Ain Shams University
Faculty of Engineering
Mechanical Power Dept.

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ENGR 360/MEP 112
Thermodynamics

Sheet (2)
Model Answer

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:

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

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

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

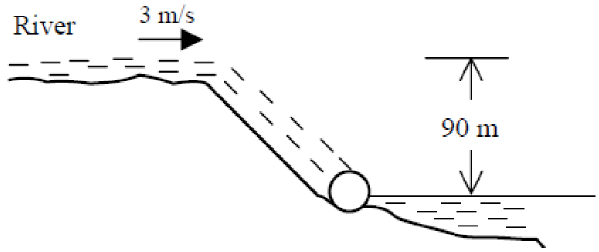
o- No, the combined pump-motor efficiency cannot be greater than either of the pump efficiency of the motor efficiency. This is because $\eta_{pump-motor} = \eta_{pump} \times \eta_{motor}$, and both $\eta_{pump}\ and\ \eta_{motor}$ are less than one, and a number gets smaller when multiplied by a number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

<u>Problem (2)</u>:

A river is flowing at a specified velocity, flow rate, and elevation. The total mechanical energy of the river water per unit mass, and the power generation potential of the entire river are to be determined.

Assumptions: 1- The elevation given is the elevation of the free surface of the river. **2-** The velocity given is the average velocity. **3-** The mechanical energy of water at the turbine exit is negligible.

Properties We take the density of water to be ρ = 1000 kg/m^3.



Analysis Noting that the sum of the flow energy and the potential energy is constant for a given fluid body, we can take the elevation of the entire river water to be the elevation of the free surface, and ignore the flow energy. Then the total mechanical energy of the river water per unit mass becomes

$$e_{\text{mech}} = pe + ke = gh + \frac{V^2}{2} = \left((9.81\,\text{m/s}^2)(90\,\text{m}) + \frac{(3\,\text{m/s})^2}{2} \right) \left(\frac{1\,\text{kJ/kg}}{1000\,\text{m}^2/\text{s}^2} \right) = 0.887\,\text{kJ/kg}$$

The power generation potential of the river water is obtained by multiplying the total mechanical energy by the mass flow rate,

$$\dot{m} = \rho \dot{V} = (1000\,\text{kg/m}^3)(500\,\text{m}^3/\text{s}) = 500{,}000\,\text{kg/s}$$

$$\dot{W}_{\text{max}} = \dot{E}_{\text{mech}} = \dot{m} e_{\text{mech}} = (500{,}000\,\text{kg/s})(0.887\ \text{kJ/kg}) = 444{,}000\,\text{kW} = \mathbf{444\ MW}$$

Therefore, 444 MW of power can be generated from this river as it discharges into the lake if its power potential can be recovered completely.

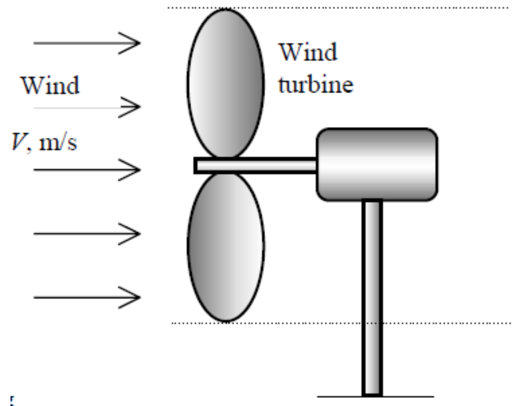
Discussion Note that the kinetic energy of water is negligible compared to the potential energy, and it can be ignored in the analysis. Also, the power output of an actual turbine will be less than 444 MW because of losses and inefficiencies.

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 $\rho = 1.25\ \text{kg/m}^3$ (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

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

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

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

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

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

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

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

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.

<u>Problem (4)</u>:

A person with his suitcase goes up to the 10^{th} floor in an elevator. The part of the energy of the elevator stored in the suitcase is to be determined.

Assumptions 1 The vibration effects in the elevator are negligible.

Analysis The energy stored in the suitcase is stored in the form of potential energy, which is $m \times g \times z$. Therefore,

$$\Delta E_{\text{suitcase}} = \Delta PE = mg\Delta z = (30\text{ kg})(9.81\text{ m/s}^2)(35\text{ m})\left(\frac{1\text{ kJ/kg}}{1000\text{ m}^2/\text{s}^2}\right) = \mathbf{10.3\ kJ}$$

Therefore, the suitcase on 10^{th} floor has 10.3 kJ more energy compared to an identical suitcase on the lobby level.

