① At inlet: $P_2 = 90$ kPa, $T_2 = 250$ K, $\gamma = 1.4$, $R = 287$ J/kgK

$C_p = \frac{\gamma}{\gamma-1} R = 1004.5$ J/kgK

$\rho_2 = \frac{P_2}{RT_2} = \underline{1.254 \text{ kg/m}^3}$

$C_{z_2} = C_2 = M_2 \cdot \sqrt{\gamma R T_2} = \underline{142.62 \text{ m/s}}$ and, $\underline{C_{\theta_2} = 0}$

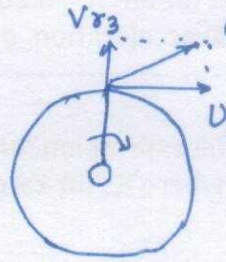
$r_{h_2} = 0.05$ m, $r_{t_2} = 0.1$ m $\Rightarrow$ $\dot{m} = \rho_2 \cdot C_{z_2} \pi (r_{t_2}^2 - r_{h_2}^2)$

$\underline{\dot{m} = 4.214 \text{ kg/s}}$

At exit: Straight radial vanes

$C_{\theta_3} = U_3$; But with slip,

$C_{\theta_3} = \varepsilon \cdot U_3$



$\therefore W = U_3 C_{\theta_3} - U_2 C_{\theta_2} = \underline{\varepsilon U_3^2}$

$N = 14400$ rpm $\Rightarrow$ $\Omega = \frac{2\pi N}{60} = \underline{1507.96 \text{ rad/s}}$

$U_3 = \Omega r_3$ where $r_3 = 0.25$ m

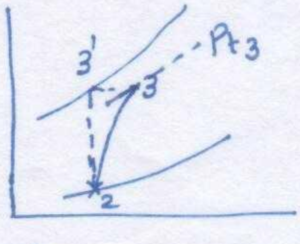
$\therefore \underline{U_3 = 377 \text{ m/s}}$ $\Rightarrow$ $W = \varepsilon U_3^2 = \underline{127.916 \text{ kJ/kg}}$

Power, $\underline{P = \dot{m} W = 539.038 \text{ kW}}$

stagnation conditions at inlet: $T_{t_2} = T_2 \cdot \left(1 + \frac{\gamma-1}{2} M_2^2\right) = \underline{260.125 \text{ K}}$

$P_{t_2} = \underline{103.416 \text{ kPa}}$

$W = C_p (T_{t_3} - T_{t_2}) \Rightarrow \underline{T_{t_3} = 387.468 \text{ K}}$



$\frac{P_{t_3}}{P_{t_2}} = \left(\frac{T_{t_3}}{T_{t_2}}\right)^{\frac{\gamma e_c}{\gamma-1}}$ where, $\underline{e_c = 0.85}$

$\frac{P_{t_3}}{P_{t_2}} = \underline{3.27}$ —— compressor pressure ratio

$\therefore P_{t_3} = \underline{\cancel{383.393}}$ kPa 338.17

At exit: $C_{\theta_3} = 339.3$ m/s, $C_{r_3} = V_{r_3} = C_{z_2} = 142.62$ m/s

$C_3 = \sqrt{C_{\theta_3}^2 + C_{r_3}^2}$ $\Rightarrow$ $\underline{C_3 = 368.055 \text{ m/s}}$

Further, $\dot{m} = 2\pi r_3 \cdot b \cdot V_{r_3} \rho_3 \Rightarrow$ ~~Width b~~ We need ρ_3.

$$C_p \cdot T_{t3} = C_p T_3 + \frac{C_3^2}{2} \Rightarrow \underline{T_3 = 320.04 \text{ K}}$$

$$\frac{P_{t3}}{P_3} = \left(\frac{T_{t3}}{T_3}\right)^{\frac{\gamma}{\gamma-1}} \Rightarrow \underline{P_3 = \cancel{196.351} \text{ kPa}}$$

173.243

$$\therefore \rho_3 = \frac{P_3}{RT_3} = \underline{\cancel{2.137} \text{ kg/m}^3}$$

1.886

9.973.

$$\therefore \underline{b = \cancel{8.8} \text{ mm}}$$

$$\cancel{M_3} \quad a_3 = \sqrt{\gamma R T_3} = 358.6 \text{ m/s}$$

$$\underline{M_3} = \frac{C_3}{a_3} \Rightarrow \underline{M_3 = 1.026}$$

Q.2] Let '3' $\Rightarrow$ inlet to diffuser & 4 $\Rightarrow$ outlet of diffuser.

$$M_3 = 1.026 \quad \& \quad \alpha_3 = \tan^{-1}\left(\frac{C_{\theta 3}}{C_{r3}}\right) = \underline{67.2^\circ}$$

For $\underline{M_3 = 1.026}$ & $\underline{\alpha_3 = 67.2^\circ}$ $\Rightarrow$ $\underline{\alpha^* \approx 70^\circ}$, $\underline{r_3/r^* \approx 1}$

For $\alpha^* = 70^\circ$ & $M_4 = 0.5$ $\Rightarrow$ $\underline{r_4/r^* \approx 1.75}$

$$\therefore \frac{r_4}{r_3} = 1.75 \Rightarrow \underline{r_4 = 0.4375 \text{ m}}$$

338.170

At diffuser exit, $P_{t4} = P_{t3} = \cancel{383.393}$ kPa

$T_{t4} = T_{t3} = 387.468$ K

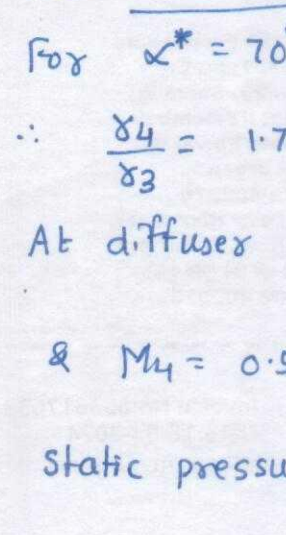
285.134

& $M_4 = 0.5 \Rightarrow \underline{P_4 = \cancel{323.207} \text{ kPa}}$

Static pressure recovery, $= P_4 - P_3 = \underline{\cancel{128.856} \text{ kPa}}$

111.891

Q.3] Small increase in $\dot{m} \Rightarrow$ increase in $C_z \Rightarrow$ Decrease in work done by the first stage $\Rightarrow$ Lead to lower ~~higher~~ output pressure & ~~higher~~ Lower density



C_z further increases due to combined effects of ① increase in $\dot{m}$, ② decrease in density

Small increase in C_z in first stage $\Rightarrow$ Negative incidence flow separation in later stages due to cascading effect.

Very high increase in C_z also leadsto negative pressure rise or throttling effect in final stages