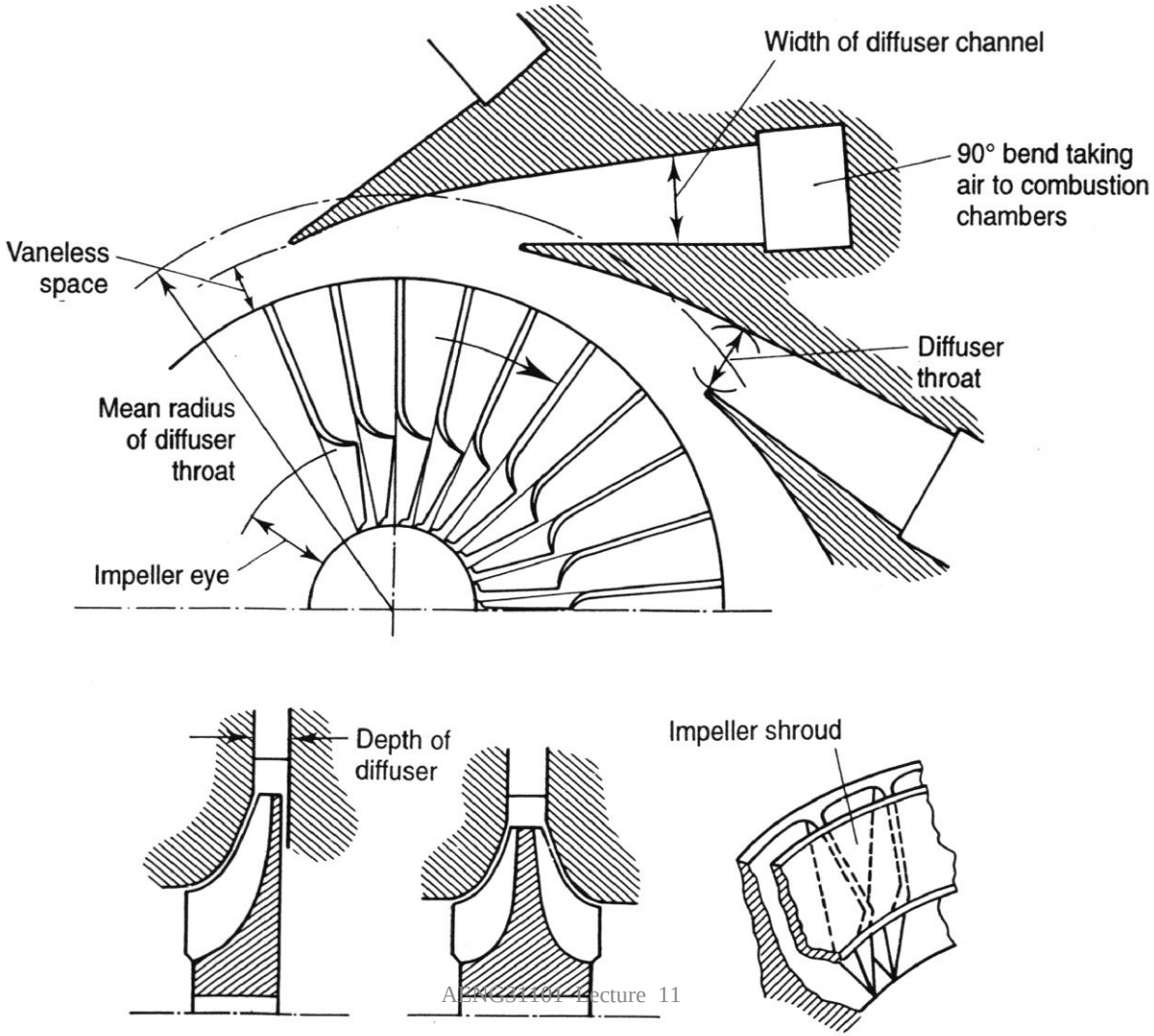
Lecture 11

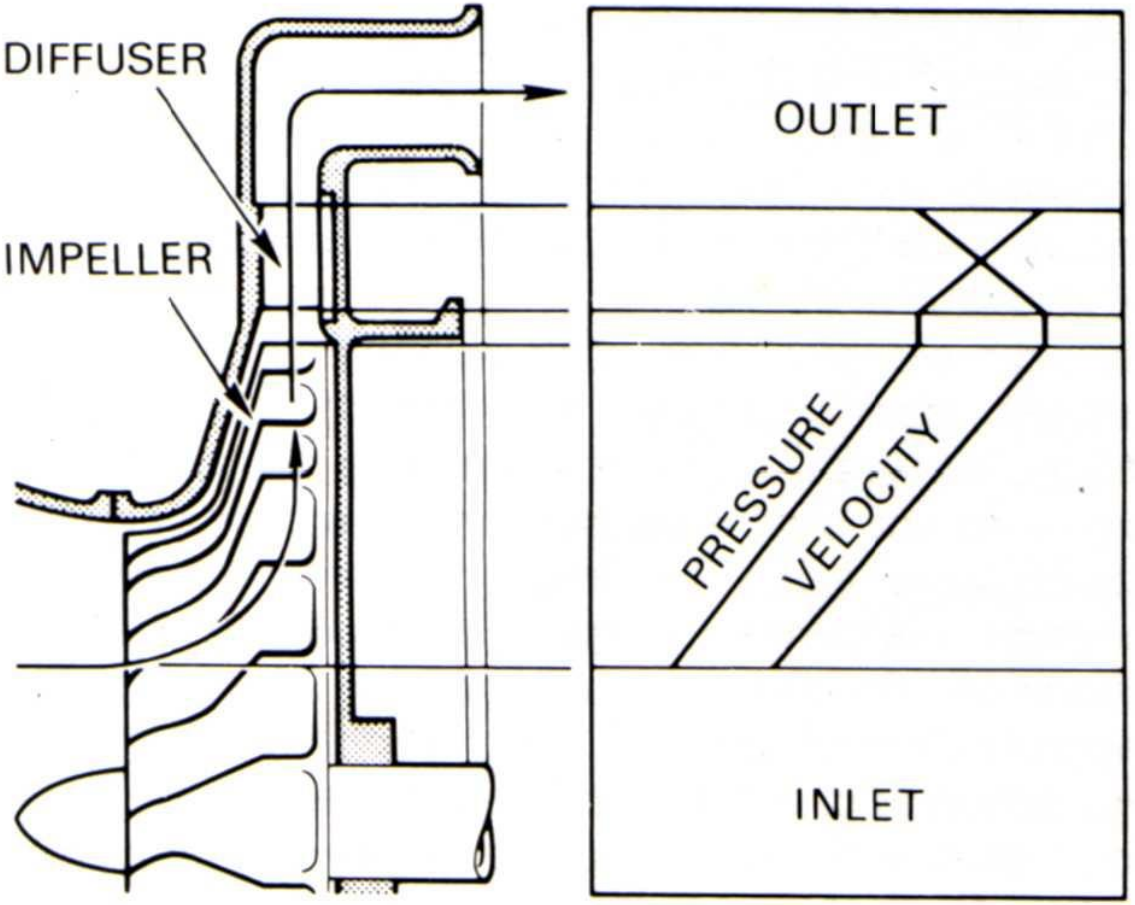
# Centrifugal Compressors

***Objective: to describe the workings of a Centrifugal Compressor***

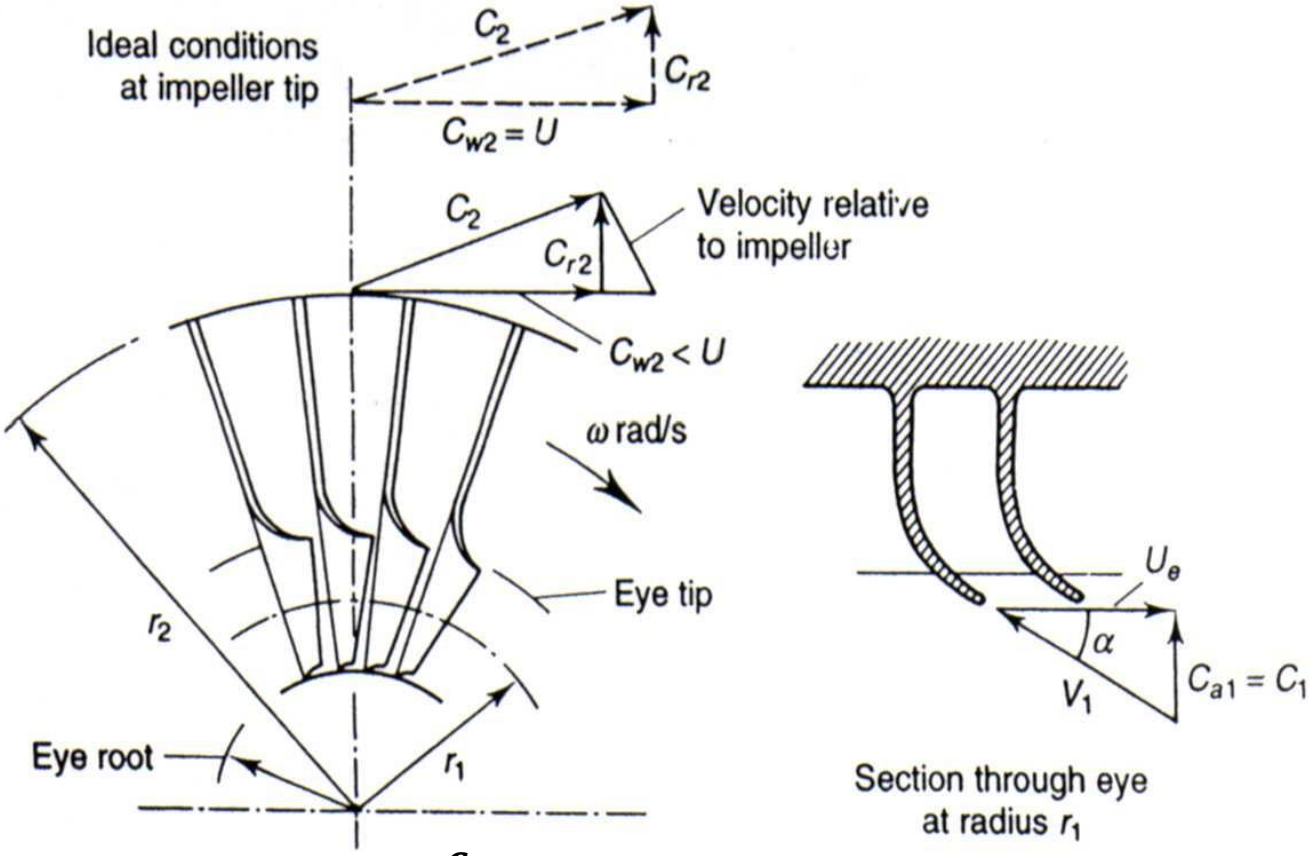
# CENTRIFUGAL COMPRESSOR LAYOUT



# Pressure & Velocity changes through a CF Compressor



# Velocity Triangles for a CF Impeller




***Slip Factor:*** $\sigma = \frac{C_{w2}}{U}$

***Power Input Factor:***

$\psi = Ratio\ of\ actual\ work\ input\ to\ theoretical\ work\ input$

# Pressure Rise for a CF Impeller

Theoretical Torque $\boldsymbol{T_{theoretical}} = C_{w2} \cdot r_2$

Work Done on Air $\boldsymbol{W} = T \cdot \omega$

Theoretical Work Done $\boldsymbol{W_{theoretical}} = C_{w2} \cdot r_2 \cdot \omega = \sigma \cdot U^2$

Actual Work Done $\boldsymbol{W_{actual}} = W_{theoretical} \cdot \psi = \sigma \cdot U^2 \cdot \psi$

No work done in diffuser $\boldsymbol{T_{o3}} = \boldsymbol{T_{o2}}$

Work Done $\boldsymbol{W_{actual}} = C_p\,(T_{o3} - T_{O1}) = \psi \cdot \sigma \cdot U^2$

