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Ans 1 (b) It necessarily violates the second law of thermodynamics because,

$$\eta = \frac{W}{Q} = 1$$

$$\Rightarrow W = Q$$

$\therefore$, Conversion of all heat into energy is not possible, i.e, η can't be 1

→ This is a contradiction of the 2nd law (efficiency can't be 100%)

(a) It doesn't violate the first law as

$Q = W$ is possible if $\Delta U = 0$.

So, energy is conserved.

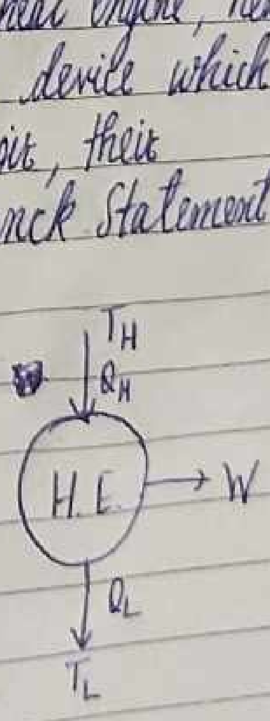
Ans 2 No, Kevin-Planck statement is related to heat engine, hence Hydroelectric power plant or other work producing device which don't exchange heat with thermal reservoir, their efficiencies are not limited by Kevin-Planck Statement.

Ans 3 (a) $\dot{Q}_H - \dot{Q}_L = 6 - 4 = 2\,kW$

$\therefore$ $\dot{W} = 2\,kW$

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

→ 1st law is satisfied



Also, $Q_L \neq 0$

→ Second law is also satisfied

Ans. 3(b) $\dot{Q}_H - \dot{Q}_L = 6 - 0 = 6\,kW$

$\dot{W} = 6\,kW$

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

$\rightarrow$ First law is satified

Now, $\dot{Q}_L = 0$

$\rightarrow 2^{nd}$ law is violated

Ans. 3(c) $\dot{Q}_H - \dot{Q}_L = 6 - 2 = 4\,kW$

$\dot{W} = 5\,kW$

$\Rightarrow \dot{Q}_H - \dot{Q}_L \neq \dot{W}$

$\rightarrow 1^{st}$ law is violated

$\dot{Q}_L \neq 0 \rightarrow 2^{nd}$ law is satisfied

Ans. 3(d) $\dot{Q}_H - \dot{Q}_L = 6 - 6 = 0\,kW$

$\dot{W} = 0\,kW$

$\rightarrow 1^{st}$ law is satisfied

~~Also, $\dot{Q}_L \neq 0$~~

~~$\rightarrow 2^{nd}$ law is also satisfied~~

Now, as $W = 0$

$\rightarrow 2^{nd}$ law is violated

Ans 4 $\dot{Q}_H - \dot{Q}_L = 500\,W = \dot{W}$

$$COP_R = \frac{\dot{Q}_L}{\dot{W}}$$

$$\Rightarrow \dot{Q}_L = (COP_R)(\dot{W})$$
$$= (2.5)(500)$$
$$\dot{Q}_L = 1250\,W$$

$$\therefore \dot{Q}_H = 1750\,W$$

So, 1750 W of power dissipates into the Kitchen air, increasing its temperature

Ans 5 $Q = 0$, $\Delta U \Rightarrow -ve$ [$\because$ temperature decreases]
Now, by 1st law
$$W = Q - \Delta U \Rightarrow +ve$$
$\therefore$ Work output

Also, heat is thrown from high temperature to a lower temperature producing work, hence 2nd law is not violated.

Ans.6 $\dot{W} = 150 \times 10^6 W$

$$\dot{Q} = \frac{60 \times 10^3}{3600} \times 3 \times 10^4 \times 10^3$$

Now, $\eta = \frac{\dot{W}}{\dot{Q}} = \frac{15 \times 10^7 \times 36 \times 10^2}{60 \times 3 \times 10^{10}} = 0.3$

