Learning Exercise Advice session 1

1. How would you define a system to determine the rate at which an automobile adds carbon dioxide to the atmosphere? (5 Points)

Answer:

a. Carbon dioxide is generated by the combustion of fuel in the engine.

b. Any system selected for this analysis must include the fuel and air while it is undergoing combustion.

c. The volume that contains this air-fuel mixture within piston-cylinder device can be used for this purpose.

d. One can also place the entire engine in a control boundary and trace the system-surroundings interactions to determine the rate at which the engine generates carbon dioxide.

2. How would you describe the state of the air in the atmosphere? What kind of process does this air undergo from a cool morning to a warm afternoon? (5 Points)

Answer:

a. In order to describe the state of the air, we need to know the value of all its properties.

b. Pressure, temperature, and water content (i.e., relative humidity or dew point temperature) are commonly cited by weather forecasters.

c. But, other properties like wind speed and chemical composition (i.e., pollen count and smog index, for example} are also important under certain circumstances.

d. Assuming that the air composition and velocity do not change and that no pressure front motion occurs during the day, the warming process is one of constant pressure (i.e., isobaric).

3. Consider an alcohol and a mercury thermometer that read exactly 0°C at the ice point and 100°C at the steam point. The distance between the two points is divided into 100 equal parts in both thermometers. Do you think these thermometers will give exactly the same reading at a temperature of, say, 60°C? Explain. (5 Points)

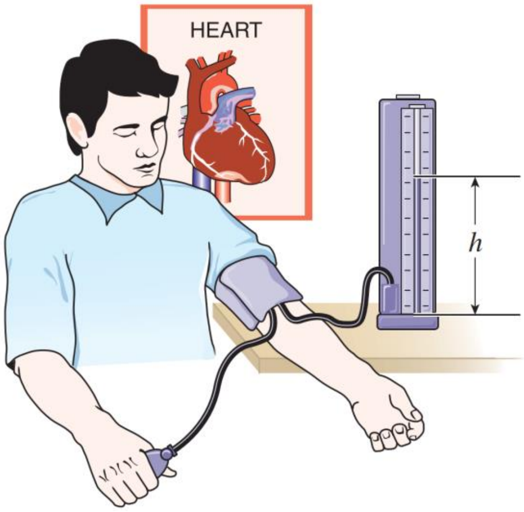
Answer:

a. Probably, but not necessarily. The operation of these two thermometers is based on the thermal expansion of a fluid.

b. If the thermal expansion coefficients of both fluids vary linearly with temperature, then both fluids will expand at the same rate with temperature, and both thermometers will always give identical readings.

c. Otherwise, the two readings may deviate.

4. The maximum blood pressure in the upper arm of a healthy person is about 120 mmHg. If a vertical tube open to the atmosphere is connected to the vein in the arm of the person, determine how high the blood will rise in the tube. Take the density of the blood to be 1050 kg/m^3. (10 Points)



A vertical tube open to the atmosphere is connected to the vein in the arm of a person. The height that the blood will rise in the tube is to be determined.

Assumptions: 1 The density of blood is constant. 2 The gage pressure of blood is 120 mmHg.

Properties: The density of blood is given to be ρ_{blood} = 1050 kg/m^3. $\rho_{mercury}$??

Analysis: For a given gage pressure, the relation $P = \rho g h$ can be expressed for mercury and blood as $P = \rho_{blood} g h_{blood}$ and $P = \rho_{mercury} g h_{mercury}$.

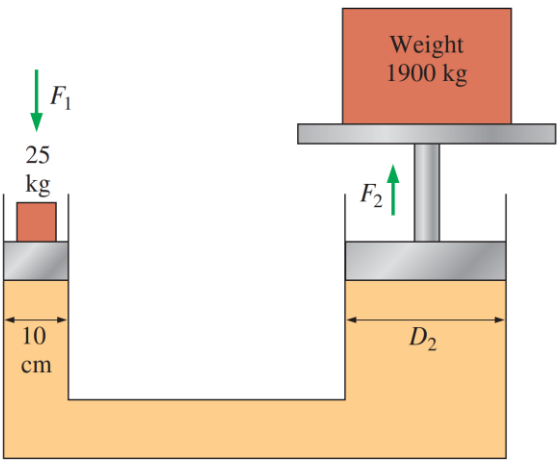
Setting these two relations equal to each other we get

$P = \rho_{blood} g h_{blood} = \rho_{mercury} g h_{mercury}$

Solving for blood height and substituting gives

$$h_{blood} = \frac{\rho_{mercury}}{\rho_{blood}} h_{mercury}$$

5. A hydraulic lift is to be used to lift a 1900-kg weight by putting a weight of 25 kg on a piston with a diameter of 10 cm. Determine the diameter of the piston on which the weight is to be placed.? (10 Points)



A hydraulic lift is used to lift a weight. The diameter of the piston on which the weight to be placed is to be determined.

