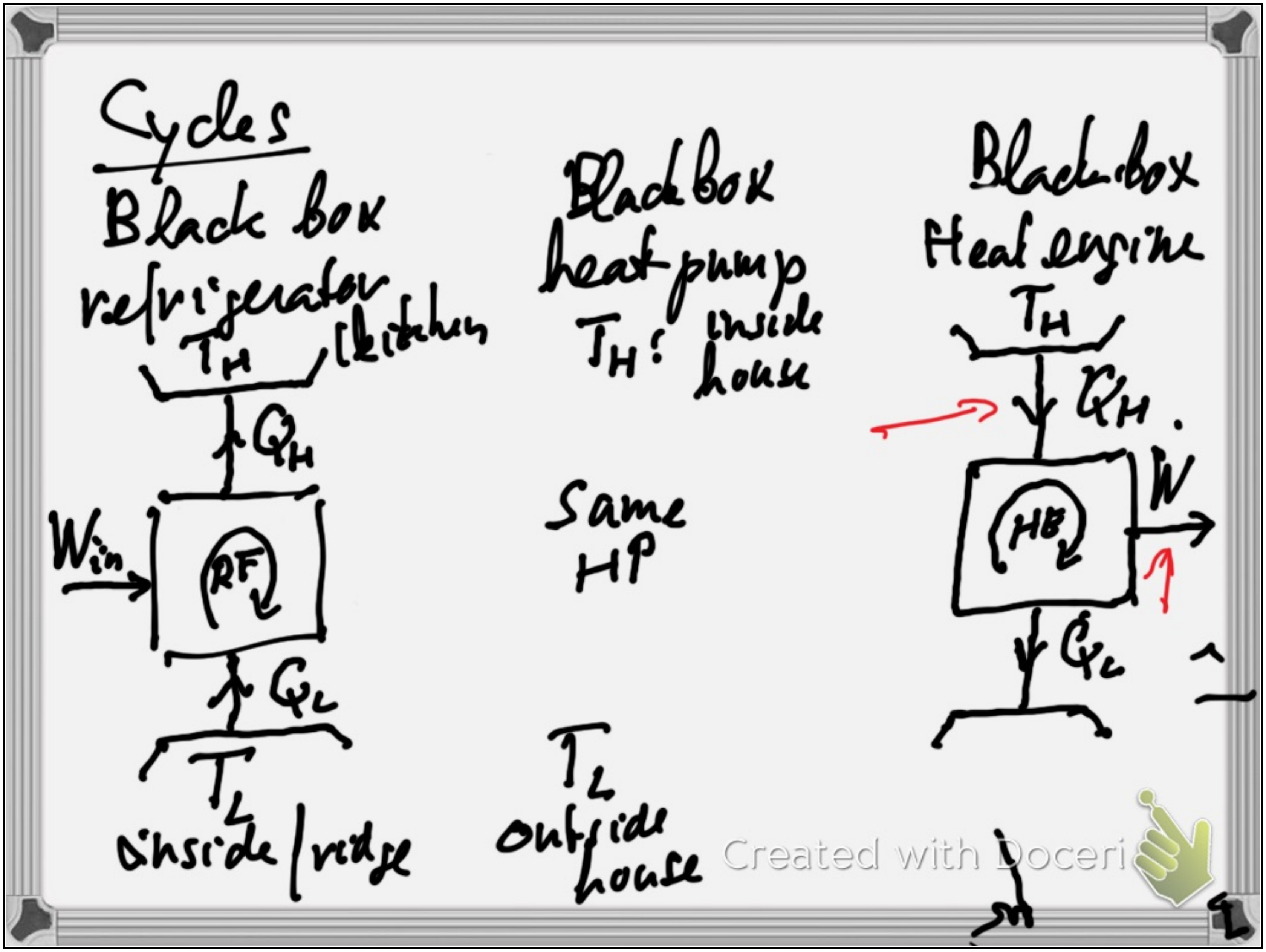
hi 3002 Second law of Thermo

momentum conservation
angular momentum

mass } conservation
energy }


Cycles
Black box
refrigerator
T_H
kitchen
Q_H
W_{in}
RF
Q_L
T_L
inside fridge
Black box
heat pump
T_H: inside house
Same HP
T_L
outside house
Black box
Heat engine
T_H
Q_H
W
HE
Q_L
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T_H : high temperature side
T_L : low temperature side
Q_L, Q_H : heat or heat flux
W : work