Discussion Noting that 1 kWh = 3600 kJ, the energy transferred to the suitcase is 10.3/3600 = 0.0029 kWh, which is very small.

<u>Problem (5)</u>:

A car is accelerated from 10 to 60 km/h on an uphill road. The work needed to achieve this is to be determined.

Analysis The total work required is the sum of the changes in potential and kinetic energies,

$$W_a = \frac{1}{2}m\left(V_2^2 - V_1^2\right) = \frac{1}{2}(1300\text{ kg})\left(\left(\frac{60{,}000\text{ m}}{3600\text{ s}}\right)^2 - \left(\frac{10{,}000\text{ m}}{3600\text{ s}}\right)^2\right)\left(\frac{1\text{ kJ}}{1000\ \text{kg}\cdot\text{m}^2/\text{s}^2}\right) = 175.5\text{ kJ}$$

$$W_g = mg\left(z_2 - z_1\right) = (1300\text{ kg})(9.81\text{ m/s}^2)(40\text{ m})\left(\frac{1\text{ kJ}}{1000\text{ kg}\cdot\text{m}^2/\text{s}^2}\right) = 510.0\text{ kJ}$$

$$W_{\text{total}} = W_a + W_g = 175.5 + 510.0 = \mathbf{686\ kJ}$$

<u>Problem (6)</u>:

The engine of a car develops 450 hp at 3000 rpm. The torque transmitted through the shaft is to be determined.

$$\dot{W}_{shaft} = 450 \times 0.746 = 335.7\ kW$$

$$\omega = \frac{2\pi N}{60} = 314.16\frac{rad}{sec}.$$

$$T = \frac{\dot{W}_{shaft}}{\omega} = 1068.5\ N.m$$

<u>Problem (7)</u>:

A linear spring is elongated by 20 cm from its rest position. The work done is to be determined.

Analysis The spring work can be determined from

$$W_{spring} = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2}(70\text{ kN/m})(0.2^2 - 0)\text{ m}^2 = 1.4\text{ kN}\cdot\text{m} = \mathbf{1.4\ \ kJ}$$

Problem (8):

The engine of a car develops 75 kW of power. The acceleration time of this car from rest to 100 km/h on a level road is to be determined.

Analysis The work needed to accelerate a body is the change in its kinetic energy,

$$W_a = \frac{1}{2}m\left(V_2^2 - V_1^2\right) = \frac{1}{2}(1500\text{ kg})\left(\left(\frac{100{,}000\text{ m}}{3600\text{ s}}\right)^2 - 0\right)\left(\frac{1\text{ kJ}}{1000\text{ kg}\cdot\text{m}^2/\text{s}^2}\right) = 578.7\text{ kJ}$$

Thus the time required is

$$\Delta t = \frac{W_a}{\dot{W}_a} = \frac{578.7\text{ kJ}}{75\text{ kJ/s}} = \mathbf{7.72\ s}$$

This answer is not realistic because part of the power will be used against the air drag, friction, and rolling resistance.

Problem (9):

A classroom is to be air-conditioned using window air-conditioning units. The cooling load is due to people, lights, and heat transfer through the walls and the windows. The number of 5-kW window air conditioning units required is to be determined.

Assumptions There are no heat dissipating equipment (such as computers, TVs, or ranges) in the room.

Analysis The total cooling load of the room is determined from

$$\dot{Q}_{\text{cooling}} = \dot{Q}_{\text{lights}} + \dot{Q}_{\text{people}} + \dot{Q}_{\text{heat gain}}$$

Where:

$$\dot{Q}_{\text{lights}} = 10 \times 100\text{ W} = 1\text{ kW}$$
$$\dot{Q}_{\text{people}} = 40 \times 360\text{ kJ / h} = 4\text{ kW}$$
$$\dot{Q}_{\text{heat gain}} = 15{,}000\text{ kJ / h} = 4.17\text{ kW}$$

Substituting,

$$\dot{Q}_{\text{cooling}} = 1 + 4 + 4.17 = 9.17\text{ kW}$$

Thus the number of air-conditioning units required is

$$\frac{9.17\text{ kW}}{5\text{ kW/unit}} = 1.83 \longrightarrow \mathbf{2\ units}$$

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 ($EE_{\text{lighting, total}}$)(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.

Problem (11):

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.