Assumptions 1: The cylinders of the lift are vertical. 2 There are no leaks. 3 Atmospheric pressure act on both sides, and thus it can be disregarded.

Analysis: Noting that pressure is force per unit area, the pressure on the smaller piston is determined from

$$P_1 = \frac{F_1}{A_1} = \frac{m_1 g}{\pi D_1^2/4}$$

From Pascal's principle, the pressure on the greater piston is equal to that in the smaller piston. Then, the needed diameter is determined from:

$$P_1 = P_2 = \frac{F_2}{A_2} = \frac{m_2 g}{\pi D_2^2/4}$$

Discussion: Note that large weights can be raised by little effort in hydraulic lift by making use of Pascal's principle.

6. What is mechanical energy? How does it differ from thermal energy? What are the forms of mechanical energy of a fluid stream? (5 Points)

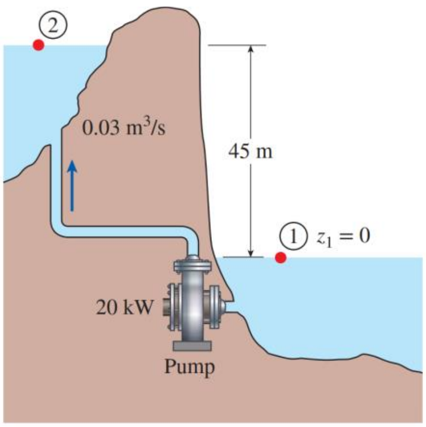
Answer:

1. 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.

2. It differs from thermal energy in that thermal energy cannot be converted to work directly and completely.

3. The forms of mechanical energy of a fluid stream are kinetic, potential, and flow energies.

7. Water is pumped from a lower reservoir to a higher reservoir by a pump that provides 20 kW of shaft power. The free surface of the upper reservoir is 45 m higher than that of the lower reservoir. If the flow rate of water is measured to be 0.03 m³/s, determine mechanical power that is converted to thermal energy during this process due to frictional effects. (Assume that the water levels of the both reservoirs don't change during water delivering). (10 Points)



Water is pumped from a lower reservoir to a higher reservoir at a specified rate. For a specified shaft power input, the power that is converted to thermal energy is to be determined.

Assumptions 1: The pump operates steadily. 2 The elevations of the reservoirs remain constant. 3 The changes in kinetic energy are negligible.

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

Analysis: The elevation of water and thus its potential energy changes during pumping, but it experiences no changes in its velocity and pressure. Therefore, the change in the total mechanical energy of water is equal to the change in its potential energy, which is gz per unit mass, and m􏰀gz for a given mass flow rate. That is,

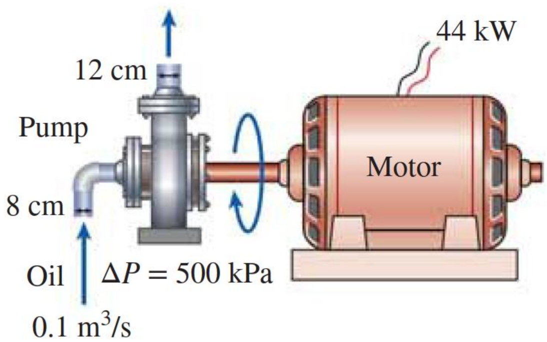
$$\Delta\dot{E}_{mech} = \dot{m}\Delta e_{mech} = \dot{m}\Delta pe = \dot{m}g\Delta z = \rho\dot{V}g\Delta z$$

Then the mechanical power lost because of frictional effects becomes

$$\dot{W}_{frict} = \dot{W}_{pump,in} - \Delta\dot{E}_{mech}$$

Discussion: The $\dot{W}_{frict}$ kW of power is used to overcome the friction in the piping system. The effect of frictional losses in a pump is always to convert mechanical energy to an equivalent amount of thermal energy, which results in a slight rise in fluid temperature. Note that this pumping process could be accomplished by a 13.2 kW pump (rather than 20 kW) if there were no frictional losses in the system. In this ideal case, the pump would function as a turbine when the water is allowed to flow from the upper reservoir to the lower reservoir and extract 13.2 kW of power from the water.

