Summary:

Jet Propulsion Cycle:

1□2 **Diffuser**: Air pressure is slightly increased as it is decelerated
2□3 **Compressor**: Air is compressed to higher pressure
3□4 **Burner Section**: Air is mixed with fuel and burned at constant P
4□5 **Turbine**: Gases are partially expanded to produce enough power to drive the compressor and other equipment
5□6 **Nozzle**: Gases expanded to atmospheric pressure and accelerated

Note: For ideal case, diffuser, compressor, turbine, and nozzle processes are modeled isentropic.

Common Assumptions:

1) Δpe ≈ 0 for all components
2) Δke ≈ 0 for compressor, burner, and turbine sections ONLY
3) Cold-air standard assumptions are applicable
4) Steady operation for all components
5) *$W_{comp,in} = W_{turb,out}$*

Analysis

1) Diffuser

$$\frac{d\dot{E}_{cv}}{dt} = \dot{m}_{air}\left[(ke+pe+h)_1 - (ke+pe+h)_2\right] \rightarrow \dot{m}_{air}\left[ke_1 + h_1 - h_2\right] = 0$$

$$\frac{V_1^2}{2} + c_p(T_1 - T_2) = 0$$

2) Nozzle

$$\frac{d\dot{E}_{cv}}{dt} = \dot{m}_{air}\left[(ke+pe+h)_5 - (ke+pe+h)_6\right] \rightarrow \dot{m}_{air}\left[h_5 - (h_6 + ke_6)\right] = 0$$

$$c_p(T_5 - T_6) - \frac{V_6^2}{2} = 0$$

Thrust

The thrust (F) is the unbalanced force that is caused by the difference in the momentum of the low-velocity air entering the engine and the high-velocity gases leaving the engine

$$F = \dot{m}_{air}(V_{exit} - V_{inlet})$$

Note: The velocities are relative to the aircraft. In still air, $V_{inlet}=V_{aircraft}$.

Propulsive Power

The propulsive power ($\dot{W}_p$) is the power developed from the thrust of the engine.

$$\dot{W}_p = \dot{m}_{air}(V_{exit} - V_{inlet})V_{aircraft}$$

Propulsive Efficiency

$$\eta_p = \frac{\dot{W}_p}{\dot{Q}_{in}}$$

Reminder

For isentropic processes with constant c_p and c_v:

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}} \quad \text{Or} \quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

Question:

A turbojet is flying with a velocity of 320 m/s at an altitude of 9150m, where the ambient conditions are 32 kPa and -32°C. The pressure ratio across the compressor is 12, and the temperature at the turbine inlet is 1400 K. Air enters the compressor at a rate of 40 kg/s, and the jet fuel has a heating value of 42,700 kJ/kg. Assuming ideal operation for all components and constant specific heats for air at room temperature, determine:

a) the temperature and pressure at the turbine exit,
b) the velocity of the exhaust gases,
c) the propulsive power developed,
d) the propulsive efficiency, and
e) the rate of fuel consumption.