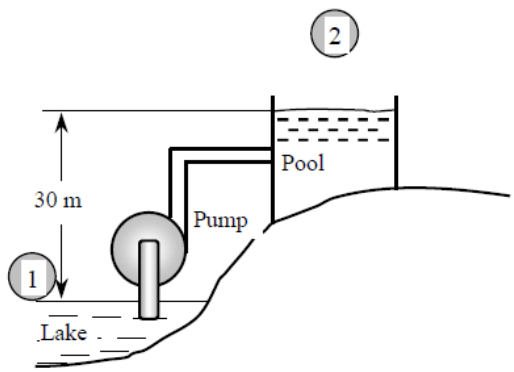
Problem (12):

A water pump is claimed to raise water to a specified elevation at a specified rate while consuming electric power at a specified rate. The validity of this claim is to be investigated.

Assumptions 1- The water pump operates steadily. **2-** Both the lake and the pool are open to the atmosphere, and the flow velocities in them are negligible.

Properties We take the density of water to be $\rho = 1000\ \text{kg/m}^3 = 1\ \text{kg/L}$.

Analysis For a control volume that encloses the pump-motor unit, the energy balance can be written as



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{\text{system}} / dt^{\nearrow 0\ \text{(steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{\text{in}} + \dot{m}\text{pe}_1 = \dot{m}\text{pe}_2 \quad \rightarrow \quad \dot{W}_{\text{in}} = \dot{m}\Delta\text{pe} = \dot{m}g(z_2 - z_1)$$

Since the changes in kinetic and flow energies of water are negligible. Also,

$$\dot{m} = \rho\dot{V} = (1\ \text{kg/L})(50\ \text{L/s}) = 50\ \text{kg/s}$$

Substituting, the minimum power input required is determined to be

$$\dot{W}_{\text{in}} = \dot{m}g(z_2 - z_1) = (50\ \text{kg/s})(9.81\ \text{m/s}^2)(30\ \text{m})\left(\frac{1\ \text{kJ/kg}}{1000\ \text{m}^2/\text{s}^2}\right) = 14.7\ \text{kJ/s} = \mathbf{14.7\ kW}$$

Which is much greater than 2 kW. Therefore, the claim is **false.**

Discussion: The conservation of energy principle requires the energy to be conserved as it is converted from one form to another, and it does not allow any energy to be created or destroyed during a process. In reality, the power required will be considerably higher than 14.7 kW because of the losses associated with the conversion of electrical-to-mechanical shaft and mechanical shaft-to-potential energy of water.

Problem (13):

An inclined escalator is to move a certain number of people upstairs at a constant velocity. The minimum power required to drive this escalator is to be determined.

Assumptions: 1- Air drag and friction are negligible. **2-** The average mass of each person is 75 kg. **3-** The escalator operates steadily, with no acceleration or breaking. **4-** The mass of escalator itself is negligible.

Analysis At design conditions, the total mass moved by the escalator at any given time is

$$\text{Mass} = (30 \text{ persons})(75 \text{ kg/person}) = 2250 \text{ kg}$$

The vertical component of escalator velocity is

$$V_{\text{vert}} = V \sin 45° = (0.8 \text{ m/s})\sin 45°$$

Under stated assumptions, the power supplied is used to increase the potential energy of people. Taking the people on elevator as the closed system, the energy balance in the rate form can be written as

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{\text{system}}/dt}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0 \quad \rightarrow \quad \dot{E}_{\text{in}} = dE_{\text{sys}}/dt \cong \frac{\Delta E_{\text{sys}}}{\Delta t}$$

$$\dot{W}_{\text{in}} = \frac{\Delta PE}{\Delta t} = \frac{mg\Delta z}{\Delta t} = mgV_{\text{vert}}$$

That is, under stated assumptions, the power input to the escalator must be equal to the rate of increase of the potential energy of people. Substituting, the required power input becomes

$$\dot{W}_{\text{in}} = mgV_{\text{vert}} = (2250 \text{ kg})(9.81 \text{ m/s}^2)(0.8 \text{ m/s})\sin 45° \left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) = 12.5 \text{ kJ/s} = \mathbf{12.5 \text{ kW}}$$

When the escalator velocity is doubled to V = 1.6 m/s, the power needed to drive the escalator becomes

$$\dot{W}_{\text{in}} = mgV_{\text{vert}} = (2250 \text{ kg})(9.81 \text{ m/s}^2)(1.6 \text{ m/s})\sin 45° \left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) = 25.0 \text{ kJ/s} = \mathbf{25.0 \text{ kW}}$$

Discussion: Note that the power needed to drive an escalator is proportional to the escalator velocity.

Problem (14):

A wind turbine produces 180 kW of power. The average velocity of the air and the conversion efficiency of the turbine are to be determined.

Assumptions: The wind turbine operates steadily.

Properties: The density of air is given to be 1.31 kg/m^3.