Note : sign conventions are different; Positive if the device works as it should

1st law: net heat in = net work out

$$Q_H - Q_L = W$$

Efficiencies $= \dfrac{\text{what you get}}{\text{what you "pay" for it}}$

H.E. $\eta_{th} = \dfrac{\dot{W}}{\dot{Q}_H}$ = thermal efficiency

$\dot{W} \rightarrow \dot{Q}_H - \dot{Q}_L$

Kelvin Planck statement of the second law
For heat engine $\dot{Q}_L$ must be positive

Refrigerator efficiency

$COP_R = \dfrac{\dot{Q}_L}{\dot{W}}$ = Coefficient of Performance

Heat pump:

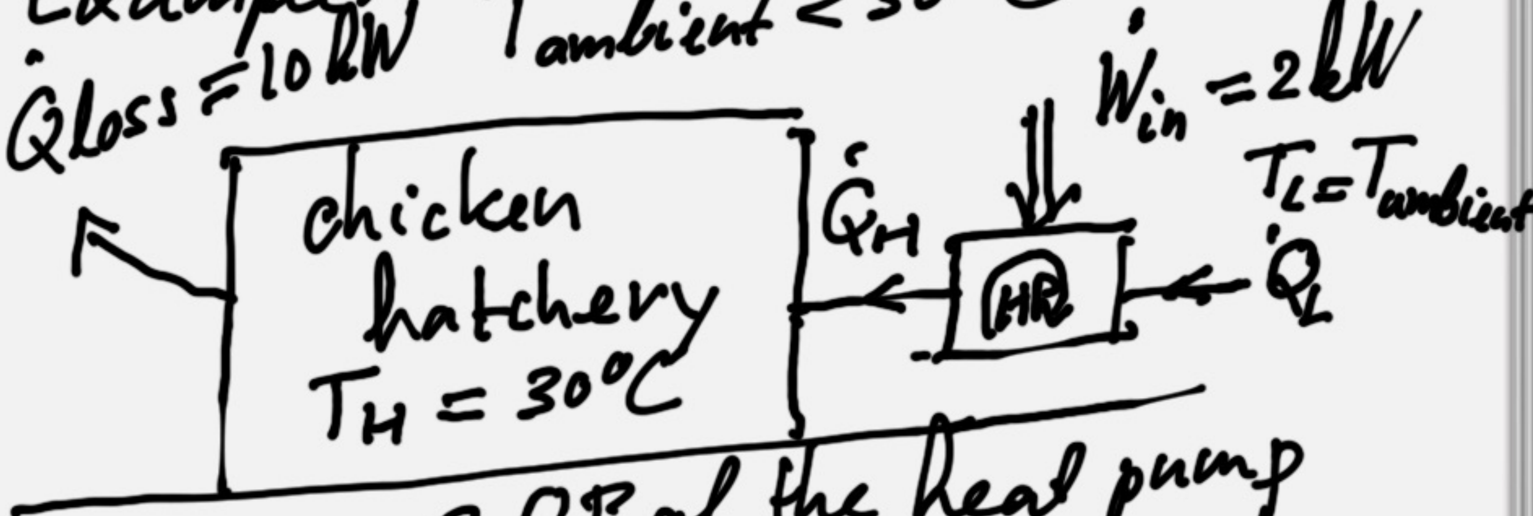
$$COP_{HP} = \frac{\dot{Q}_H}{\dot{W}_{(in)}} = \frac{\dot{Q}_H}{\dot{Q}_H - \dot{Q}_C}$$

↑ 1st law

Clausius statement of the second law: $\dot{W}_{in}$ must positive for a heat pump or refrigerator

The two formulations are equivalent

Example:



Asked: C.O.P. of the heat pump

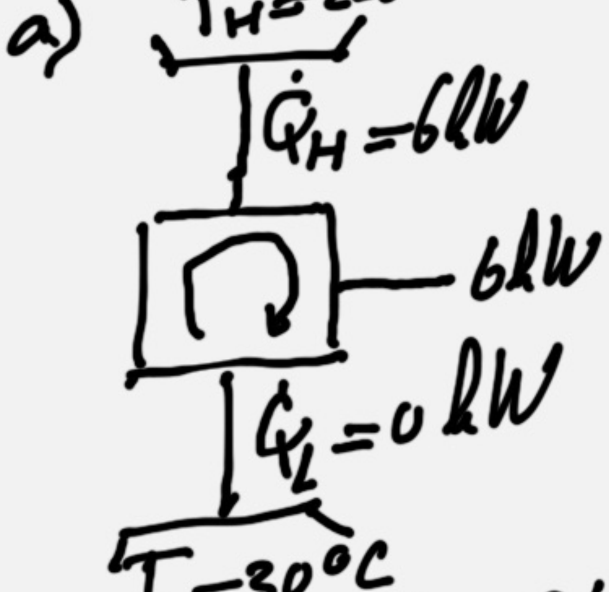
$\dot{Q}_H = 10\ kW \qquad \dot{W} = 2\ kW$