$\therefore$ $\boxed{\text{Efficiency} = 30\%}$

Ans.7 $\dot{Q}_H = 15090 \text{ kJ/h}$

$\dot{Q}_L = 10000 \text{ kJ/h}$

$\dot{W} = 1.5 \text{ kW}$

$$COP_{H.P.} = \frac{\dot{Q}_H}{W} = \frac{15090}{3600 \times 1.5} = 2.79$$

$\Rightarrow$ $\boxed{COP_{HP} = 2.79}$

Ans.8 $\dot{W} = 450 W$

$$COP_R = 2.5 = \frac{\dot{Q}_L}{\dot{W}}$$

$\Rightarrow$ $\boxed{\dot{Q}_L = 1125 W}$

Also, $\boxed{\dot{Q}_H = 1575 W}$

Now, $(\dot{Q}_L)(t) = (mC\Delta T)$

$\Rightarrow (1125)(t) = (5\times10)(4.2)(20-8)\times10^3$

$\Rightarrow t = \dfrac{5\times42\times12\times10^3}{1125} = 2240$ seconds

$\therefore$ $\boxed{t = 2240 \text{ seconds}}$

The system is realistic as it follows the first & second law of thermodynamics.

Ans 9 $\dot{Q}_H = 60000 - 4000$
$= 56000$ kJ/h

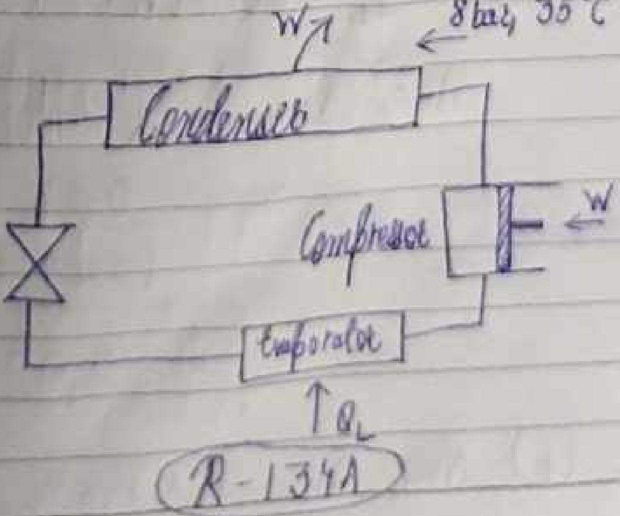
Now, $COP_{HP} = \dfrac{\dot{Q}_H}{\dot{W}}$

$\Rightarrow \dot{W} = \dfrac{56000}{3600\times2.5}$

$\Rightarrow \boxed{\dot{W} = 6.22 \text{ KW}}$

Ans 10 $W = 12$ KW
$h_1 = 271.17$ KJ/kg
$h_2 = 95.46$ KJ/kg

$\dot{Q}_H = \dot{m}(h_1 - h_2)$
$= (0.018)(271.17 - 95.46)$
$\boxed{\dot{Q}_H = 3.163 \text{ KW}}$