Thus pressure rise: $\dfrac{p_{O3}}{p_{O1}} = \left(\dfrac{T'_{O3}}{T_{O1}}\right)^{\frac{\gamma}{\gamma-1}}$ $\eta_{isen} = \dfrac{T'_{O3} - T_{O1}}{T_{O3} - T_{O1}}$

$$\frac{p_{O3}}{p_{O1}} = \left(1 + \frac{\eta_{isen}\psi\sigma U^2}{C_p T_{O1}}\right)^{\frac{\gamma}{\gamma-1}}$$

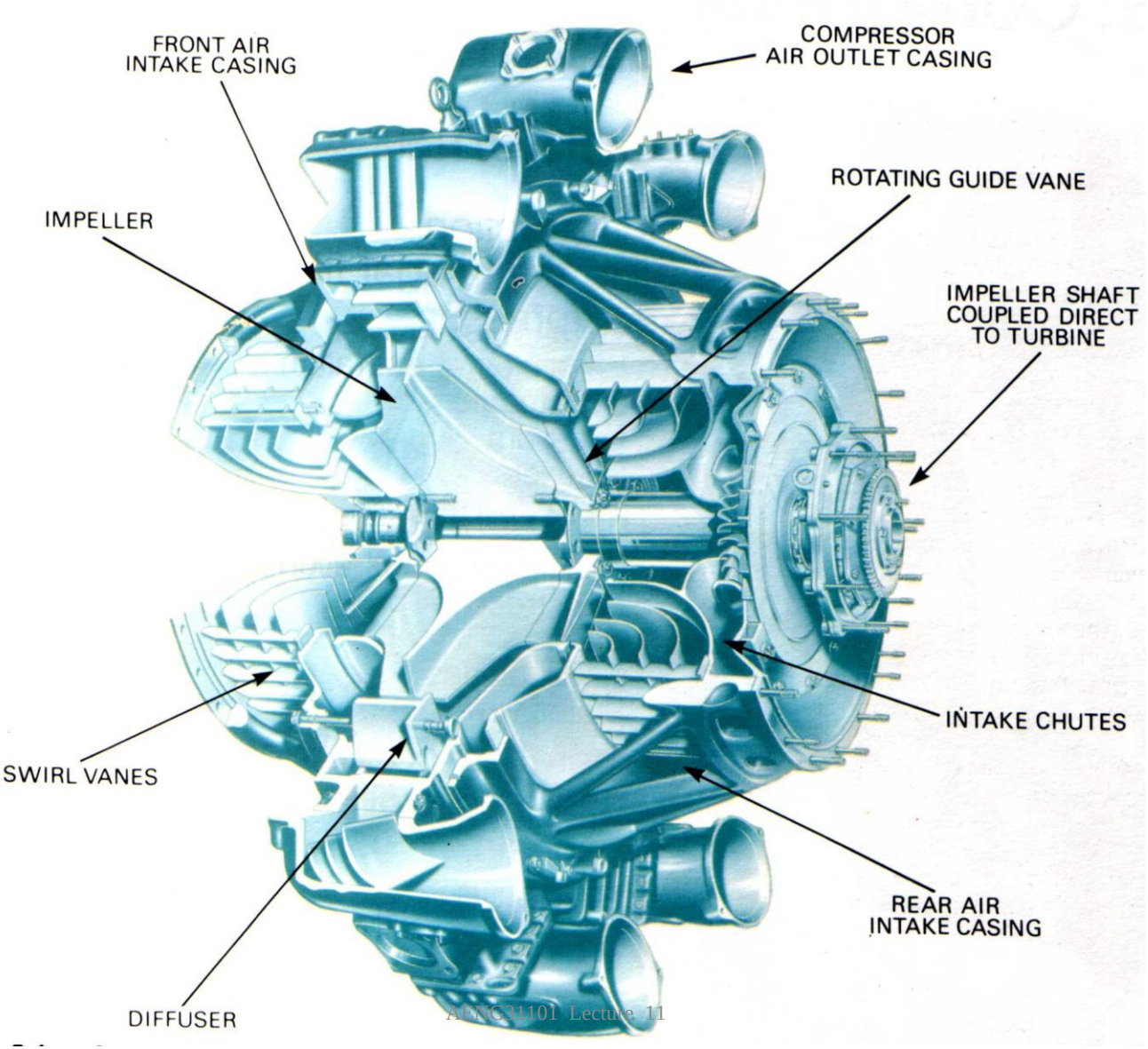
# Factors effecting Pressure Rise

- Isentropic Efficiency