$$COP_{HP} = \frac{\dot{Q}_H}{\dot{W}} = \frac{10\ kW}{2\ kW} = 5$$

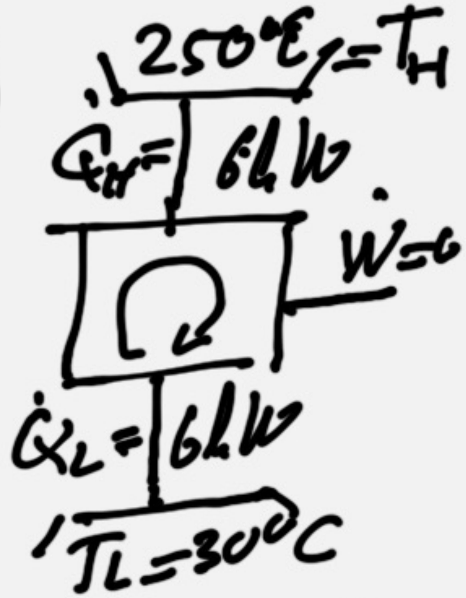
Example 1

$\dot{Q}_H - \dot{Q}_L = \dot{W}$

a)



b)

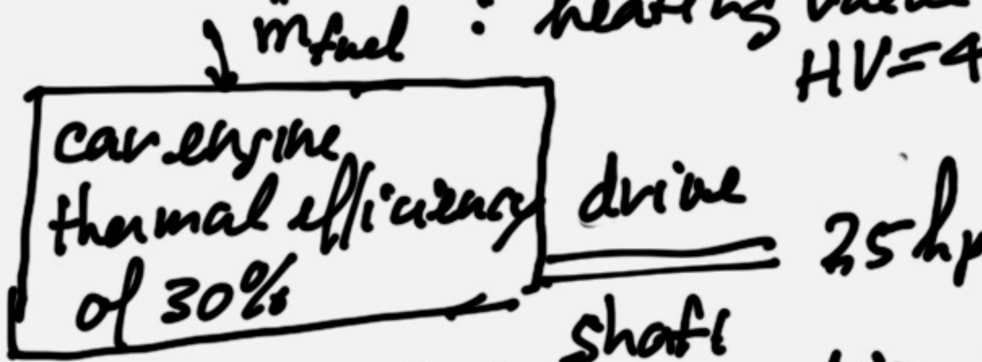


a) 1st law OK. Can this be a heat engine? No: KP. Can this be a R.C.
can this be a H.P. Not possible, violates Clausius

b) 1st law HP, R.C.
HE

Car engine example

$\dot{m}_{fuel}$: heating value $HV = 40{,}000 \frac{kJ}{kg}$



Asked: rate of fuel consumption (R.O.F.C)
combined power rejected through the radiator and exhaust (CPRTTRAE)

Q: what is R.O.F.C. $\dot{m}_{fuel}$

Q: what is thermal efficiency of 30% → 25hp

$$0.30 = \eta_{th} = \dot{W}_{out} / \dot{Q}_H$$

$$0.30 = \frac{25\,hp}{Q_H} = \frac{}{\dot{m}_{fuel}\,HV}$$

($\dot{m}_{fuel}$ → kg/s, HV → kJ/kg)

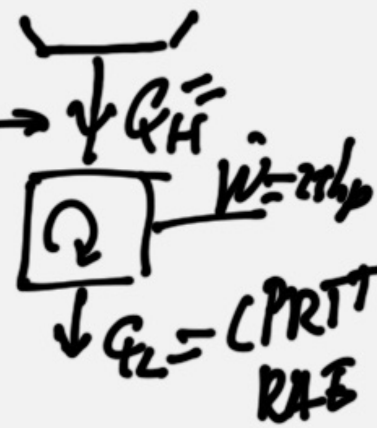
$$0.30 = \frac{25\,hp \;\; 0.7355\,\frac{kW}{hp}}{\dot{m}_{fuel}\;40{,}000\,\frac{kJ}{kg}} \rightarrow$$

