

An Introduction to Mechanical Engineering | (4th Edition)

Problem

A four-stroke gasoline engine produces an output of 35 kW. Using the density of gasoline listed in Table 6.1, the heating value for gasoline in Table 7.3, and a typical efficiency listed in Table 7.6, estimate the engine's rate of fuel consumption. Express your answer in the units of liters per hour.

Table 6.1 Density and Viscosity Values for Several Gases and Liquids at Room Temperature and Pressure	Fluid		Density, ρ		Viscosity, μ	
			kg/m ³	slug/ft ³	kg/(m · s)	slug/l
	Air		1.20	2.33×10^{-3}	1.8×10^{-5}	3.8×10^{-6}
	Helium		0.182	3.53×10^{-4}	1.9×10^{-5}	4.1×10^{-6}
	Freshwater		1000	1.94	1.0×10^{-3}	2.1×10^{-4}
	Seawater		1026	1.99	1.2×10^{-3}	2.5×10^{-4}
	Gasoline		680	1.32	2.9×10^{-4}	6.1×10^{-5}
	SAE 30 oil		917	1.78	0.26	5.4×10^{-4}

Heating Values for Certain Fuels*	Type	Fuel	MJ/kg	Btu/lbm	
	Gas	Natural gas	47	20.2×10^3	
		Propane	46	19.8×10^3	
	Liquid	Gasoline	45	19.3×10^3	
		Diesel	43	18.5×10^3	
		Fuel oil	42	18.0×10^3	
	Solid	Coal	30	12.9×10^3	
		Wood	20	8.6×10^3	
	*The numerical values are representative, and values for specific fuels could vary with their chemical composition.				

Typical Efficiencies of Thermal and Energy Systems	Energy System		Required Input	Desired Output	Real Efficiency
	Engines and motors				
	Internal-combustion engine	Gasoline	Crankshaft work	15–25	
	Diesel engine	Diesel	Crankshaft work	35–45	
	Electric motor	Electricity	Shaft work	80–95	
	Automobile	Gasoline	Motion	10–15	
	Electrical power generation				
	Fossil-fuel plant	Fuel	Electricity	30–45	
	Fuel cells	Fuel and oxidant	Electricity	30–60	
	Nuclear plant	Fuel	Electricity	32–35	
	Photovoltaic solar cell	Sunlight	Electricity	5–15	
	Wind turbine	Wind	Shaft work	30–50	
	Wave energy convertor	Waves and currents	Electricity	10–20	
	Hydroelectric plant	Water flow	Electricity	70–90	
	Residential				
	Forced-air furnace	Natural gas	Heat	80–90	
	Hot water heater	Natural gas	Heat	60–65	

Step-by-step solution

Step 1 of 6

Calculate the maximum rate of heat input to engine to produce 35 kW power.

$$Q_{\max} = \frac{W}{\eta_{\min}}$$

Here, power output of engine is W and the efficiency is $\eta_{\min}$.

Substitute 35 kW for W and 15% for $\eta_{\min}$.

$$Q_{\max} = \frac{35}{0.15} = 233.33 \text{ kW}$$

Comment

Step 2 of 6

Calculate the maximum mass flow rate as follows:

$$Q_{\max} = \dot{m}_{\max} \times H$$

Here, the heating value of gasoline is H .

Substitute 233.33 kW for $Q_{\max}$ and 45000 kJ for H .

$$233.33 \text{ kW} = \dot{m}_{\max} \times 45000 \text{ kJ}$$

$$\dot{m}_{\max} = \frac{233.33}{45000}$$

$$\dot{m}_{\max} = 0.00518 \frac{\text{kg}}{\text{s}} \times \frac{3600 \text{ sec}}{1 \text{ h}}$$

$$= 18.6664 \frac{\text{kg}}{\text{h}}$$

Comment

Step 3 of 6

Calculate the volume flow rate of fuel consumption as follows:

$$\dot{V}_{\max} = \frac{\dot{m}_{\max}}{\rho}$$

Here, the density of the gasoline is ρ .

Substitute 680 kg/m³ for ρ and 18.6664 $\frac{\text{kg}}{\text{h}}$ for $\dot{m}_{\max}$.

$$\begin{aligned} \dot{V}_{\max} &= \frac{18.648 \text{ m}^3}{680 \text{ hr}} \\ &= 0.0274235 \frac{\text{m}^3}{\text{hr}} \times \frac{1 \text{ h}}{10^{-3} \text{ m}^3} \\ &= 27.423 \text{ l/m}^3 \end{aligned}$$

Comment

Step 4 of 6

Calculate the minimum rate of heat input to engine to produce 35 kW power.

$$Q_{\min} = \frac{W}{\eta_{\max}}$$

Substitute 35 kW for W and 25% for $\eta_{\max}$.

$$Q_{\min} = \frac{35}{0.25} = 140 \text{ kW}$$

Comment

Step 5 of 6

Calculate the minimum mass flow rate of for maximum heat input as follows:

$$Q_{\min} = \dot{m}_{\min} \times H$$

Substitute 140 kW for W and 45000 kJ for H .

$$140 \text{ kW} = \dot{m}_{\min} \times 45000 \text{ kJ}$$

$$\dot{m}_{\min} = \frac{140}{45000}$$

$$\dot{m}_{\min} = 0.003111 \text{ kg/s} \times \frac{3600 \text{ sec}}{1 \text{ h}}$$

$$= 11.2 \frac{\text{kg}}{\text{h}}$$

Comment

Step 6 of 6

Calculate the volume flow rate of fuel consumption as follows:

$$\dot{V}_{\min} = \frac{\dot{m}_{\min}}{\rho}$$

Substitute 680 kg/m³ for ρ and 11.2 $\frac{\text{kg}}{\text{h}}$ for $\dot{m}_{\min}$.

$$\begin{aligned} \dot{V}_{\min} &= \frac{11.2 \text{ m}^3}{680 \text{ hr}} \\ &= 0.0169117 \frac{\text{m}^3}{\text{hr}} \times \frac{1 \text{ h}}{10^{-3} \text{ m}^3} \\ &= 16.91 \text{ l/m}^3 \end{aligned}$$

Therefore the consumption of gasoline varies from 25.423 l to 16.91 l per hour.

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1

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Recommended solutions for you in Chapter 7

Chapter 7, Problem 16P

A welding rod with is 20 cm long and has a diameter of 4 mm. The two ends of the rod are held at 500°C and 50°C. (a) In the...

See solution

$$k = 30 \text{ (Btu/h)/(ft} \cdot \text{°F)}$$

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