CAIE Physics A-level

Topic 21: Alternating Currents

Notes

21 - Alternating Currents

21.1 - Characteristics of Alternating Currents

We can describe the nature of **alternating currents** in the same way as we can describe **waves-** in terms of their **frequency**, **time period**, and **peak value** or **amplitude**. An alternating current differs from a direct current in that it reverses direction periodically. Oscillating like a wave, it reaches a peak value in each direction whereas a direct current stays at a constant positive value.

Alternating currents typically vary **sinusoidally**, and therefore their current or voltage can be represented by an equation of the form

$$x = x_0 sin(\omega t)$$

where x is the voltage or amplitude, x_0 is its peak value magnitude, t is the time and ω is the angular frequency of the wave.

The angular frequency is related to the normal frequency f by $\omega = 2\pi f$.

The **mean power** $< P >$ delivered by the alternating current wave is given as $< P > = < I_0{}^2 R\, sin^2(\omega t) >$. Since $I_0{}^2$ and R are constant, and the average of $sin^2(\omega t)$ is ½, the mean power is equal to **half the maximum power** $< P > = \frac{1}{2}P = \frac{1}{2}I_0{}^2 R = \frac{1}{2}V_0{}^2/R$. In the same way we can average the squares of the voltage or current by comparing with their maximum values: $< V^2 > = \frac{1}{2}V_0{}^2$, $< I^2 > = \frac{1}{2}I_0{}^2$.

The **root mean square (rms)** voltage or current is defined as the square root of the mean of the squares of the voltage/current stated above. For a sinusoidal alternating current, this yields rms values of

$$V_{rms} = \frac{V_0}{\sqrt{2}}, \quad I_{rms} = \frac{I_0}{\sqrt{2}}$$

21.2 - Rectification and Smoothing

Rectification is the act of nullifying or reversing the negative parts of the alternating current wave in order to turn it into a direct current. **Half-wave rectification** is the process of removing the negative parts of the wave, while **full-wave rectification** reverses them to make them positive.

Half-wave rectification can be achieved using a **diode** which acts like a filter on the circuit, only allowing through the half of the alternating current which is oscillating in the positive direction.

Such a circuit and the graphical result thereof are shown below:

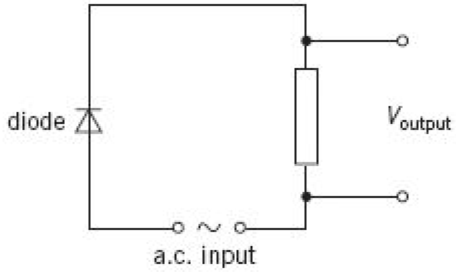

Figure 24.4 Single-diode circuit for half-wave rectification

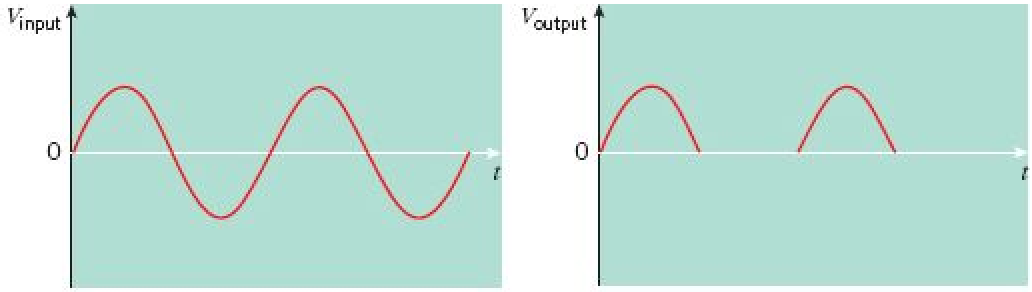

Figure 24.5 Half-wave rectification

To achieve the more complex full-wave rectification, a **bridge rectifier** of four diodes can be constructed. In the circuit shown below, P and Q are the input terminals. In the first half wave cycle P is positive and so the current is conducted through the 1st and 2nd diodes. In the next half wave cycle Q will be positive, and so conduction will be through the 3rd and 4th diodes. The resistor will therefore always have its top terminal positive and the bottom negative, ensuring a unidirectional current.

