**Energy Units:**

1. Joule (J)
2. Watt-hour (Wh)
3. Calorie
4. British Thermal Unit (BTU)

**Relations Between Energy Units:**

Table 1: Relation between the energy units and the SI energy unit (Joule)

|  |  |
| --- | --- |
| 1 Calorie | 4.18 J |
| 1 kWh | 3.6 MJ |
| 1 BTU | 1055 J |

Table 2: Relation between kWh and BTU

|  |  |
| --- | --- |
| 1 kWh |  3428 BTU |

**Energy formulas:**

Table 3: Energy formulas

|  |  |  |
| --- | --- | --- |
| Kinetic Energy | $$E\_{k}=\frac{1}{2}mv^{2}$$ | m: massv: velocity |
| Heat Energy | $$\frac{∆Q}{∆T}=mC\_{h}$$ | m: massCh: specific heat (J/K) |
| Potential Energy | $$E\_{p}=mgh$$ | m: massg: gravity constanth: height |

**Renewable Energy Formulas:**

Table 4: Renewable Energy formulas

|  |  |  |
| --- | --- | --- |
| Capacity Factor | $$CF=\frac{E\_{actual}}{E\_{Theoritical}}$$∴ $E\_{Theoritical}=C×H$ | C: Rated capacity of the generatorH: working period |

**Example 1 (Unit Converging):**

A marathon runner burns 2,000 calories during the race (26.2 miles). The race was completed in 4 hours. How many kWh does he burn? What is the average output power?

Answer:

1. Energy calculation:
2. Converting the calories into Joules:

1 calorie = 4.18 J from Table.1

2000 calorie = 2000 x 4.18 = 8.36 kJ

1. Converting from Joules into kWh:

3.6 MJ = 1 kWh from Table.1

8.36 kJ = 0.00232 kWh

1. Power calculation:
2. Power is the energy over the time period

P = 0.00232/4 = 580 mW

**Example 2 (Kinetic Energy):**

A wind turbine converts with 30% efficiency the kinetic energy of the air mass that passes through its rotor area. Assume the air is travelling at a speed of 10m/s, the density of air is 1.2 kg/m^3 and the rotor diameter is 90 m. How much electric energy, in kWh, does the wind turbine produce during one hour?

Answer:

To get the kWh energy of the wind turbine we should find the Joule energy that the air causes using the kinetic energy formula.

$$E\_{k(air)}=\frac{1}{2}m\_{air}v\_{air}^{2}$$

The mass of the air is unknown but its speed is. To get the mass we should use the density equation:

$$ρ=\frac{m}{V}$$

The volume of the air can be calculated as the volume in **one second** considering a cylindrical shape for the air mass passing through the turbine blade.

$$V=r^{2}πl\_{sec}$$

where *l* is the length of the air mass passing through the turbine in **one second** and *r* is the radius of the rotor blades.

The question is asking for the energy generated in one hour so the length of the air mass in one hour is:

$$l\_{hour}=3600l\_{sec}$$

Now the mass can be found as:

$$m\_{air}=ρ(r^{2}πl\_{hour})$$

The kinetic energy can be formulated as:

$$E\_{k(air)}=\frac{1}{2}ρ(r^{2}πl\_{hour})v\_{air}^{2}$$

Finally substituting the values of the variables, we get:

$$E\_{k(air)}=\frac{1}{2}\left(1.2\right)\left(45^{2}π\right)\left(10×3600\right)\left(10\right)^{2}=13.7412 GJ$$

Converting the Joules energy into kWh gives:

3.6 MJ = 1 kWh

13741.2 MJ = 3817 kWh

Finally, the efficiency of the turbine is 30% so the final energy is:

Total Energy = (3817) x 0.3 = 1145.1 kWh.

**Example 3 (Temperature and heat):**

You plan on using large mirrors to reflect sunlight onto a container to heat your shower water. You will use 30 liters of water in your shower at a temperature of 120 °F, the unheated water is at 60 °F. How much energy must be applied to the water in kWh? Ignore the presence of the container in the calculation.

• Note: 𝐶ℎ = 4186 J/K for water, 1L weighs 1 kg.

Answer:

To get the kWh energy that must be supplied to the water we should find the Joule energy that is needed to heat the water to the 120 ℉ from 60 ℉ using the thermal equation.

$$\frac{∆Q}{∆T}=mC\_{h}$$

where T is in Kelvin.

Converting the ℉ temperatures to kelvins gives:

$$K=\left(°F-32\right)×\frac{5}{9}+273.15$$

60 ℉ = 288.706 K

120 ℉ = 322.039 K

Therefore, the temperature difference can now be calculated as:

$$∆T=322.039-288.706=33.333$$

The next step is to find the heat transfer in joule:

$$∆Q=\left(33.333\right)\left(30\right)\left(4186\right)=4.186 MJ$$

Finally, we convert the joules into kWh using Table.1

3.6 MJ = 1 kWh

4.186 MJ = 1162.7 kWh