CANKAYA UNIVERSITY
FACULTY OF ENGINEERING AND ARCHITECTURE
MECHANICAL ENGINEERING DEPARTMENT

ME 211 THERMODYNAMICS I
Fall 2015
CHAPTER 2 EXAMPLES SOLUTIONS

19)A major force opposing the motion of a vehicle is the rolling resistance of the tires, F_r given by

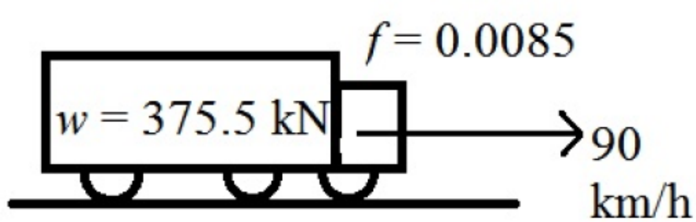
$F_r = f\,W$

where f is a constant called the rolling resistance coefficient and W is the vehicle weight. Determine the power, in kW, required to overcome rolling resistance for a truck weighing 375.5 kN that is moving at 90 km/h. Let f=0.0085.

solution

To determine the power required by the truck moving at speed of 90km/h to overcome the rolling resistance, proceed as follows:

Schematic and given data



Write the expression for **power**

$$\dot{W}_r = F_r \cdot V \qquad (1)$$

Here, $\dot{W}$ is power, F is force and V is velocity

It is known that force for rolling resistance

$$F_r = f\,\mathscr{W} \qquad (2)$$

Substitute, 0.0085 for f, 375.5 kN for $\mathscr{W}$, and 90km/h for V

$$\begin{aligned}\dot{W}_r &= (0.0085)(375.5\text{ kN})(90\text{ km/h})\\ &= (0.0085)(375.5\times10^3\text{ N})\left(90\times\frac{10^3}{3600}\text{ m/s}\right)\\ &= 79.79375\times10^3\text{ W}\\ &\cong 79.8\text{ kW}\end{aligned}$$

Thus, the power required by moving truck to overcome rolling resistance is $\boxed{79.8\text{ kW}}$

Substitute equation (2) in equation (1)

$$\dot{W}_r = (f\mathscr{W})\cdot V$$

Here,

The rolling resistance (f) is 0.0085
The weight ($\mathscr{W}$) of truck is 375.5 kN
The speed (V) of the moving truck is 90 km/h

20)For a process taking place in a closed system containing gas, the volume and pressure relationship is $p\forall^{1.4} = \text{constant}$. The process starts with initial conditions, $p_1 = 1.5\text{bar}, \forall_1 = 0.03\text{m}^3$ and ends with final volume, $\forall_2 = 0.05\text{m}^3$. Determine the work done by the gas.

Solution:
Write the given pressure volume relationship for the system.

$$pV^{1.4} = C$$

Here, C is constant.

Re-arrange above expression to obtain the following relation:

$$p = \frac{C}{V^{1.4}} \quad \ldots\ldots (1)$$

Write the given pressure volume relationship for the initial and final states as follows:

$$p_1V_1^{1.4} = p_2V_2^{1.4} = C \quad \ldots\ldots (2)$$

Therefore,

$$p_1V_1^{1.4} = p_2V_2^{1.4}$$

$$p_2 = p_1\left(\frac{V_1}{V_2}\right)^{1.4}$$

Substitute 1.5 bar for p_1, 0.03 m^3 for V_1 and 0.05 m^3 for V_2.

$$p_2 = (1.5)\left(\frac{0.03}{0.05}\right)^{1.4}$$

$$= 0.73 \text{ bar}$$

Use the following expression for work done (W) by the gas:

$$W = \int_{V_1}^{V_2} p\,dv$$

Here, p is pressure.