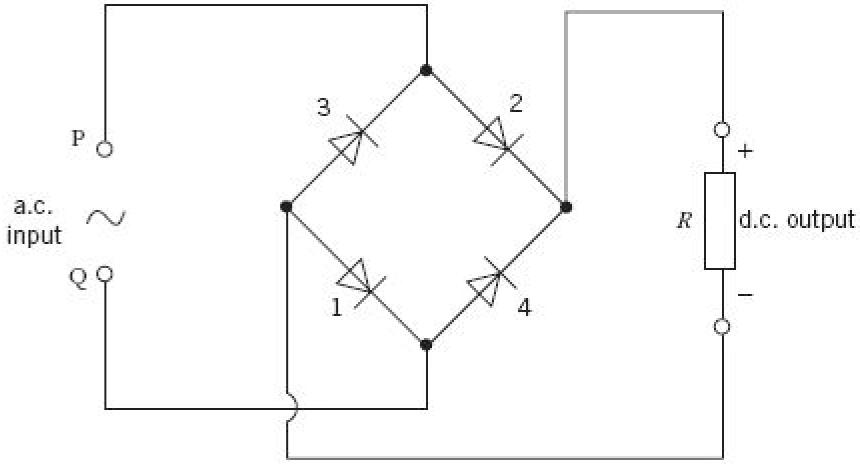

Figure 24.7 Four-diode (bridge) circuit for full-wave rectification

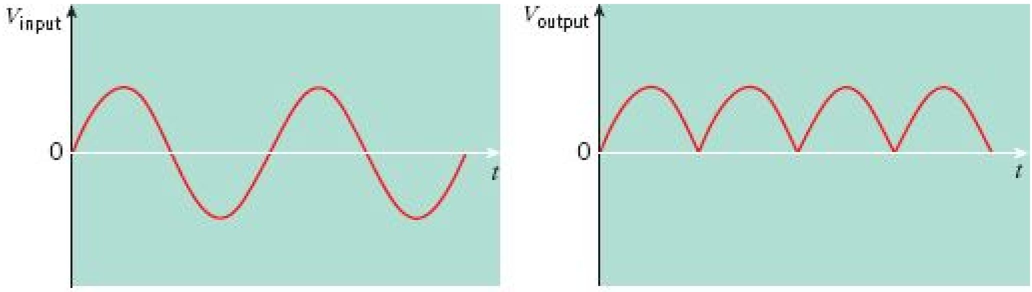

Figure 24.6 Full-wave rectification

The signal resulting from this is still not ideal for a direct current device, since it oscillates rather than remaining at one steady value. **Smoothing**, where these oscillations in voltage are flattened, can be done with a single **capacitor** like in the circuit below:

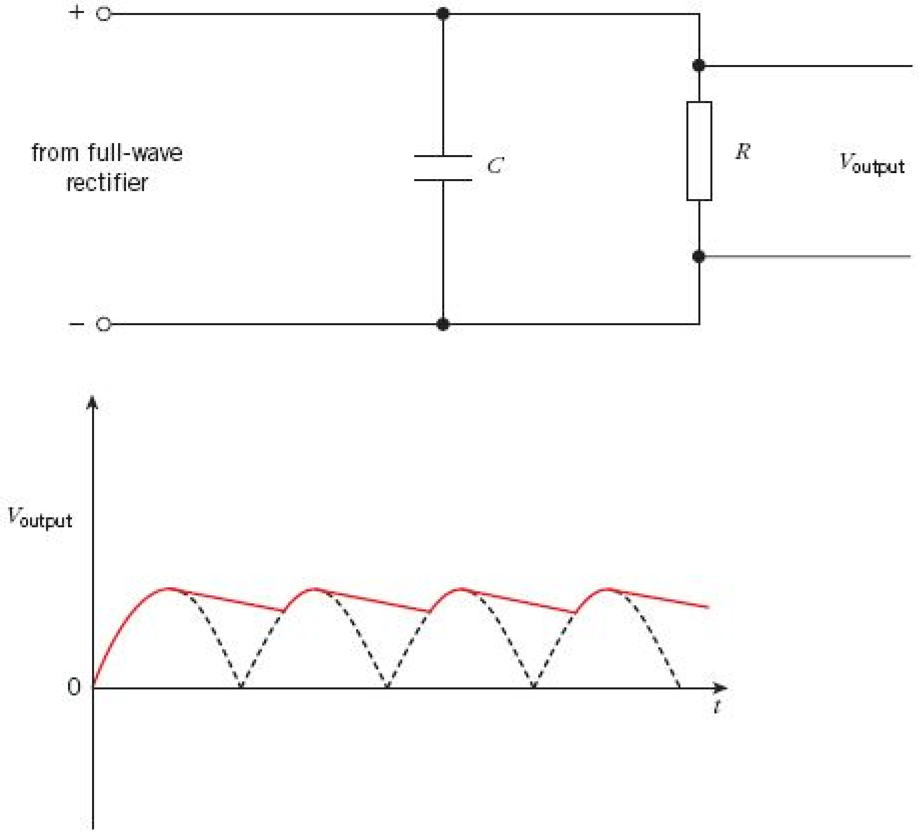

Figure 24.8 Smoothing by capacitor

As the input voltage rises, the capacitor charges. It then releases this charge while the current falls, which 'smooths' out fluctuations from the input voltage. If the **time-constant RC** of the capacitor-resistor circuit is significantly greater than the input current's half cycle, then there will be a small 'rippling' effect on the direct current produced. A smaller time constant will cause a larger ripple, as shown below.

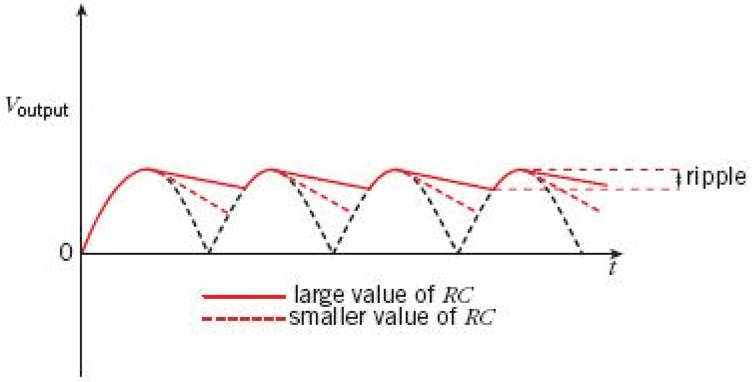

Figure 24.9 Magnitude of the ripple

Image sources:
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