- Slip Factor $\sigma = (1 - K/n) \sim 0.9$

  n = number of vanes; k = Constant
- Power Input Factor $\psi \sim 1.04$ (approx.)
- Diffuser losses
- Impeller Tip Speed

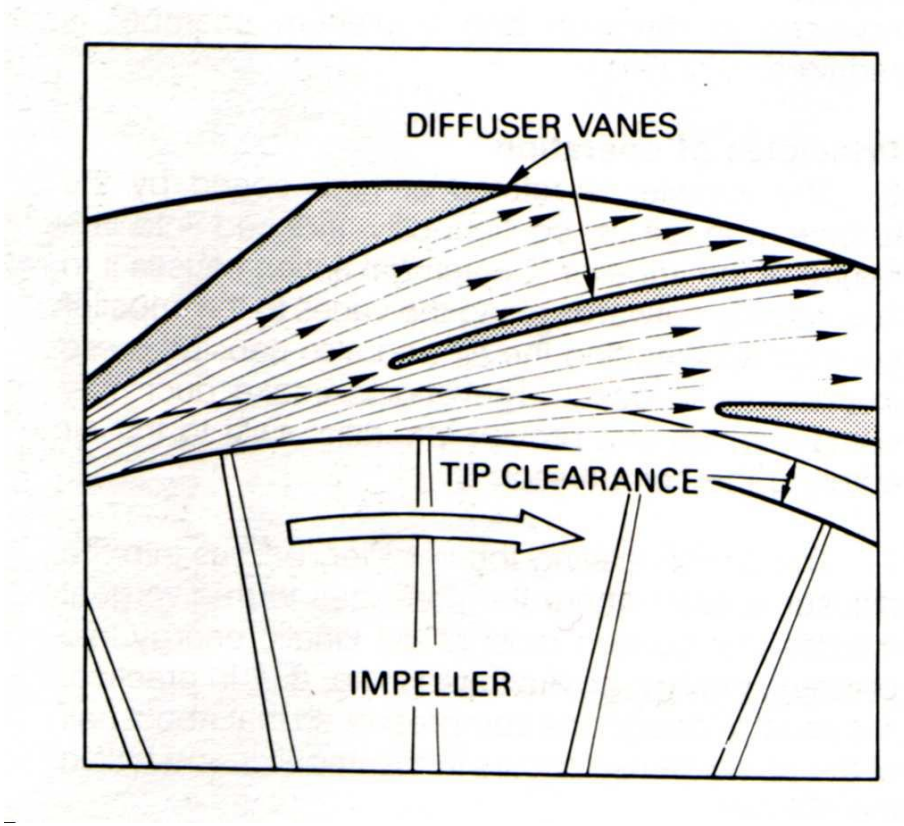
  450 - 500 M/Sec for light alloys; higher for Titaniums etc.
- Pressure ratios for CF compressors (with $T_o = 288$) = 4 : 1 for light alloys greater with Titaniums