Analysis: (a) The blade diameter and the blade span area are

$$D = \frac{V_{\text{tip}}}{\pi \dot{n}} = \frac{(250\ \text{km/h})\left(\dfrac{1\ \text{m/s}}{3.6\ \text{km/h}}\right)}{\pi(15\ \text{L/min})\left(\dfrac{1\ \text{min}}{60\ \text{s}}\right)} = 88.42\ \text{m}$$

$$A = \frac{\pi D^2}{4} = \frac{\pi(88.42\ \text{m})^2}{4} = 6140\ \text{m}^2$$

Then the average velocity of air through the wind turbine becomes

$$V = \frac{\dot{m}}{\rho A} = \frac{42{,}000\ \text{kg/s}}{(1.31\ \text{kg/m}^3)(6140\ \text{m}^2)} = \mathbf{5.23\ m/s}$$

(b) The kinetic energy of the air flowing through the turbine is

$$\dot{\text{KE}} = \frac{1}{2}\dot{m}\text{V}^2 = \frac{1}{2}(42{,}000\ \text{kg/s})(5.23\ \text{m/s})^2 = 574.3\ \text{kW}$$

Then the conversion efficiency of the turbine becomes

$$\eta = \frac{\dot{W}}{\dot{\text{KE}}} = \frac{180\ \text{kW}}{574.3\ \text{kW}} = \mathbf{0.313 = 31.3\%}$$

Discussion: Note that about one-third of the kinetic energy of the wind is converted to power by the wind turbine, which is typical of actual turbines.

<u>Problem (15)</u>:

A pump is pumping oil at a specified rate. The pressure rise of oil in the pump is measured, and the motor efficiency is specified. The mechanical efficiency of the pump is to be determined.

Assumptions: 1- The flow is steady and incompressible. **2-** The elevation difference across the pump is negligible.

Properties The density of oil is given to be ρ = 860 kg/m^3.

Analysis Then the total mechanical energy of a fluid is the sum of the potential, flow, and kinetic energies, and is expressed per unit mass as

$$e_{\text{mech}} = gh + Pv + V^2/2$$

To determine the mechanical efficiency of the pump, we need to know the increase in the mechanical energy of the fluid as it flows through the pump, which is

$$\Delta \dot{E}_{\text{mech,fluid}} = \dot{m}(e_{\text{mech,out}} - e_{\text{mech,in}}) = \dot{m}\left((Pv)_2 + \frac{V_2^2}{2} - (Pv)_1 - \frac{V_1^2}{2} \right) = \dot{V}\left((P_2 - P_1) + \rho \frac{V_2^2 - V_1^2}{2} \right)$$

Since

$$\dot{m} = \rho \dot{V} = \dot{V} / v$$

and there is no change in the potential energy of the fluid. Also,

$$V_1 = \frac{\dot{V}}{A_1} = \frac{\dot{V}}{\pi D_1^2 / 4} = \frac{0.1\ \text{m}^3/\text{s}}{\pi (0.08\ \text{m})^2 / 4} = 19.9\ \text{m/s}$$

$$V_2 = \frac{\dot{V}}{A_2} = \frac{\dot{V}}{\pi D_2^2 / 4} = \frac{0.1\ \text{m}^3/\text{s}}{\pi (0.12\ \text{m})^2 / 4} = 8.84\ \text{m/s}$$

Substituting, the useful pumping power is determined to be

$$\dot{W}_{\text{pump,u}} = \Delta \dot{E}_{\text{mech,fluid}}$$

$$= (0.1\ \text{m}^3/\text{s})\left(400\ \text{kN/m}^2 + (860\ \text{kg/m}^3) \frac{(8.84\ \text{m/s})^2 - (19.9\ \text{m/s})^2}{2} \left(\frac{1\ \text{kN}}{1000\ \text{kg} \cdot \text{m/s}^2} \right) \right)\left(\frac{1\ \text{kW}}{1\ \text{kN} \cdot \text{m/s}} \right)$$

$$= 26.3\ \text{kW}$$

Then the shaft power and the mechanical efficiency of the pump become

$$\dot{W}_{\text{pump,shaft}} = \eta_{\text{motor}} \dot{W}_{\text{electric}} = (0.90)(35\ \text{kW}) = 31.5\ \text{kW}$$

$$\eta_{\text{pump}} = \frac{\dot{W}_{\text{pump, u}}}{\dot{W}_{\text{pump, shaft}}} = \frac{26.3\ \text{kW}}{31.5\ \text{kW}} = 0.836 = \mathbf{83.6\%}$$

Discussion: The overall efficiency of this pump/motor unit is the product of the mechanical and motor efficiencies, which is 0.9×0.836 = 0.75.