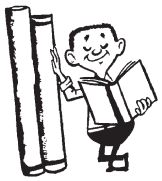
Jet Propulsion

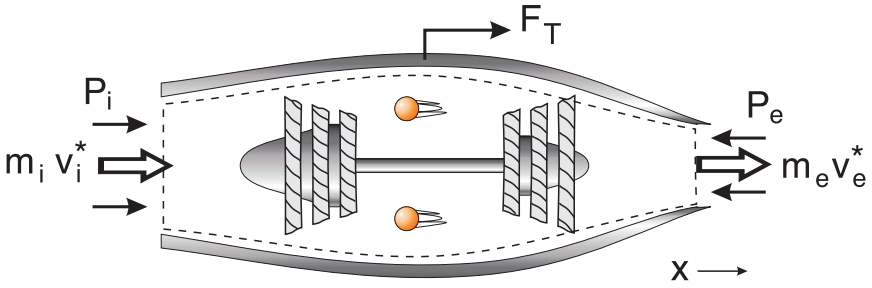


Reading	Problems
9-11	9-145, 9-147

Gas Turbines for Aircraft Propulsion

- gas turbines are well suited to aircraft propulsion because of their favorable power-to-weight ratio
- typically operate at higher pressure ratios, often in the range of 10 to 25

Conservation of Momentum



where v_i^* is the velocity of the aircraft

$$\frac{d(Mom)_{x,cv}}{dt} = (\dot{M}om)_{x,in} - (\dot{M}om)_{x,out} + \sum F_x$$

for steady flow $\Rightarrow \dfrac{d}{dt} = 0$ and

$$\dot{m}_i v_i^* - \dot{m}_e v_e^* + F_T + P_i A_i - P_e A_e = 0$$

Since the air-fuel mass ratio is high

$$\dot{m}_{fuel} << \dot{m}_i \qquad \Rightarrow \ \dot{m}_i \approx \dot{m}_e$$

and

$$P_e \approx P_i \approx P_{atm}$$

Therefore

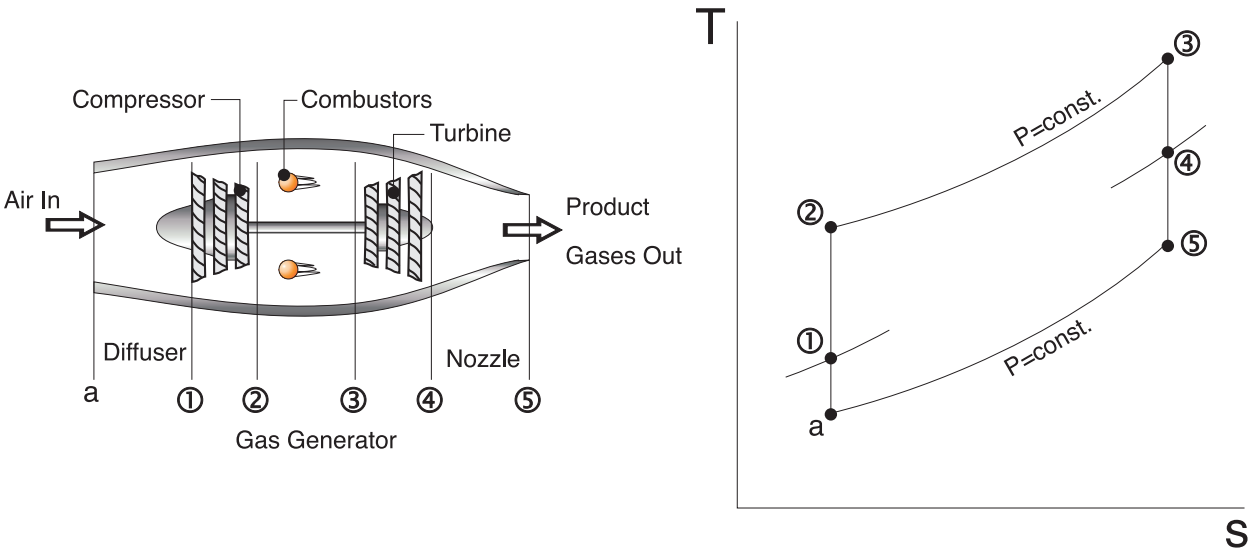
$$\begin{aligned} F_T &= \dot{m}_e v_e^* - \dot{m}_i v_i^* - \underbrace{P_{atm}(A_i - A_e)}_{negligible} \\ &= \dot{m}_i (v_e^* - v_i^*) \end{aligned}$$

