ex: Air turbine producing 52 kJ/kg

Find: Heat transfer
Assume: Steady, TPG

$T_1 = 30C$ $p_1 = 2.5$ atm
$V_1 = 120$ m/s

$T_2 = -10C$
$p_2 = 1$ atm
$V_2 = 20$ m/s

$w_{out} = 52$ kJ/kg

PICO:

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \cancel{\frac{dE}{dt}}^{\,0} + \dot{m}_2\left(h_2 + \frac{V_2^2}{2}\right) + \dot{W}_{out} + \dot{Q}_{out}$$

$$q_{out} = (h_{01} - h_{02}) - w_{out} = (h_1 - h_2) + \left(\frac{V_1^2 - V_2^2}{2}\right) - w_{out}$$

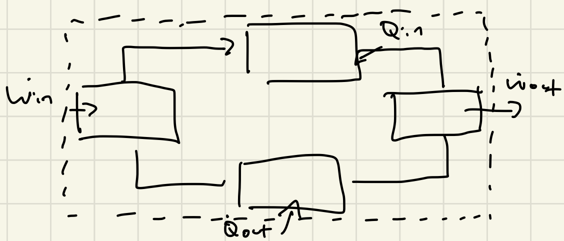
$$(h_1 - h_2) = \int_{T_1}^{T_2} c_p\, dT \approx c_p(T_2 - T_1)$$

$c_{p,air}$ (263 - 303K) = 1.003 - 1.005 kJ/kgK
↑ close enough together (linear), so take average

$\dot{q}_{out}$ = plug = ANS

Thermodynamic cycle → Do thermodynamic action until it comes back to original state
→ Fridge (you want closed)
→ Jet engines (you want open)

In closed system at steady-state: $\cancel{dU}^{\,0} = \delta Q_{net,in} - \delta W_{net,out}$

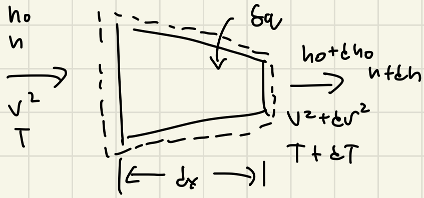



⇒ $Q_{net,in} = W_{net,out}$
→ Throwing hot air out, you're wasting energy

Cycle (thermal) efficiency $\eta = \frac{W_{net,out}}{Q_{in}} = \frac{\dot{W}_{net,out}}{\dot{Q}_{in}}$ → what we want / → what we pay for

Energy removed by heat transfer from "cold" system $\dot{Q}_{in,cold} = \dot{Q}_{out,hot} - \dot{W}_{in}$

Ex Assume no work but flow work (thus also inviscid), TPG




1st Law: $\delta q = dh_0 = dh + d(v^2/2)$

$$= c_p\, dT + \frac{1}{2} dv^2$$

$$\frac{\delta q}{c_p T} = \frac{dT}{T} + \frac{1}{2 c_p T} dv^2$$

will show = mach number $M^2$

$$\boxed{\frac{dT}{T} = \frac{\delta q}{c_p T} - \frac{(\gamma - 1)}{2} \frac{v^2}{\gamma R T} \frac{dv^2}{v^2}}$$

$$\boxed{\delta q = dh_0 = c_p\, dT_0}$$

→ Stagnation $h_0$ and $T_0$ constant for adiabatic flow (+ no work but flow work)

→ First law is limited. Things can't go back

→ Introduce entropy

→ think of flywheel that spins air then stops. After stop, air is still moving fast, but randomly

→ Breaking a balloon is creating entropy, balloon can't be put back together

→ Entropy is bad. Decreases available energy.

Consider PICO for entropy for isolated systems

Input = output = 0

⇒ Production = change

⇒ $\delta P_s = dS$

$= \Delta S \geq 0$

So in isolated system,

→ $P_s < 0$ is an impossible process

→ No production is reversible process (no friction, no electrical resistance, quasi-Eq)

→ Yes production is irreversible process