Electric Power and Energy Definition and Measurement

Lesson 20

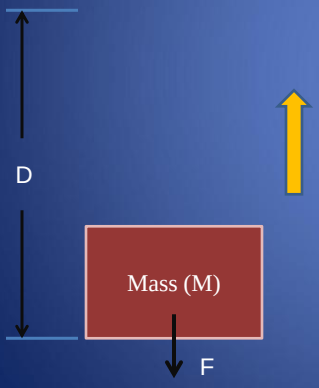
EET 150

Learning Objectives

- In this lesson you will:
- see the definitions of work, energy and power
- learn to measure and compute power in simple dc circuits
- define power in Ac circuits
- see how power varies with time in Ac circuits
- learn how voltage and current relationships effect ac power
- define electric energy
- see the construction of a energy meter
- learn to read an energy meter

Work, Energy and Electric Power

Energy and work occur when a force acts on a mass



Lifting a weight requires work and dissipates energy

Work = (Force)(Distance)

W (Joules) = F (Newtons) X D (Meters)

Power is how fast work is done

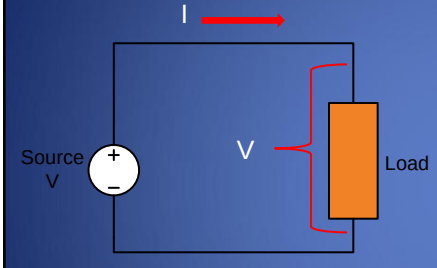
Rate of energy consumption

Power = Work/Time

P (Watts) = W (Joules)/ t (seconds)

Force = (Mass)(Acceleration of gravity) = Weight

Electric Power Dc Circuits



Power = Voltage X Current

P (Watts) = V (Volts) x I (Amps)

If load is a resistor then:

Know load current $P = I^2 \times R$

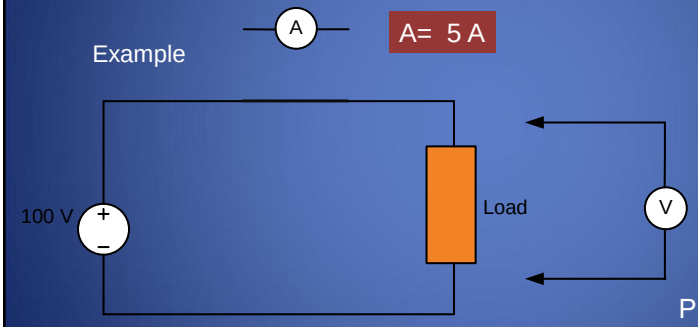
Know load voltage $P = \frac{V^2}{R}$

Where R is resistance in ohms (Ω)

Measuring Dc Power

Both current and voltage measurements are necessary to measure power.

Example

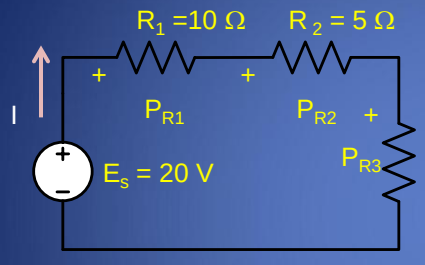


P =V·I

P =(100 V)·(5 A)

