# Assignment 1

# Group assignment

**Problem (1):**

**a-** The forms of energy involved are electrical energy and sensible internal energy. Electrical energy is converted to sensible internal energy, which is transferred to the water as heat.

**b-** The macroscopic forms of energy are those a system possesses as a whole with respect to some outside reference frame. The microscopic forms of energy, on the other hand, are those related to the molecular structure of a system and the degree of the molecular activity, and are independent of outside reference frames.

**c-** The sum of all forms of the energy a system possesses is called total energy. In the absence of magnetic, electrical and surface tension effects, the total energy of a system consists of the kinetic, potential, and internal energies.

**d-** Thermal energy is the sensible and latent forms of internal energy, and it is referred to as heat in daily life.

**e-** The mechanical energy is the form of energy that can be converted to mechanical work completely and directly by a mechanical device such as a propeller. It differs from thermal energy in that thermal energy cannot be converted to work directly and completely. The forms of mechanical energy of a fluid stream are kinetic, potential, and flow energies.

**f-** Energy can cross the boundaries of a closed system in two forms: heat and work.

**g-** The form of energy that crosses the boundary of a closed system because of a temperature difference is heat; all other forms are work.

**h-** It is a work interaction since the electrons are crossing the system boundary, thus doing electrical work.

**i-** This is neither a heat nor a work interaction since no energy is crossing the system boundary. This is simply the conversion of one form of internal energy (chemical energy) to another form (sensible energy).

**j-** Point functions depend on the state only whereas the path functions depend on the path followed during a process. Properties of substances are point functions, heat and work are path functions.

**k-** The work done is the same, but the power is different.

**l-** No. This is the case for adiabatic systems only.

**m-** Energy can be transferred to or from a control volume as heat, various forms of work, and by mass transport.

**n-** The turbine efficiency, generator efficiency, and combined turbine-generator efficiency are defined as follows:

$$\eta_{turbine} = \frac{Mechanical\ energy\ output}{Mechanical\ energy\ extracted\ from\ Fluid} = \frac{\dot{W}_{shaft,out}}{|\Delta \dot{E}_{mech,fluid}|}$$

$$\eta_{generator} = \frac{Electrical\ power\ output}{Mechanical\ power\ input} = \frac{\dot{W}_{elect,out}}{\dot{W}_{shaft,in}}$$

$$\eta_{turbine-gen} = \eta_{turbine} \times \eta_{generator} = \frac{\dot{W}_{elect,out}}{\dot{E}_{mech,in} - \dot{E}_{mech,out}} = \frac{\dot{W}_{elect,out}}{|\Delta \dot{E}_{mech,fluid}|}$$

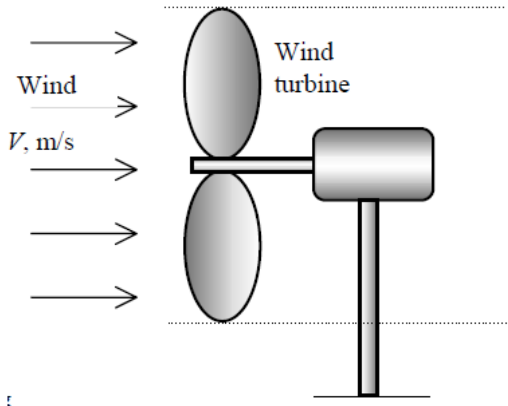
**o-** No, the combined pump-motor efficiency cannot be greater than either of the pump efficiency of the motor efficiency. This is because $\eta_{pump-motor} = \eta_{pump} \times \eta_{motor}$ , and both $\eta_{pump}\ and\ \eta_{motor}$ are less than one, and a number gets smaller when multiplied by a number smaller than one.

**Problem (3):**

Two sites with specified wind data are being considered for wind power generation. The site better suited for wind power generation is to be determined.

**Assumptions: 1-** The wind is blowing steadily at specified velocity during specified times. **2-** The wind power generation is negligible during other times.

**Properties** We take the density of air to be $\rho = 1.25\ kg/m^3$ (it does not affect the final answer).




**Analysis:** Kinetic energy is the only form of mechanical energy the wind possesses, and it can be converted to work entirely. Therefore, the power potential of the wind is its kinetic energy, which is $V^2/2$ per unit mass, and $\dot{m}V^2/2$ for a given mass flow rate. Considering a unit flow area (A = 1 $m^2$), the maximum wind power and power generation becomes

$$e_{mech,1} = ke_1 = \frac{V_1^2}{2} = \frac{(7\text{ m/s})^2}{2}\left(\frac{1\text{ kJ/kg}}{1000\text{ m}^2/\text{s}^2}\right) = 0.0245\text{ kJ/kg}$$

