Work, Energy and Power(II)

Lecture#2

Electrical Technology
(Admirality)

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Mechanical Work

Mechanical Work is done when a force acting on a body causes it to move.

Work done = Force × distance moved in direction of force by point of application of force

Unit of Force

The M.K.S. unit of force is the newton. It is the force required to give a mass of one kilogram an acceleration of one metre per second per second.

1 *kilogram (force)* = 9·81 *newtons and* 1 *pound (force)* = 4·45 *newtons.*

Unit of Work

The M.K.S. unit of work is the joule. It is the work done when the point of application of a force of one newton is moved one metre in the direction of the force. 1 *joule* = 1 *newton-metre*.

Foot Pound (ft lb)

The British unit of work is the foot-pound.

1 ft = 0·3048m and 1 lb = 4·45 Nw

∴ 1 ft lb = 0·3048 × 4·45 = 1·356 joules or 1 joule = 0·7375 ft lb

Energy

Energy is capacity for doing work. Energy may exist in several forms and may be changed from one form to another. A lead-acid cell changes chemical energy to electrical energy on discharge and vice-versa on charge, a generator changes mechanical energy to electrical energy, an electric radiator converts electrical energy to heat energy, etc.

The Joule

Work cannot be done without energy being used, and the amount of work done is a measure of the energy used. Mechanical, electrical, and heat energy are all measured in joules in the M.K.S. system.

One joule of energy is expended electrically when one coulomb is moved through a p.d. of one volt, and 4187 joules of mechanical or electrical energy, if wholly converted to heat, will raise the temperature of one kilogram of water by 1°C.

The work done in moving a quantity of electricity Q coulombs through a p.d. of V volts is VQ joules.

$$W = VQ \qquad (19)$$

If current I amperes flows through a circuit of resistance R ohms for time t seconds, then work done or electrical energy expended $= VQ$ joules where V $(= IR)$ is the volt drop across the circuit.

But $$Q = It \qquad (20)$$

$\therefore$ Energy expended

$$= VIt \text{ joules} \qquad (21)$$

$$= I^2Rt \text{ joules} \qquad (22)$$

$$= \frac{V^2t}{R} \text{ joules} \qquad (23)$$

Power

Power is rate of doing work

$$P = \frac{W}{t} \qquad \text{...(24)}$$

The electrical unit of power is the joule per second, called the *watt* (W). Hence another name for the joule is the watt-second.

The joule or watt-second is a very small unit of electrical energy and for commercial purposes energy is measured in watt-hours (Wh) or kilowatt-hours (kWh). The kWh is called a Board of Trade (B.O.T.) Unit.

1 B.O.T. Unit = 1 kWh = 1000 Wh = 3600000 joules

Power in an Electrical Circuit

$$P = \frac{W}{t} = \frac{VQ}{t} = VI \text{ watts} \qquad \text{..........(25)}$$

$$= I^2R \text{ watts} \qquad \text{..........(26)}$$

$$= \frac{V^2}{R} \text{ watts} \qquad \text{..........(27)}$$

The foot-pound-second unit of power is the *horse-power* (h.p.). It is a rate of working of 33,000 ft lb per minute, *i.e.* 550 ft lb per second.

1 h.p. = 550 ft lb/sec = 550 × 1·356 joules/sec = 746 watts

1 kilowatt (kW) = 1000 watts = 1·34 h.p.

Example 1. How many kilowatts will be required to light a factory in which 250 lamps each taking 1·3 amperes at 230 volts are used?

$$\begin{aligned} \text{Watts} &= VI \\ \text{Total watts required} &= 230 \times 1{\cdot}3 \times 250 \\ &= 74750 \\ &= 74{\cdot}75 \text{ kW} \end{aligned}$$

Example 2. A 100-volt lamp has a hot resistance of 500 ohms. Find what current it takes, its power rating in watts and the amount of energy it consumes in 40 hrs.

$$\text{Current taken} = \frac{V}{R} = \frac{100}{500} = 0{\cdot}2 \text{ ampere}$$

$$\text{Power rating} = V \times I = 100 \times 0{\cdot}2 = 20 \text{ watts}$$

$$\text{Energy consumed in 40 hr} = 20 \times 40 = 800 \text{ watt-hours}$$

Example 3. An electric iron is marked 200 volts, 350 watts. What current does it take and what is its hot resistance? What is the weekly cost of using it for 30 minutes daily at 2d. per unit?

$$\text{Current taken} = \frac{350}{200} = 1 \cdot 75 \text{ amperes}$$

$$\text{Hot resistance} = \frac{200}{1 \cdot 75} = 114 \cdot 3 \text{ ohms}$$

$$\text{Energy consumed per week} = 350 \times 7 \times \tfrac{1}{2} \text{ Wh} = \frac{350 \times 7 \times \frac{1}{2}}{1000} \text{ kWh}$$

$$= 1 \cdot 225 \text{ kWh}$$

$$\therefore \quad \text{Cost} = 1 \cdot 225 \times 2\text{d.} = 2 \cdot 45\text{d.}$$

Example 4. A factory is supplied with power at 210 volts through a pair of feeders of total resistance 0·025 ohm. The load consists of 250, 60-watt lamps, and four motors each taking 40 amperes.

Find (a) Total current required.

(b) Voltage at station end of feeders.

(c) Power wasted in feeders.

Lamp load $= 250 \times 60 = 15{,}000$ watts

Motor load $= 4 \times 210 \times 40 = 33{,}600$ watts

Total load $= 48{,}600$ watts

(a) Total current required $= \dfrac{48600}{210} = 231{\cdot}4$ amperes

Volt drop in feeders $= 231{\cdot}4 \times 0{\cdot}025$

$= 5{\cdot}78$ V $= 5{\cdot}8$ volts

(b) Voltage at station end of feeders $= 210 + 5{\cdot}8$

$= 215{\cdot}8$ volts

(c) Power wasted in feeders $= I^2R = 231{\cdot}4^2 \times 0{\cdot}025$ watts

$= 1{,}339$ watts