C_T} = \frac{q_1}{C_1} + \frac{q_2}{C_2}$$
$$\text{but } q_T = q_1 = q_2$$
$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{C_1}{C_2} = \frac{\frac{q_1}{V_1}}{\frac{q_2}{V_2}} = \frac{\frac{1}{V_1}}{\frac{1}{V_2}} = \frac{V_2}{V_1}$$

1. Calculate the equivalent capacitance of each network below.

a)

$3\mu F$

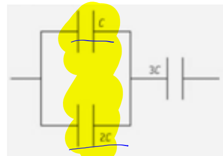


$C_{eq} = 5\mu F$

b)

$\frac{1}{3c} + \frac{1}{3c} = \frac{1}{C_{tot}}$

3c

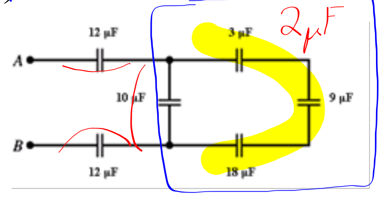


1.5 c

c)

12 μF

2 μF

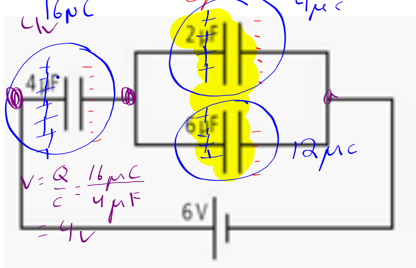


4 μF

2. In each circuit, calculate the potential difference across the 4μF capacitor.

a)

8 μF



4v 16μC

4μC

12μC

$V = \frac{Q}{C} = \frac{16\mu C}{4\mu F} = 4v$

$C = \frac{Q}{V}$

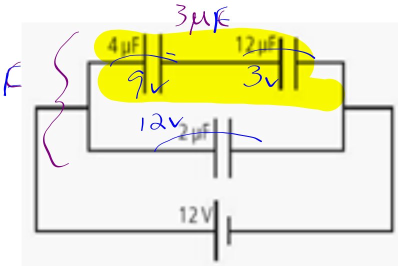
$C_{TOT} = \frac{8}{3}\mu F$

$Q_{TOT} = \frac{8}{3}\mu F \cdot 6v = 16\mu C$

b)

3μF

5μF



9v 3v 12v

Highest capacitance = lowest voltage = inverse ratio