Specific Impulse: $I = \dfrac{F_T}{\dot{m}_i} = v_e^* - v_i^* = \dfrac{\text{thrust}}{\text{mass}}$

Propulsive Power: $\dot{W}_T = F_T \, v_i^* \approx \dot{m}_i (v_e^* - v_i^*) v_i^*$

Propulsive Efficiency: $\eta = \dfrac{\dot{W}_T}{\dot{Q}_{in}}$

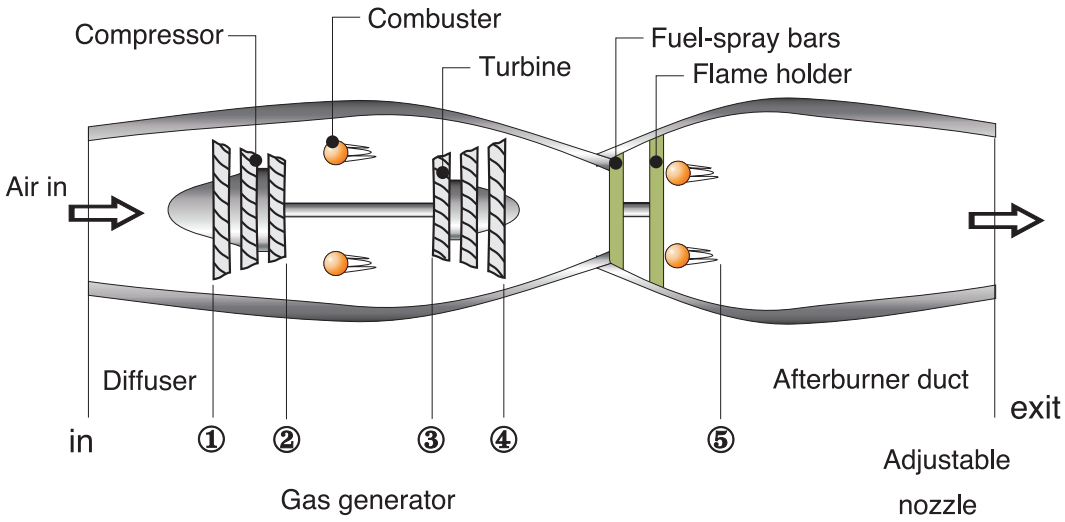
Turbojet Engine



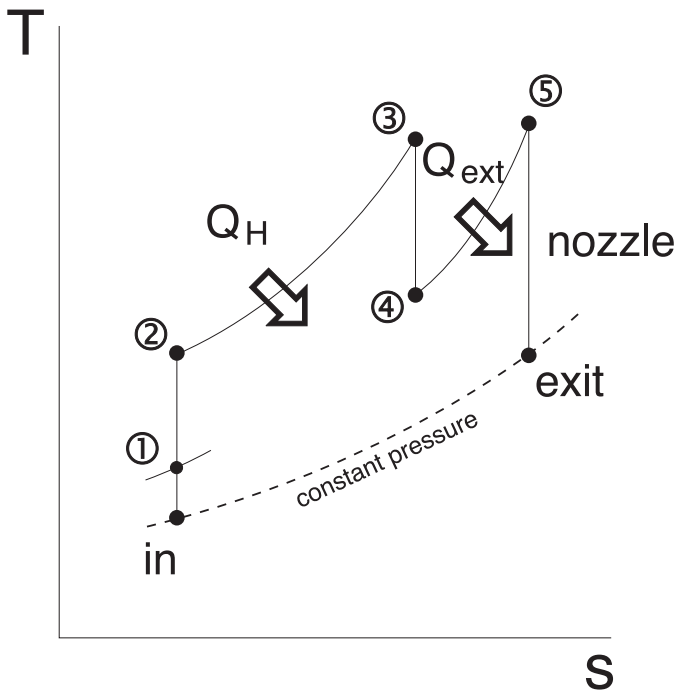
Sections

- **a-1**: **diffuser**
  - decelerates the incoming flow relative to the engine
- **1-4**: gas generator
  - compressor, combustor and turbine
    - 1-2: isentropic compression
    - 2-3: constant pressure heat addition
    - 3-4: isentropic expansion through the turbine during which work is developed
  - turbine power just enough to drive the compressor
- **4-5**: nozzle
  - isentropic expansion through the nozzle, air accelerates and the pressure deceases
  - gases leave the turbine significantly higher in pressure than atmospheric pressure
  - gases are expanded to produce a high velocity, $\boldsymbol{v}_e^* >> \boldsymbol{v}_i^*$ results in a thrust

