Q. 1 steam enters an insulated nozzle operating at a steady state at pressure and temperature of 1.0 MPa and 350 ^{0}C, respectively, with a velocity of 30 *m/sec*. The pressure and temperature of the steam at the exit of the nozzle are 0.3 MPa and 200 ^{0}C. Determine the exit velocity of the fluid from the nozzle [5 pionts]

$$E_{in} - E_{out} = \Delta E_{sys} \text{ (steady)}$$

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

$$Q_{in} + W_{in} + h_{in} + KE_{in} + PE_{in} = Q_{out} + W_{out} + h_{out} + KE_{out} + PE_{out}$$

$$h_{in} + KE_{in} = KE_{out} + h_{out}$$

$$h_{in} = h @ 1\,MPa, 350°C = 3158.2\ kJ/kg$$

(Table A-6)

@ ②:–

300 kPa + 200°C ⟹ Superheated

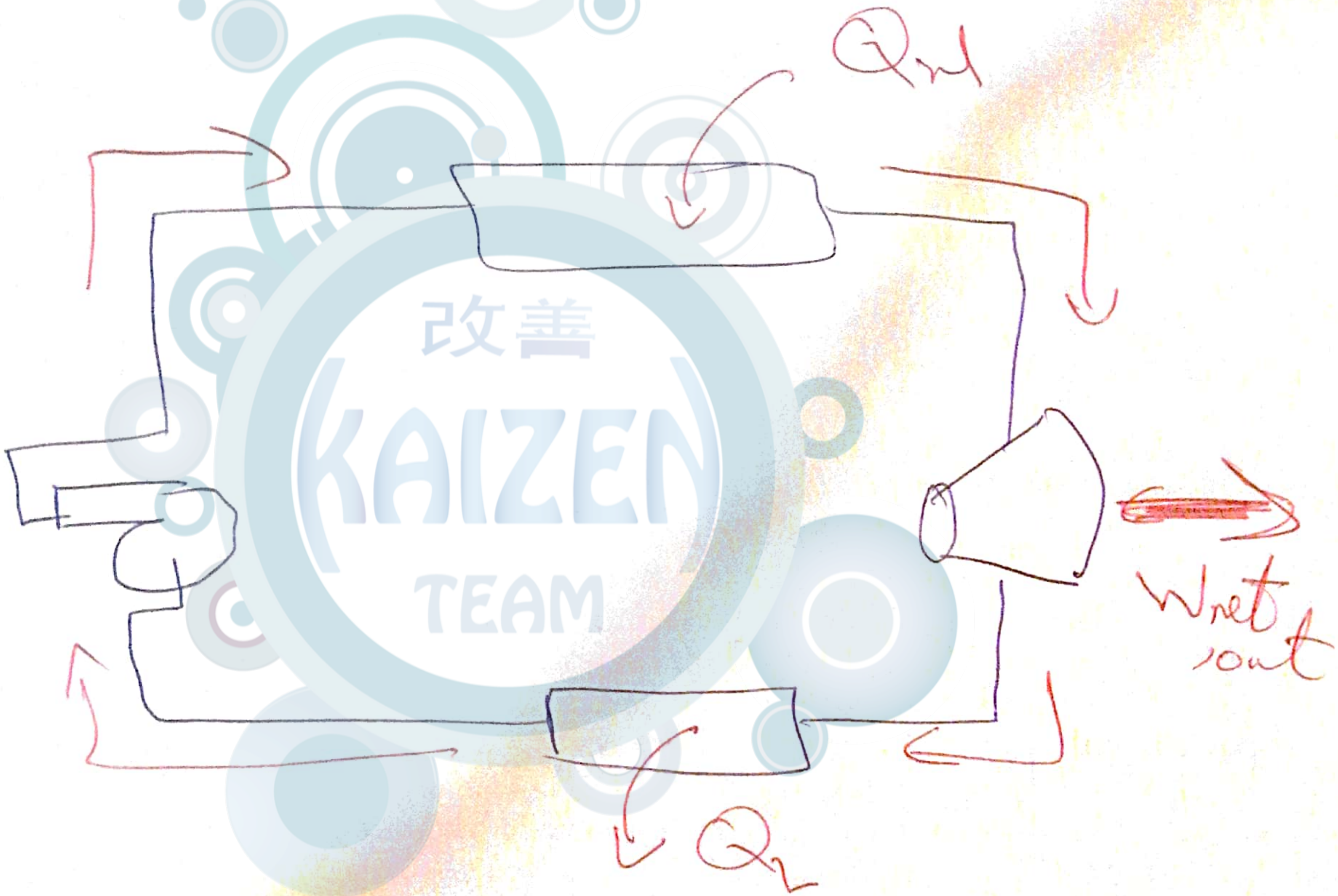
⟹ $h_{out} = 2865.9\ kJ/kg$

$$3158.2 + \frac{(30)^2}{2000} = \frac{V_{out}^2}{2000} + 2865.9$$

$$V_{out} = 765.18\ m/s$$

Q2. A heat engine delivers work output with a value of 60 kJ while rejecting 70 kJ of heat. Calculate the maximum ratio of the temperature limits between which the engine operated. If the engine is reversed, what is the COP of the obtained heat pump during both Winter and Summer [10 pionts]

