Power

Electrical Power

Power = Voltage multiplied by Current

$$P = VI$$

Voltage is measured in Volts, current is measured in Amperes, and Power is measured in Watts. In the US, electricity is supplied at 110 Volts.

Power = Energy divided by time.

$$P = E/t$$

or Energy = Power multiplied by time

$$E = Pt$$

For household calculations, time is measured in Hours, and Energy is measured in Watt.Hour. However, more conventional unit is

kiloWatt.Hour = 1000 Watt.Hour

Energy is priced as cents per kiloWatt.Hour. Across the US, the price varies from 11 cents/kiloWatt.Hour to 32 cents/kiloWatt.Hour in Hawaii and some parts of California.

The average price of electricity is 15 cents/kiloWatt.Hour

Check your electricity bill to find the price in your area.

Automobile

We want to calculate the power from the engine to drive a car at a uniform speed on a level roadway. When the car is speeding up or going up a hill, more power is needed, but for now, we will keep our calculations simple. Also, we have not included the power that is used in water-pump, alternator, the fan, and heater or air-conditioner.

The car needs power to overcome air-resistance and rolling resistance, which is the friction between the wheels and the roadway.

In the very first step, we change the speed of the car from miles-per-hour to feet-per-second, by using this formula:

mile/hour = (mile/hour) x (1760 yard/mile) x (3 feet/yard) X (hour/60 min) x (min/60 sec)

or

mile/hour = (1760 x 3)/(60 x 60) feet/sec

Then we use this formula for calculating the air-resistance:

Air-resistance (pounds) = 0.5 x density of air (slug/cu.ft) x drag-coefficient x area (sq.ft) x speed (ft/sec) x speed (ft/sec)

Density of air at sea-level at 70-degreees Fahrenheit = 0.0023 slug/cu.ft

Drag coefficient is a number that the car manufacturer can provide. Typically the drag coefficient is 0.3 for sedans, 0.65 for convertibles, 0.9 for pick-ups, and 0.96 for semis.

Area is almost equal to the area that is blocked from your view by the car when you stand in front of it. Typically, the area is 16 sq.ft for sedans; higher for pick-ups and much higher for semis.

We use this formula for calculating the rolling-resistance:

Rolling Resistance (pounds) = Friction Coefficient x Weight of car (pounds)

Typical friction coefficient for tire on concrete is 0.012.

Total Resistance (pounds) = Air-Resistance (pounds) + Rolling Resistance (pounds)

We find the engine power from this formula:

Power (lb.ft/sec) = Total Resistance (lb) x Speed (ft/sec)

The unit lb.ft/sec is not typical for power. We do the following unit change:

550 lb.ft/sec = 1 horse-power

and calculate power in horse-power or hp.

Water Power

Energy is the ability to push harder, reach higher speeds, and reach higher heights.

Water, or any other liquid, can store energy in three pockets.

1. Pressure Pocket (push)
2. Speed Pocket
3. Height Pocket

Total energy of water = pressure energy + speed energy + height energy

Pumps add energy to water. Hydroelectric turbines take energy away from water.

Energy Conservation Law: When there is no pump or turbine, the total energy of water does not change.

What is pressure? Stretch your palm out. The pressure due to atmosphere standing above your palm is 14.7 lb/sq. in. If the area of your palm is 15 sq.in, then the push-down from the atmosphere on your palm is 220.5 lb. Why don't we feel this heavy load? Because, the push-up from the atmosphere on your palm is also 220.5 lb.

We will use the symbol p for pressure from the atmosphere.

When you shoot a water jet upward from a nozzle at ground level, the water jet loses all its speed at a certain height. We write the energy conservation law as

$$P + \frac{1}{2}\rho V^2 = P + 386.4\rho h$$

$$\frac{1}{2}\rho V^2 = 386.4\rho h$$

$$\frac{1}{2}V^2 = 386.4h$$

$$V^2 = 772.8h$$

$$V = \sqrt{772.8h}$$

Mass Conservation Law: Mass cannot be created or destroyed

Mass of water flowing through the pipe = Mass of water flowing through the jet

$$\rho UB = \rho VA$$

$$UB = VA$$

$$U = \frac{VA}{B}$$

Using energy conservation law one more time

$$Q + \frac{1}{2}\rho U^2 = P + \frac{1}{2}\rho V^2$$

$$Q = \text{pressure of atmosphere} + \frac{1}{2}\rho V^2 - \frac{1}{2}\rho U^2$$

Density of water

$$\rho = 0.0011 \, \text{slug / cu.in}$$