Substitute $\frac{C}{V^{1.4}}$ for p from equation (1).

$$
\begin{aligned}
W &= \int_{V_1}^{V_2} \frac{C}{V^{1.4}}\,dv \\
&= C\int_{V_1}^{V_2} \frac{dv}{V^{1.4}} \\
&= C\left[\frac{V^{-1.4+1}}{-1.4+1}\right]_{V_1}^{V_2} \\
&= \frac{C}{0.4}\left(V_1^{-0.4} - V_2^{-0.4}\right) \\
&= \frac{1}{0.4}\left(CV_1^{-0.4} - CV_2^{-0.4}\right)
\end{aligned}
$$

Use equation (2) to modify above expression:

$$
\begin{aligned}
W &= \frac{1}{0.4}\left[\left(p_1V_1^{1.4}\right)\left(V_1^{-0.4}\right) - \left(p_2V_2^{1.4}\right)\left(V_2^{-0.4}\right)\right] \\
&= \frac{p_1V_1 - p_2V_2}{0.4}
\end{aligned}
$$

Substitute 1.5 bar for p_1, 0.73 bar for p_2, $0.03\ \text{m}^3$ for V_1 and $0.05\ \text{m}^3$ for V_2.

$$
\begin{aligned}
W &= \frac{(1.5\ \text{bar})\left(0.03\ \text{m}^3\right) - (0.73\ \text{bar})\left(0.05\ \text{m}^3\right)}{0.4} \\
&= \frac{\left[\begin{array}{l}\left(1.5\times10^5\ \text{N}/\text{m}^2\right)\left(0.03\ \text{m}^3\right) \\ -\left(0.73\times10^5\ \text{N}/\text{m}^2\right)\left(0.05\ \text{m}^3\right)\end{array}\right]}{0.4} \qquad \left[1\ \text{bar} = 10^5\ \text{N}/\text{m}^2\right] \\
&= \frac{850}{0.4}\ \text{J} \\
&= 2125\ \text{J}
\end{aligned}
$$

Thus, work done by the gas is $\boxed{2125\ \text{J}}$.

21)An electric motor that is connected to a supply voltage of 100 V draws 10 amp current. The output shaft of the motor has a rotational speed of 800 rpm and develops a torque of 11 N. m. For steady state operation of the motor, determine the rate of heat transfer.

Solution:

To determine the rate of heat transfer $\dot{Q}$, write the energy rate balance equation as follows:

$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

Here, $\frac{dE}{dt}$ is rate of change in energy, $\dot{Q}$ is heat transfer rate and $\dot{W}$ is rate of work done.

Under steady state condition, $\frac{dE}{dt} = 0$, so modify above expression to obtain the following expression:

$$0 = \dot{Q} - \dot{W}$$

$$\dot{Q} = \dot{W} \qquad \ldots\ldots (1)$$

The net rate of work done by the motor is equal to the sum of power developed by shaft $\left(\dot{W}_{\text{shaft}}\right)$ and electric power consumed by motor $\left(\dot{W}_{\text{electric}}\right)$. Therefore,

$$\dot{W} = \dot{W}_{\text{electric}} + \dot{W}_{\text{shaft}} \qquad \ldots\ldots (2)$$

Calculate the electric power consumed by the motor from the following relation:

$$\dot{W}_{\text{electric}} = -VI$$

Here, V is voltage and I is current.

Substitute 100 V for V and 10 amp for I.

$$\begin{aligned}\dot{W}_{\text{electric}} &= -(100)(10) \\ &= -1000 \text{ W}\end{aligned}$$

Calculate the power developed by the output shaft from the following relation:

$$\dot{W}_{\text{shaft}} = \tau\left(\frac{2\pi N}{60}\right)$$

Here, τ is torque and N is rotational speed in RPM.

Substitute $11 \text{ N}\cdot\text{m}$ for τ and 800 RPM for N.

$$\begin{aligned}\dot{W}_{\text{shaft}} &= (11)\left(\frac{2\pi}{60}\right)(800) \\ &= 921.5 \text{ W}\end{aligned}$$

Substitute 921.5 W for $\dot{W}_{\text{shaft}}$ and -1000 W for $\dot{W}_{\text{electric}}$ in equation (2).

$$\begin{aligned}\dot{W} &= \dot{W}_{\text{electric}} + \dot{W}_{\text{shaft}} \\ &= -1000 \text{ W} + 921.5 \text{ W} \\ &= -78.5 \text{ W}\end{aligned}$$

Substitute -78.5 W for $\dot{W}$ in equation (1) to determine the value of rate of heat transfer.

$$\begin{aligned}\dot{Q} &= \dot{W} \\ &= -78.5 \text{ W}\end{aligned}$$

Negative sign indicates that heat is lost by the motor and the rate of heat transfer is $\boxed{78.5 \text{ W}}$.