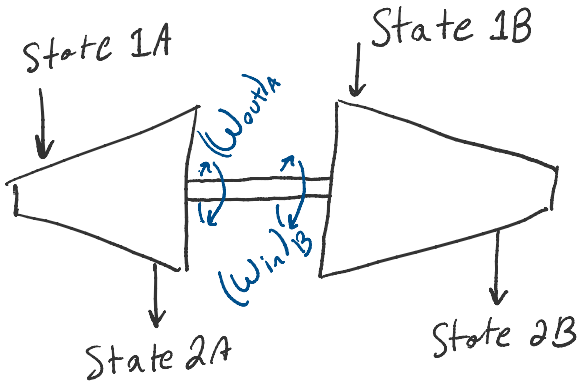
Q2

October 15, 2022 5:51 PM




# Turbine

| State 1 | State 2 |
|---|---|
| $T_1 = 400^\circ C = 673K$ | $T_2 = 100^\circ C = 373K$ |
| $P_1 = ?$ | $P_2 = 200kPa$ |
| $V_1 = 29 m/s$ | $V_2 = 5 m/s$ |
| $A_1 = 1 m^2$ | |

$$E_{out} = E_{in}$$
$$W_{out} + KE_{out} + H_{out} = KE_{in} + H_{in}$$
$$-W_{out} = \Delta H + \Delta KE$$
$$-W_{out} = \dot{m}(\Delta h + \Delta ke)$$

$\therefore 300 \leq \Delta T \leq 500 \rightarrow \Delta h = c_p(T_2 - T_1)$ (Table A2b)

$$\frac{c_p - 1.029}{523 - 500} = \frac{1.040 - 1.029}{550 - 500}$$
$$c_p = 1.034 \ kJ/kg \cdot K$$

$$P_{1A} V_{1A} = R_{air} T_{1A}$$
$$v = R_{air} T / P$$

$$P_{1A}\underline{v}_{1A} = R_{air}T_{1A}$$

$$\underline{v}_{1A} = R_{air}T_{1A}/P_{1A}$$

$$\dot{m}_A = \frac{A_{1A}V_{1A}}{\underline{v}_{1A}} = \frac{P_{1A}A_{1A}V_{1A}}{R_{air}T_{1A}}$$

$$(\dot{W}_{out})_A = -\frac{P_{1A}A_{1A}V_{1A}}{R_{air}T_{1A}}\left(C_p(T_{2A}-T_{1A}) + \frac{\frac{1}{2}(V_{2A}^2 - V_{1A}^2)}{1000}\right) \quad (1)$$

## Compressor

| State 1 | State 2 | |
|---|---|---|
| $T_{1B} = 150°C$ | $T_{2B} = 500°C$ | @ 100 kPa, $T_1 > T_{sat}$ ∴ superheated |
| $P_{1B} = 100\ kPa$ | $P_{2B} = 2\ MPa$ | $h_{1B} = 2776.6\ kJ/kg$ from Table A6 |
| $V_{1B} \doteq 0\ m/s$ | $V_{2B} = 100\ m/s$ | @ 2 MPa, $T_{2B} > T_{sat}$ |
| $\dot{m}_B = 10\ kg/s$ | | $h_{2B} = 3468.3\ kJ/kg$ from Table A6 |

$$E_{in} = E_{out}$$

$$H_{in} + KE_{in} + \dot{W}_{in} = H_{out} + KE_{out}$$

$$(\dot{W}_{in})_B = \dot{m}_B\left[(h_{2B}-h_{1B}) + \frac{1}{2}(V_{2B}^2 - V_{1B}^2)\right]$$

$$(\dot{W}_{in})_B = \dot{m}_B\left((h_{2B}-h_{1B}) + \frac{\frac{1}{2}(V_{2B}^2 - V_{1B}^2)}{1000}\right) \quad (2)$$

$$\bigstar\ (\dot{W}_{in})_B = (\dot{W}_{out})_A = \dot{W}$$

$$\dot{W} = \dot{m}_B\left((h_{2B}-h_{1B}) + \frac{\frac{1}{2}(V_{2B}^2 - V_{2B}^2)}{1000}\right) = -\frac{P_{1A}A_{1A}V_{1A}}{R_{air}T_{1A}}\left(C_p(T_{2A}-T_{1A}) + \frac{\frac{1}{2}(V_{2A}^2 - V_{1A}^2)}{1000}\right)$$

$$\dot{W} = (10)\left((3468.3-2776.6) + \frac{\frac{1}{2}(100^2 - 0^2)}{1000}\right)$$