Heat engine :-



$$\left(\frac{T_H}{T_L}\right)_{max} = \frac{Q_H}{Q_L}$$

$$W_{net} = 60\,kJ$$

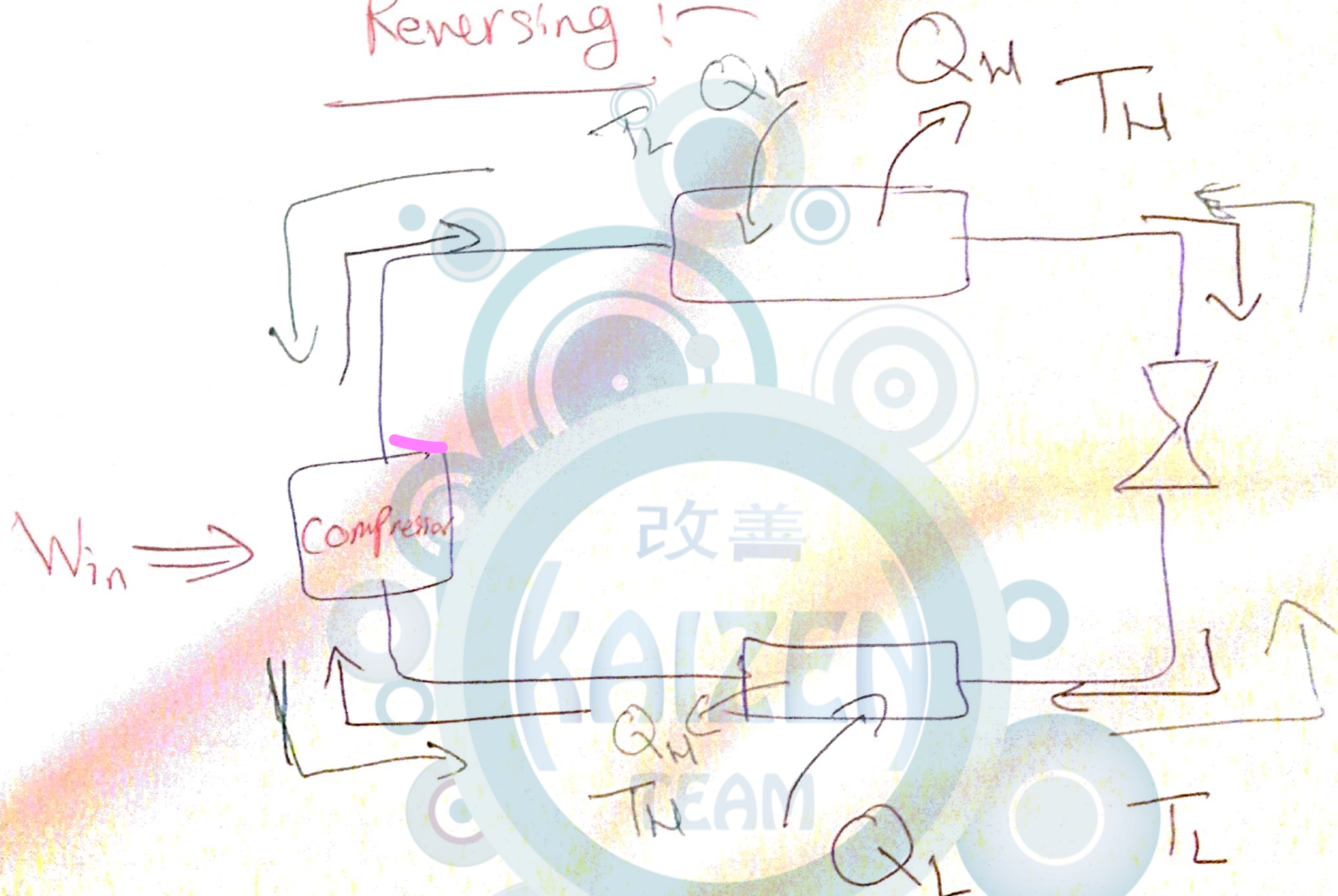
$$Q_L = 70\,kJ$$

$$Q_H - Q_L = W_{net}$$

$$Q_H = 60 + 70 = 130\,kJ$$

$$\left(\frac{T_H}{T_L}\right)_{max} = \frac{130}{70} = 1.857$$

Reversing!



- Summer (Refrigerator)
- Winter (Heat pump)

The work generated by the turbine will drive the compressor

$$\hookrightarrow W_{in} = W_{net,out} = 60\,kJ$$

$$Q_L = 70\,kJ$$

$$Q_H = 130\,kJ$$

$$COP_{HP} = \frac{Q_H}{W_{in}} = \frac{130}{60} = 2.167$$

$$COP_R = \frac{Q_L}{W_{in}} = \frac{70}{60} = 1.167.$$

Q.3 A heat pump heats a house in the winter and then reverses to cool it in the summer. The interior temperature should be 20°C in the winter and 25°C in the summer. Heat transfer through the walls and ceilings is estimated to be 2400 kJ per hour per degree temperature difference between the inside and outside. [10 pionts]

a. If the outside winter temperature is 0°C, what is the minimum power required to drive the heat pump?

b. For the same power as in part (a), what is the maximum outside summer temperature for which the house can be maintained at 25°C?