$$e_{mech,2} = ke_2 = \frac{V_2^2}{2} = \frac{(10\text{ m/s})^2}{2}\left(\frac{1\text{ kJ/kg}}{1000\text{ m}^2/\text{s}^2}\right) = 0.050\text{ kJ/kg}$$

$$\dot{W}_{max,1} = \dot{E}_{mech,1} = \dot{m}_1 e_{mech,1} = \rho V_1 A ke_1 = (1.25\text{ kg/m}^3)(7\text{ m/s})(1\text{ m}^2)(0.0245\text{ kJ/kg}) = 0.2144\text{ kW}$$

$$\dot{W}_{max,2} = \dot{E}_{mech,2} = \dot{m}_2 e_{mech,2} = \rho V_2 A ke_2 = (1.25\text{ kg/m}^3)(10\text{ m/s})(1\text{ m}^2)(0.050\text{ kJ/kg}) = 0.625\text{ kW}$$

Since 1 kW = 1 kJ/s. Then the maximum electric power generations per year become

$$E_{max,1} = \dot{W}_{max,1}\Delta t_1 = (0.2144\text{ kW})(3000\text{ h/yr}) = \mathbf{643\ kWh/yr}\text{ (per m}^2\text{ flow area)}$$

$$E_{max,2} = \dot{W}_{max,2}\Delta t_2 = (0.625\text{ kW})(2000\text{ h/yr}) = \mathbf{1250\ kWh/yr}\text{ (per m}^2\text{ flow area)}$$

Therefore, second site is a better one for wind generation.

Discussion: Note the power generation of a wind turbine is proportional to the cube of the wind velocity, and thus the average wind velocity is the primary consideration in wind power generation decisions.

**Problem (10):**

The classrooms and faculty offices of a university campus are not occupied an average of 4 hours a day, but the lights are kept on. The amounts of electricity and money the campus will save per year if the lights are turned off during unoccupied periods are to be determined.

**Analysis:** The total electric power consumed by the lights in the classrooms and faculty offices is

$$\dot{E}_{\text{lighting, classroom}} = (\text{Power consumed per lamp}) \times (\text{No. of lamps}) = (200 \times 12 \times 110\ \text{W}) = 264{,}000 = 264\ \text{kW}$$
$$\dot{E}_{\text{lighting, offices}} = (\text{Power consumed per lamp}) \times (\text{No. of lamps}) = (400 \times 6 \times 110\ \text{W}) = 264{,}000 = 264\ \text{kW}$$
$$\dot{E}_{\text{lighting, total}} = \dot{E}_{\text{lighting, classroom}} + \dot{E}_{\text{lighting, offices}} = 264 + 264 = 528\ \text{kW}$$

Noting that the campus is open 240 days a year, the total number of unoccupied work hours per year is

Unoccupied hours = (4 hours/day)(240 days/year) = 960 h/yr

Then the amount of electrical energy consumed per year during unoccupied work period and its cost are

Energy savings ($\dot{E}_{\text{lighting, total}}$)(Unoccupied hours) = (528 kW)(960 h/yr) = 506,880 kWh

Cost savings = (Energy savings)(Unit cost of energy) = (506,880 kWh/yr)(0.18 EGP/kWh) = 91,238 EGP/yr

**Discussion:** Note that simple conservation measures can result in significant energy and cost savings.

**<u>Problem (11)</u>:**

A room contains a light bulb, a TV set, a refrigerator, and an iron. The rate of increase of the energy content of the room when all of these electric devices are on is to be determined.

**Assumptions: 1-** The room is well sealed, and heat loss from the room is negligible. **2-** All the appliances are kept on.

**Analysis:** Taking the room as the system, the rate form of the energy balance can be written as

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{\text{system}} / dt}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} \quad \rightarrow \quad dE_{\text{room}} / dt = \dot{E}_{in}$$

since no energy is leaving the room in any form, and thus $\dot{E}_{out} = 0$

$$\begin{aligned} \dot{E}_{\text{in}} &= \dot{E}_{\text{lights}} + \dot{E}_{\text{TV}} + \dot{E}_{\text{refrig}} + \dot{E}_{\text{iron}} \\ &= 100 + 110 + 200 + 1000\ \text{W} \\ &= 1410\ \text{W} \end{aligned}$$

Substituting, the rate of increase in the energy content of the room becomes

$$dE_{\text{room}} / dt = \dot{E}_{\text{in}} = \mathbf{1410\ W}$$

**Discussion:** Note that some appliances such as refrigerators and irons operate intermittently, switching on and off as controlled by a thermostat. Therefore, the rate of energy transfer to the room, in general, will be less.