a) $\boxed{\dot{W} = 6967\ kW}$

$$\dot{W} = -P_{1A}A_{1A}V_{1A}/(R_{air}T_{1A}) + \frac{1}{1000}(V_{2B}^2 - V_{1B}^2)$$

$$\dot{\omega} = -\frac{P_{1A} A_{1A} V_{1A}}{R_{air} T_{1A}} \left( C_p (T_{2A} - T_{1A}) + \frac{\frac{1}{2}(V_{2A}^2 - V_{1A}^2)}{1000} \right)$$

$$6967 = -\frac{P_{1A}(1)(20)}{(0.287)(400+273)} \left[ 1.034(100-400) + \frac{1}{2000}(5^2 - 20^2) \right]$$

$$6967 = P_{1A}(32.139)$$

b) $\boxed{P_{1A} = 216.77 \text{ kPa}}$

$$\dot{m}_B = \frac{A_{2B} V_{2B}}{v_{2B}}$$

$$A_{2B} = \frac{\dot{m}_B v_{2B}}{V_{2B}} = \frac{(10) v_{2B}}{100} = \frac{v_{2B}}{10}$$

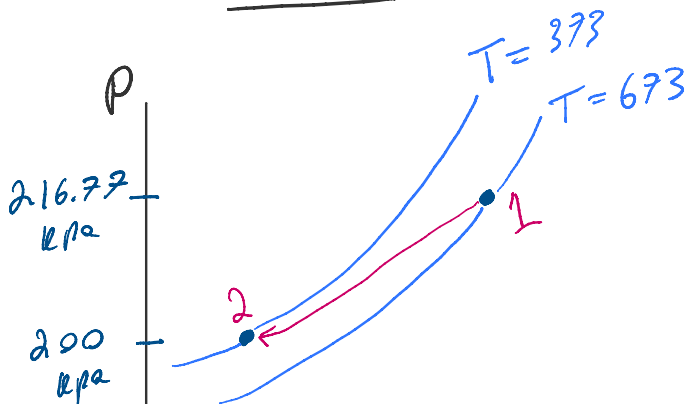
@ $P_{2B} = 2 \text{ MPa}, 500^\circ\text{C} > T_{sat}$ ∴ superheated

$v_{2B} = 0.17568 \text{ m}^3/\text{kg}$

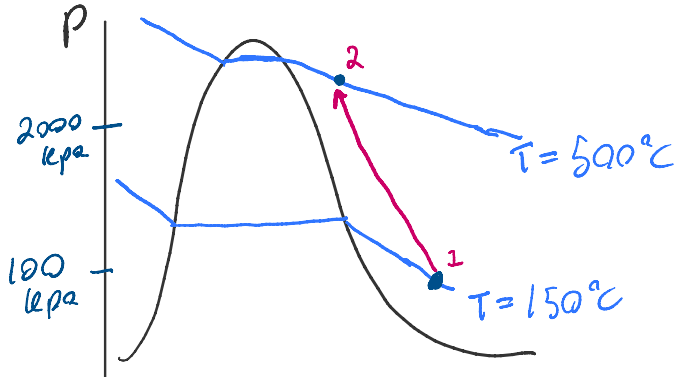
c) $A_{2B} = 0.17568/10 = \boxed{0.017568 \text{ m}^2}$

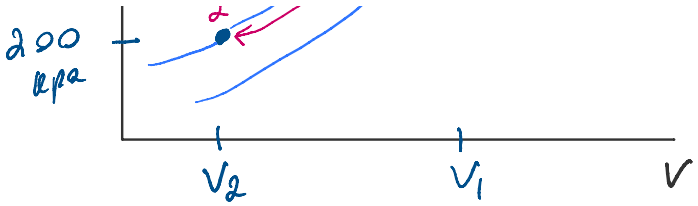
d)

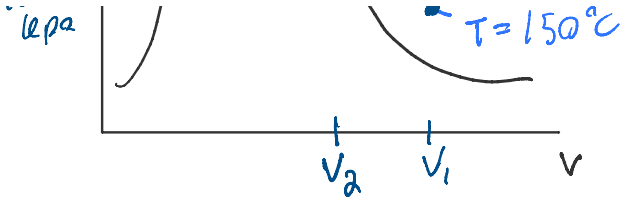
Turbine




Compressor




200
kPa
$V_2$
$V_1$
V


kPa
T = 150°C
$V_2$
$V_1$
V