P =500 W

Calculating Power in Series Dc Circuit



$$I = \frac{20\,V}{5+10+15\,\Omega} = \frac{20\,V}{30\,\Omega} = 0.667\,A$$

$$P_{R1} = I^2 \cdot R_1 = 0.667^2 \cdot 10 = 4.45\,W$$

$$P_{R2} = I^2 \cdot R_2 = 0.667^2 \cdot 5 = 2.24\,W$$

$$P_{R3} = I^2 \cdot R_3 = 0.667^2 \cdot 15 = 6.674\,W$$

Resistors heat up if power rating is too small

Measuring Power in Series Dc Circuit

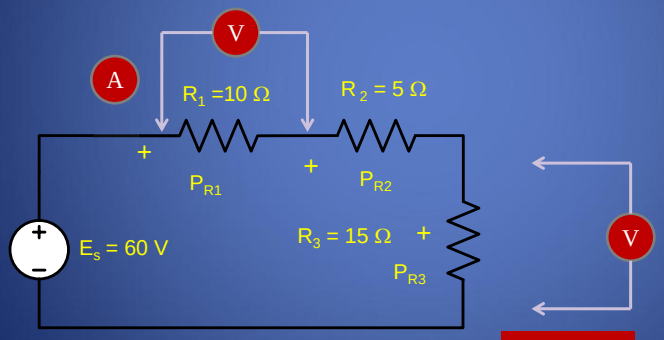
I = 2 A

$P_{R1} = V_{R1} \cdot I = 20 \cdot 2 = 40$ W

$P_{R2} = V_{R2} \cdot I = 10 \cdot 2 = 20$ W

$V_{R1} = 20$ V

$V_{R2} = 10$ V



$V_{R3} = 30$ V

$P_{R3} = V_{R3} \cdot I = 30 \cdot 2 = 60$ W

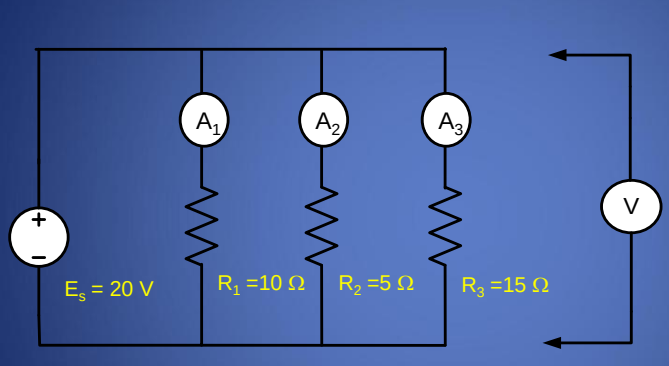
Measuring Power in Parallel Dc Circuits

V = 20 V

$I_1 = 2$ A

$I_2 = 4$ A

$I_3 = 1.33$ A



$P_{R1} = V \cdot I_1 = 20 \cdot 2 = 40$ W

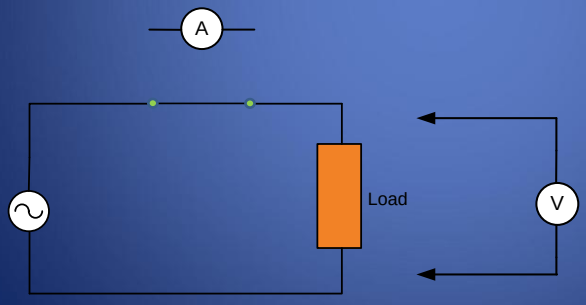
$P_{R2} = V \cdot I_2 = 20 \cdot 4 = 80$ W

$P_{R3} = V \cdot I_3 = 20 \cdot 1.33 = 26.6$ W

Power in Ac Circuits

Ac circuits dissipate some energy as light, heat, or motion. Other energy goes to charging and discharging capacitors and building magnetic fields in inductors

P = active power (light, heat, motion)
Q = Reactive power (Charging capacitors, inductor magnetic fields)

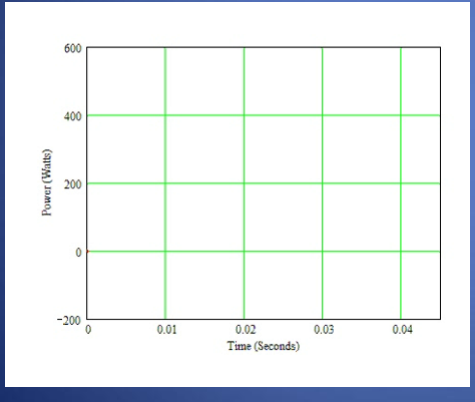


S = V·I Apparent Power

$$S = \sqrt{P^2 + Q^2}$$

Ac Power

Ac power changes with time. For Ac sources and resistor loads, this graph plots the power.