$$Q = \frac{2400\ kJ}{hr \cdot ^\circ C}$$ per degree temp. difference between inside & outside

(a) <u>In winter :-</u>

$T_H = 20^\circ C$

$T_L = 0^\circ C$

$W_{in,minimum} = ??$

at $W_{in\ minimum}$, $COP \equiv max.$

$\equiv COP_{carnot}$

$$COP_{HP,\ carnot} = \frac{1}{1 - T_L/T_H} = 14.65$$

$$= \frac{Q_H}{W_{in}}$$

$$Q_H = \frac{2400\ kJ}{hr \cdot ^\circ C} \cdot (20-0)^\circ C$$ difference between inside and out side

$$= 48000\ \frac{kJ}{hr}$$

$$W_{in,\ min} = \frac{Q_H}{COP_{HP\ carnot}} = \frac{48000}{14.65}$$

$$\equiv 3276.451\ kJ/h$$

(b) In summer :–

$W_{in} = 3276.451 \text{ kJ/h}$ (same as part a)

$T_L = 25°C$ (Interior temp. in summer)

$T_{H_{max}} = ??$

$T_{H_{max}}$ is at $COP_{R_{max}} = COP_{R_{carnot}}$

$$COP_{R_{carnot}} = \frac{1}{\frac{T_H}{T_L} - 1} = \frac{Q_{L_{max}}}{W_{in}}$$

$$Q_{L_{max}} = 2400(T_{H_{max}} - T_L)$$

$$= 2400(T_{H_{max}} - (25+273))$$

$$\frac{1}{\frac{T_H}{T_L} - 1} = \frac{Q_{L_{max}}}{W_{in}}$$

$$\frac{1}{\frac{T_{H_{max}}}{298} - 1} = \frac{2400(T_{H_{max}} - 298)}{3276.451}$$

Solve for $T_{H_{max}}$:–

$T_{H_{max}} = 318.17 \text{ K} = 45.17°C$