Afterburner

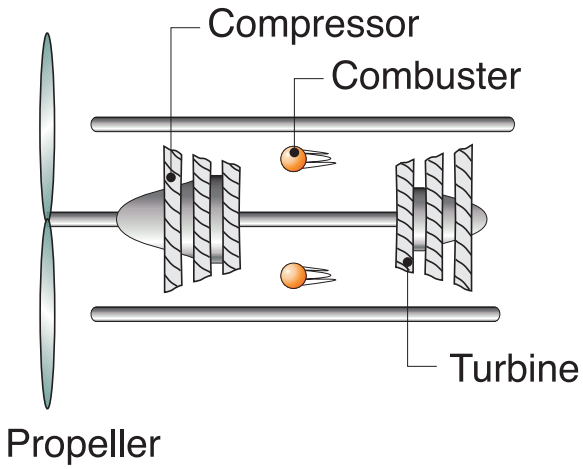


- similar to a reheat device
- produces a higher temperature at the nozzle inlet, $T_5 > T_4$
- results in an increase in velocity



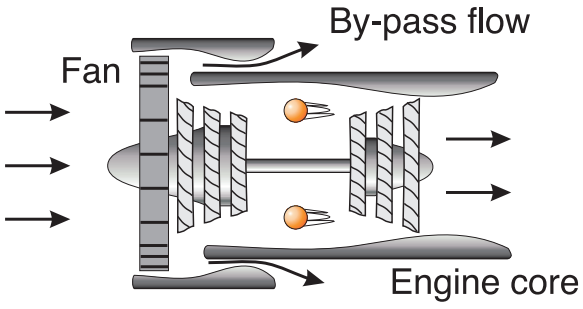
Other Types of Engines

1. Turbo-Prop Engine



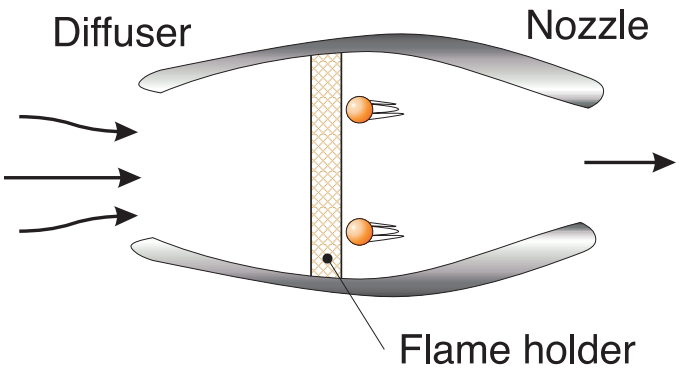
- gas turbine drives the compressor and the propeller
- most of the thrust is from the propeller
- works by accelerating large volumes of air to moderate velocities
- propellers are best suited for low speed ($<$ 300 mph) flight
- new turbo-props are suitable for velocities up to 500 mph
- by-pass ratio of 100:1 or more

2. Turbo-Fan Engine (Ducted Turbo-Prop Engine)



- by-pass ratio can be adjusted
- typical by-pass ratios are 5-6

3. Ramjet



- compression is achieved by decelerating the high-speed incoming air in the diffuser

4. Pulse Jet Engine

- similar to a ram jet but lets in a slug of air at a time and then closes a damper during the combustion stage
- uses a shutter-type valve for damper control