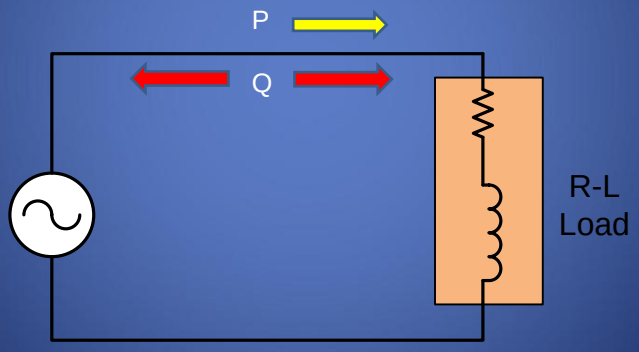


Power wave never negative

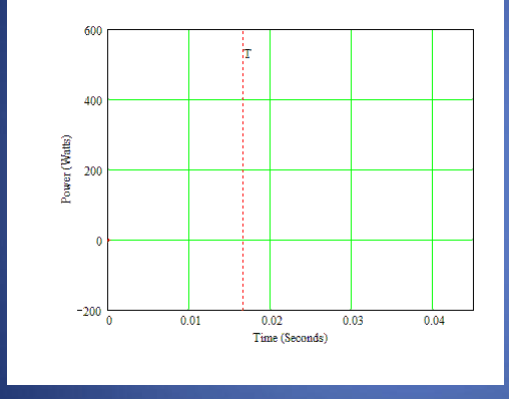
Power wave is zero twice in a period.

Ac Reactive Power

Reactive power flows back and forth between the source and the load



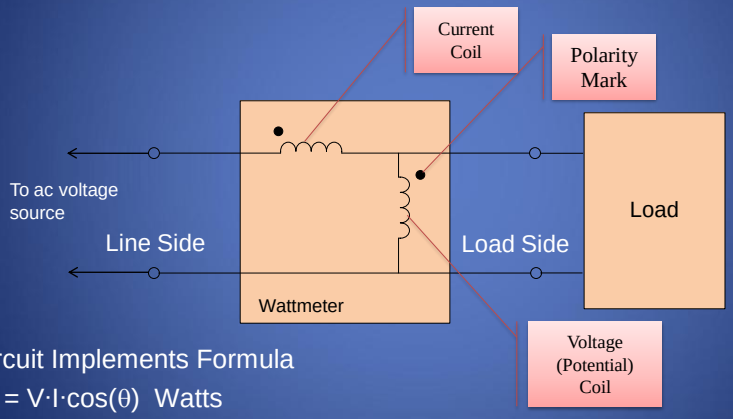
Ac Power-Active and Reactive



Power wave goes negative showing power returned to source

Measuring Ac Power Using the Wattmeter

The Wattmeter has internal voltage and current measuring elements and displays Watts (W)

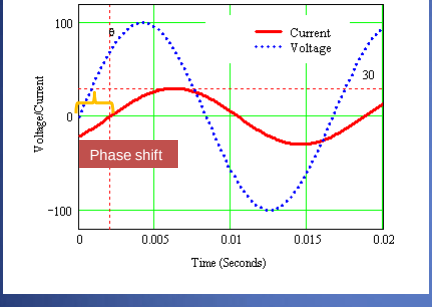


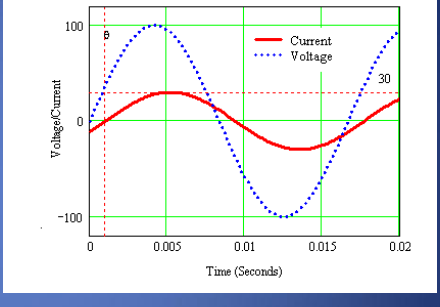
Circuit Implements Formula

$P = V \cdot I \cdot \cos(\theta)$ Watts

V = Rms value of voltage waveform
I = Rms value of current waveform
θ = phase angle between V and I waves