# Typical Centrifugal Compressor



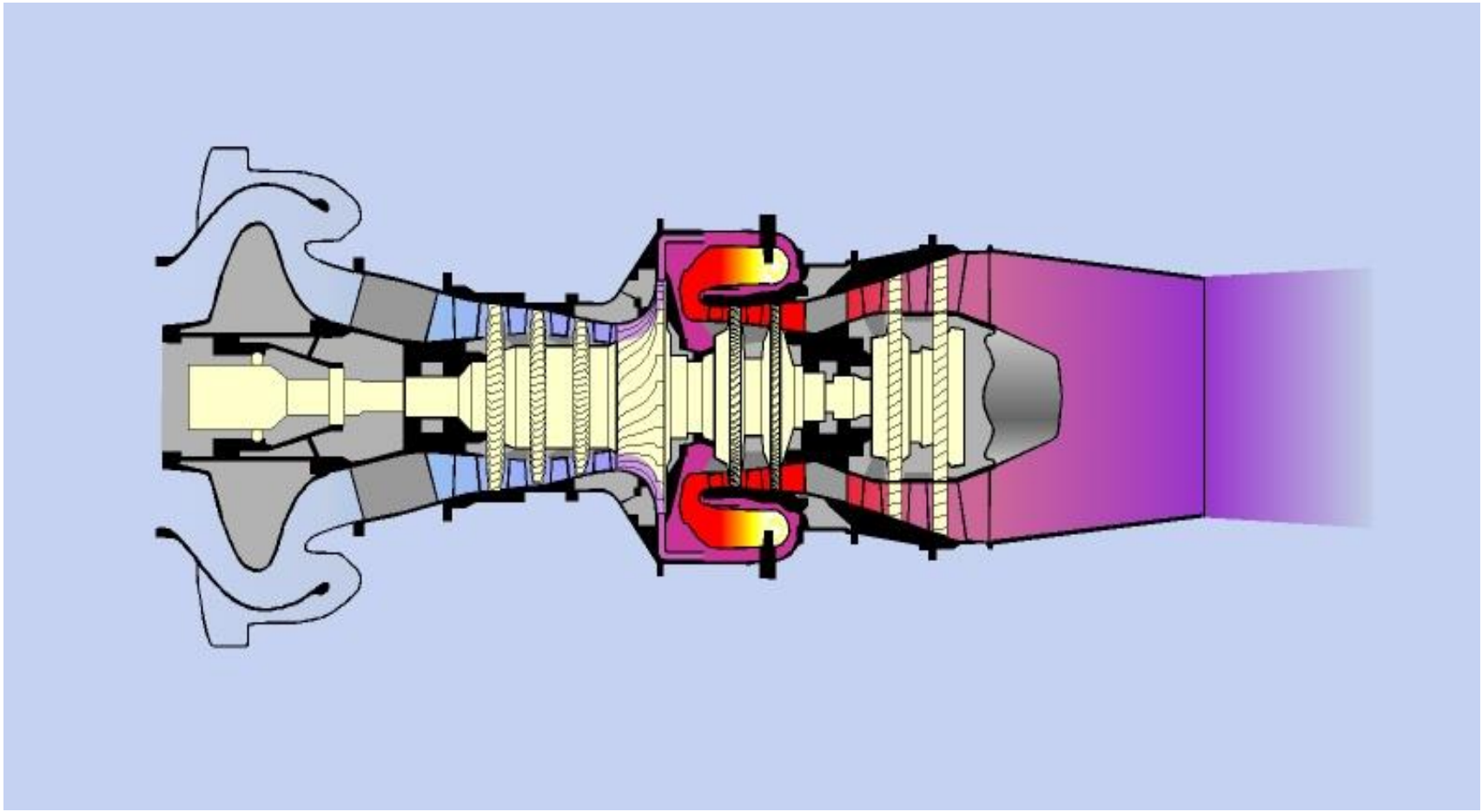
# Centrifugal Compressors

Impeller

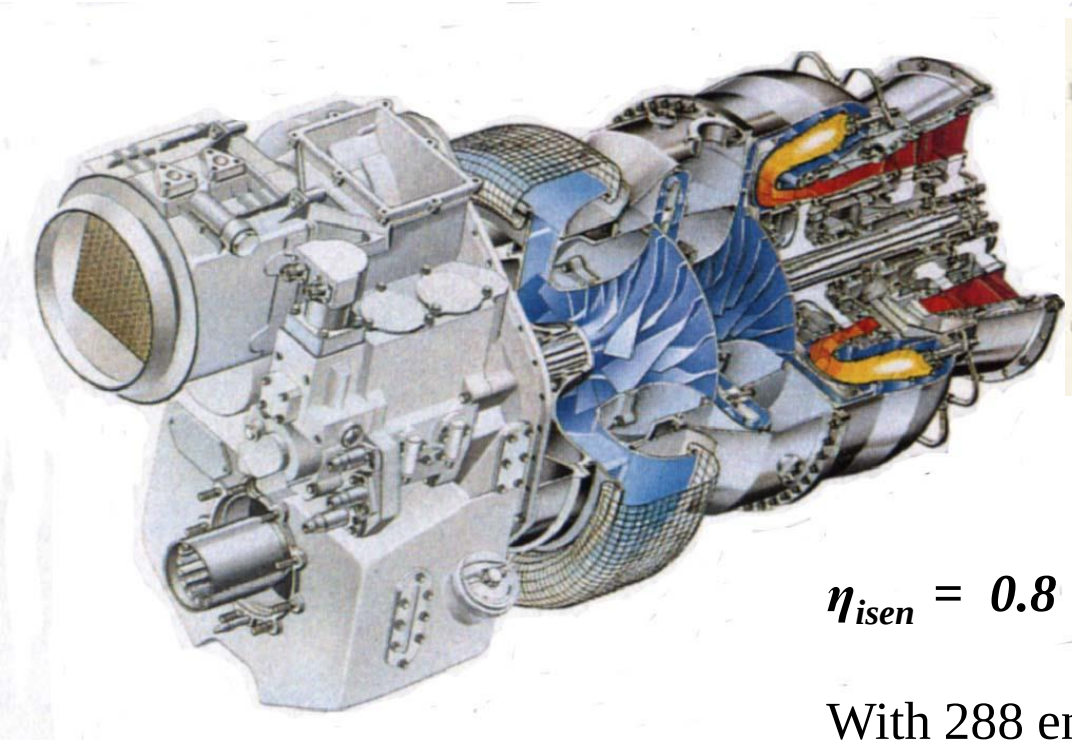


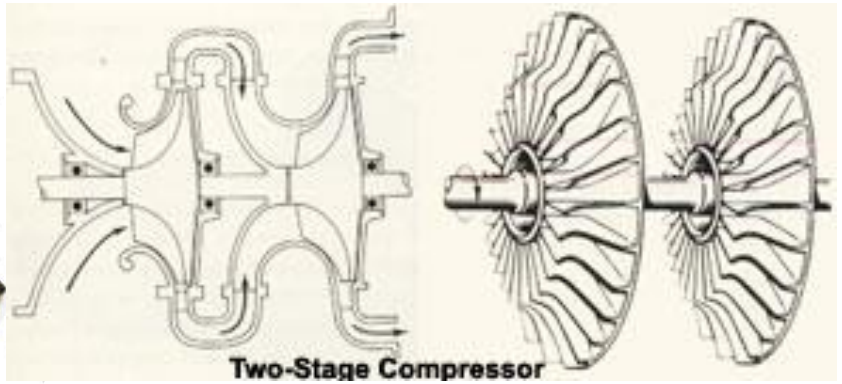

Airflow at entry to diffuser

# Typical Engine layout with a Centrifugal Compressor



# MTR 390






$\eta_{isen} = 0.8 \quad \psi = 1.04 \quad \sigma = 0.92 \quad U = 450\ m/s$

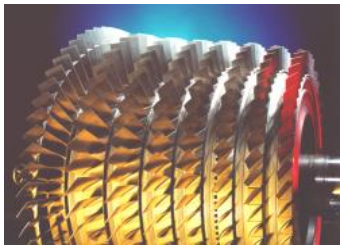
$$\frac{p_{O3}}{p_{O1}} = \left(1 + \frac{\eta_{isen}\psi\sigma U^2}{C_p T_{O1}}\right)^{\frac{\gamma}{\gamma-1}}$$

With 288 entry to first stage,
Pressure Ratio ~ 4.4 & Temperature at exit ~ 450

With 450 entry to second stage,
Pressure Ratio ~ 2.8
Overall Pressure ratio ~ 12.5

# Class Exercise

## *Which type of compressor?*

Centrifugal or  Axial

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# High By-pass ratio Turbofans for Passenger Aircraft