8. An oil pump is drawing 44 kW of electric power while pumping oil with ρ = 860 kg/m^3 at a rate of 0.1 m^3/s. The inlet and outlet diameters of the pipe are 8 cm and 12 cm, respectively. If the pressure rise of oil in the pump is measured to be 500 kPa and the motor efficiency is 90 percent, determine the mechanical efficiency of the pump. (15 Points)



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 r = 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 $e_{mech} = gh + Pv + V^2/2$. 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

$$\Delta\dot{E}_{mech} = \dot{m}\Delta e_{mech} = \dot{m}\left(e_{mech,out-e_{mech},in,}\right) = \dot{m}\left((P\gamma)_2 + \frac{V_2^2}{2} - (Pv)_1 + \frac{V_1^2}{2}\right)$$

$$= \dot{v}\left((P_1 - P_2) + \rho\frac{V_2^2 - V_1^2}{2}\right)$$

since $\dot{m} = \rho\dot{V} = \dot{V}/\gamma$, and there is no change in the potential energy of the fluid. Also,

$$V_1 = \frac{\dot{v}}{A_1} = \frac{\dot{v}}{\pi D_1^2/4}$$
$$V_2 = \frac{\dot{v}}{A_2} = \frac{\dot{v}}{\pi D_2^2/4}$$

Substituting, the useful pumping power is determined to be

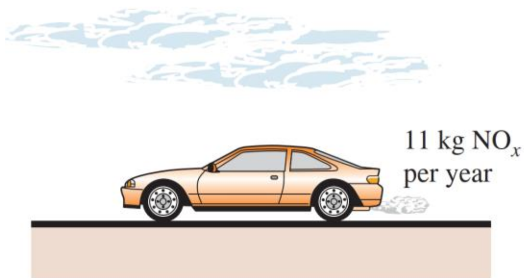
$$\dot{W}_{pump,u} = \Delta\dot{E}_{mech,fluid} =$$

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

$$\dot{W}_{pump,shaft} = \eta_{motor}\dot{W}_{electric}$$
$$\eta_{pump} = \frac{\dot{W}_{pump,u}}{\dot{W}_{pump,shaft}}$$

Discussion: The overall efficiency of this pump/motor unit is the product of the mechanical and motor efficiencies, which is 0.826.

9. A typical car driven 20,000 km a year emits to the atmosphere about 11 kg per year of NOx (nitrogen oxides), which cause smog in major population areas. Natural gas burned in the furnace emits about 4.3 g of NOx per therm (1 therm = 105,500 kJ), and the electric power plants emit about 7.1 g of NOx per kWh of electricity produced. Consider a household that has two cars and consumes 9000 kWh of electricity and 1200 therms of natural gas per year. Determine the amount of NOx emission to the atmosphere per year for which this household is responsible. (15 Points)



A household has 2 cars, a natural gas furnace for heating, and uses electricity for other energy needs. The annual amount of NOx emission to the atmosphere this household is responsible for is to be determined.

Properties: The amount of NOx produced is 7.1 g per kWh, 4.3 g per therm of natural gas, and 11 kg per car (given).

Analysis Noting that this household has 2 cars, consumes 1200 therms of natural gas, and 9,000 kWh of electricity per year, the amount of NOx production this household is responsible for is

Amount of NOx produced= (No. of cars)(Amount of NOx produced per car)
+(Amount of electricity consumed)(Amount of NOx per kWh)
+(Amount of gas consumed)(Amount of NOx per gallon)

Discussion: Any measure that saves energy will also reduce the amount of pollution emitted to the atmosphere.

10. How does energy conversion affect the environment? What are the primary chemicals that pollute the air? What is the primary source of these pollutants? Is there any solution to reduce the

effect of energy conversion on the environment pollutions? Please write an essay (400-500 words) to explain your solutions. (20 Points).