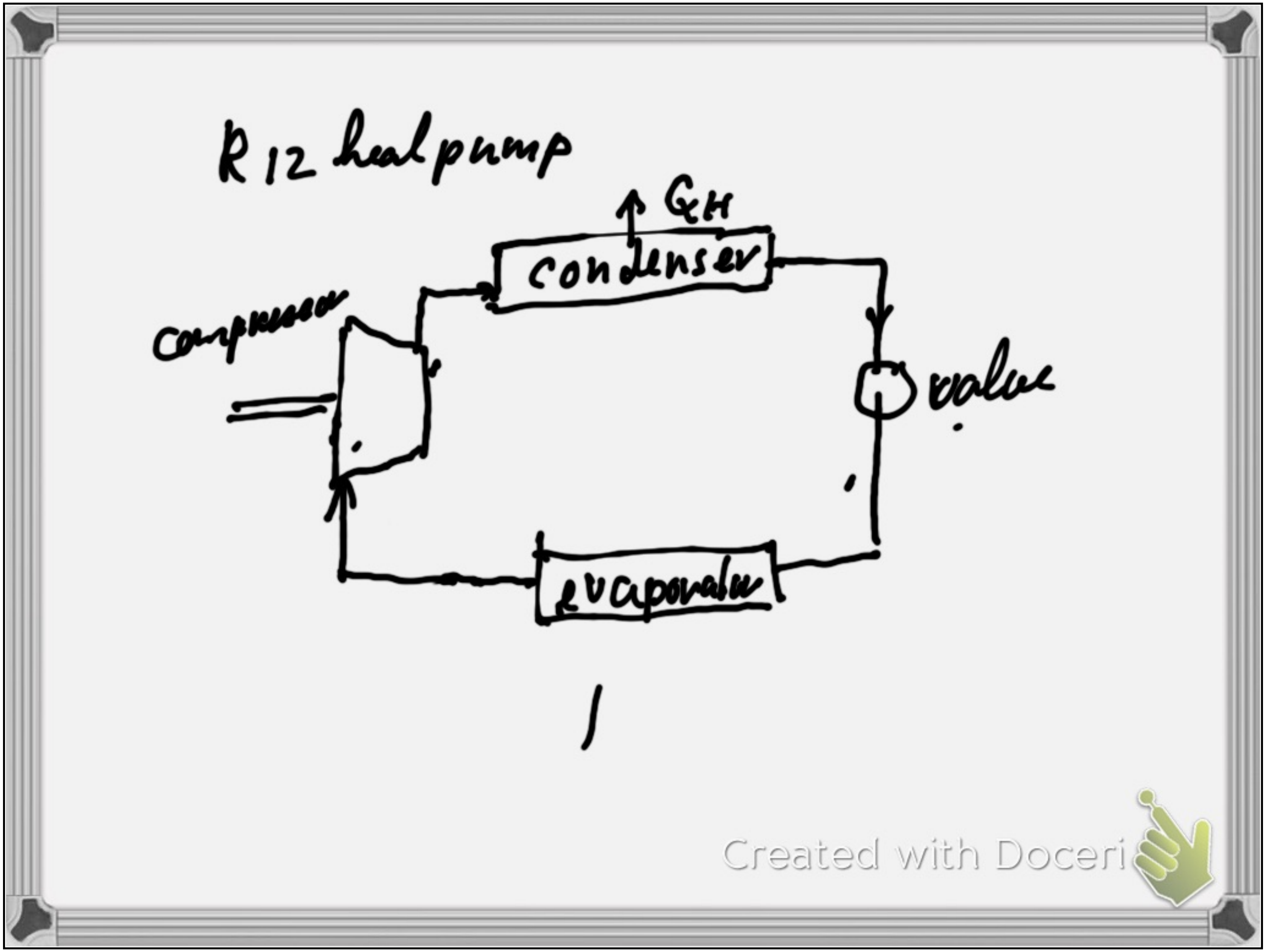
$\dot{m}_{fuel} = 0.00153$ R.G.F.C.

what is CPRTTRAE

$$\dot{Q}_L = \dot{m}_{fuel}\,HV - \dot{W}$$

$$= 42.8\,kW$$




R12 heatpump
QH
condenser
compressor
valve
evaporator
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