Phase Shift and Ac Power





$V_{rms} = 100(0.707) = 70.7$ V
$I_{rms} = 30(0.707) = 21.21$ A
$\theta = 45$ degrees

P=(70.7)(21.21)cos(45 deg)= 1060 W

$V_{rms} = 100(0.707) = 70.7$ V
$I_{rms} = 30(0.707) = 21.21$ A
$\theta = 23.5$ degrees

P=(70.7)(21.21)cos(23.5 deg)= 1375 W

Electric Energy Measurement

ENERGY = (instantaneous power) x (time)

$W = p \times t$ where W = energy
p = instantaneous power
t = time

kWh meters sum power over time interval using a rotating disk.

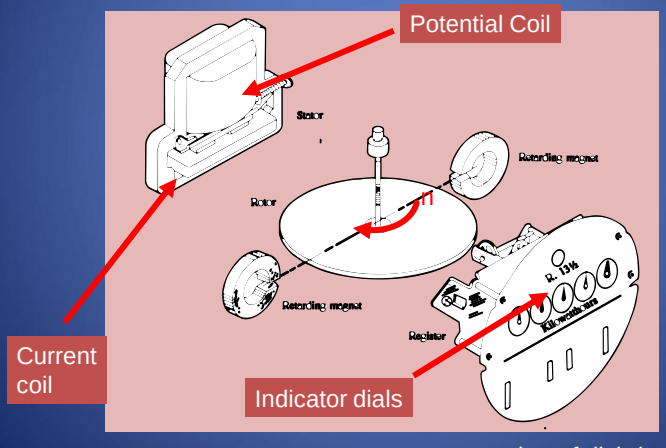
Number of revolutions, n, proportional to energy

so $n = C_p \times P \times t$

C_p = meter energy constant
(units kWh/rev)

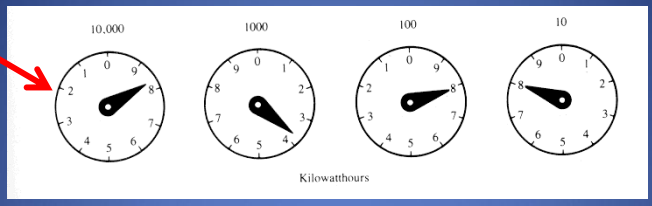
Energy Meter Construction

kWh meter measures the electric energy we all consume in our homes and businesses



n=number of disk (rotor) revolutions

How to Read an Energy Meter



1.) Start from left-most Dial (10,000)

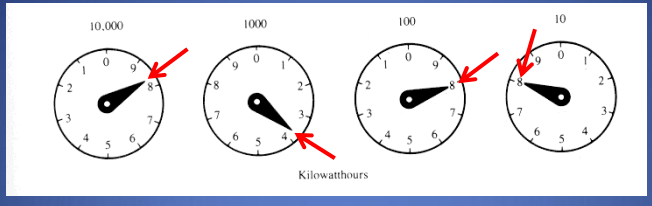
2.) Record value just past by pointer

3.) Record value of each dial

4.) Subtract present reading from last meter reading

5.) Difference is the usage in kWh for period

Reading an Energy Meter



Example Compute the usage for the last 30 days if the last meter reading was 7129 and the current meter reading is shown above

Note direction of rotation of the meter dials and read the last integer that the pointer has past.

Reading 8 3 8 8

Energy usage is the difference between the two readings

8388 - 7129 = 1259 kWh

Electric Power and Energy Definition and Measurement

END LESSON 20
EET 150
COMING NEXT: MORE ELECTRONIC CIRCUIT CONSTRUCTION TECHNIQUES