(a) Now, $COP = \frac{3.163}{1.2}$

$\Rightarrow \boxed{COP \approx 2.64}$

(b) $\dot{Q}_H - \dot{Q}_L = \dot{W}$

$\Rightarrow \boxed{\dot{Q}_L \approx 1.96\ KW}$

Ans.11 $P = 1.2$ bar, $x = 0.2$

Now, $h_1 = h_f + x h_{fg}$; $P = 1.2$ bar

$= 21.32 + (0.2)(233.86)$

$\boxed{\Rightarrow h_1 = 67.892}$

$\therefore \cancel{\frac{h - h_1}{h_2 - h_1} = \frac{P - P_1}{P_2 - P_1}}$

$\Rightarrow \boxed{h_2 = 238.9\ KJ/kg}$ at $P = 1.2$ bar, $T = -20°C$

(a) Now, $\dot{Q}_L = (COP)(\dot{W}) = (1.2)(0.45) = 0.54\ KW$

Also, $\dot{Q}_L = \dot{m}(h_2 - h_1)$

$\therefore \dot{m} = \frac{0.54}{(238.9 - 67.892)}$

$\Rightarrow \boxed{\dot{m} = 0.0031\ kg/s}$

(b) Now, $\dot{Q}_H = \dot{Q}_L + \dot{W} = 0.54 + 0.45$

$\Rightarrow \boxed{\dot{Q}_H = 0.99\ KW}$

Ans 12 $\dot{W} = \dot{Q}_H - \dot{Q}_L$

Also, $\frac{\dot{Q}_H}{\dot{Q}_L} = \frac{T_H}{T_L} = \frac{800}{280}$

$\Rightarrow \boxed{\dot{Q}_H = 2.857\,\dot{Q}_L}$

$\therefore \dot{W} = (2.857 - 1)\,\dot{Q}_L$

$\Rightarrow 4 = (1.857)(\dot{Q}_L)$

$\Rightarrow \dot{Q}_L = \frac{4}{1.857} \times 3600 \text{ kJ/hr}$

$\Rightarrow \dot{Q}_L \approx 7754.45 \text{ kJ/hr}$

$\therefore \dot{Q}_H = (2.857)(7754.45)$

$\Rightarrow \boxed{\dot{Q}_H \approx 22150 \text{ kJ/h}}$

Ans 13 $\dot{m} = 440 \text{ kg/sec}$

$h_1 = 675.47 \text{ kJ/kg}$

$h_2 = 108.77 \text{ kJ/kg}$

$\dot{Q}_H = \dot{m}(h_1 - h_2)$

$= 440(675.47 - 108.77)$

$= 249348 \text{ kW}$

(a) $\eta = \frac{\dot{W}}{\dot{Q}_H} = \frac{22000}{249348} \times 100 \approx 8.8\%$

(b) $\eta_{max} = 1 - \frac{T_L}{T_H}$

$$= \left[1 - \frac{(273+25)}{(273+160)}\right] \times 100$$

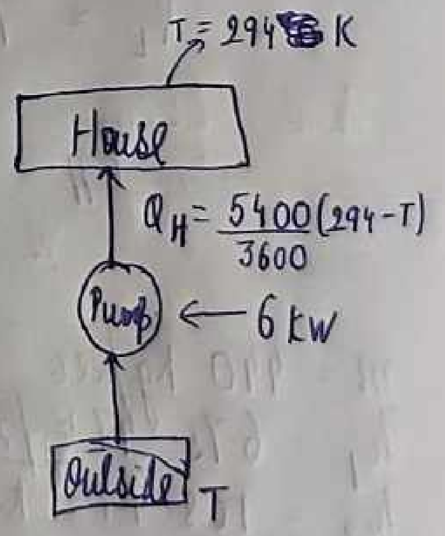
$\Rightarrow \boxed{\eta_{max} \approx 31.2\%}$

(c) $\dot{Q}_L = \dot{Q}_H - \dot{W}$

$$= 249348 - 22000$$

$\boxed{\dot{Q}_L \approx 227.3 \text{ MW}}$

Ans 14 $\frac{Q_H}{Q_L} = \frac{294}{T} = \frac{5400}{3600} \times \left(\frac{294-T}{T}\right) \times \frac{1}{Q_L}$



$\Rightarrow Q_L = \frac{(294-T)(54)(T)}{(36)(294)} = (Q_H)\left(\frac{T}{294}\right)$

Now, $Q_H - Q_L = W$

$\Rightarrow \left(\frac{3}{2}\right)(294-T)\left(1 - \frac{T}{294}\right) = \cancel{6}\,2$

$\Rightarrow (294-T)^2 = 4 \times 294$

$\Rightarrow 21°C - T = 34.29°C$

$\Rightarrow \boxed{T \approx -13.3°C}$

Ans 15 $\eta_{max} = 1 - \frac{T_L}{T_H} = 1 - \frac{300}{1173}$

$\Rightarrow \boxed{\eta_{max} = 0.744}$

$\therefore \dot{W}_{max} = \eta_{max} \dot{Q}_H = (0.744)(8000\ kJ/min)$

$\Rightarrow \boxed{\dot{W}_{max} = 595.2\ KJ/min}$

Now, $COP_{ref} = \frac{1}{\left(\frac{T_H}{T_L} - 1\right)} = \frac{1}{\left(\frac{27+273}{-5+273} - 1\right)}$

$\Rightarrow \boxed{COP = 8.37}$

(a) $\therefore \dot{Q}_L = (COP)(\dot{W}_{max}) = (8.37)(595.2)$

$\Rightarrow \boxed{\dot{Q}_L = 4982\ KJ/min}$

(b) For air, $\dot{Q}_L = \dot{Q}_H - \dot{W}_{out} = 800 - 595.2$

$\Rightarrow \boxed{\dot{Q}_L = 204.8\ KJ/min}$

Now, $\dot{Q}_H = \dot{Q}_L + \dot{W}_{in} = 4982 + 595.2$

$\Rightarrow \boxed{\dot{Q}_H = 5577.2\ KJ/min}$

$\therefore \dot{Q}_{ambient} = \dot{Q}_H + \dot{Q}_L = 204.8 + 5577.2$

$$\Rightarrow \boxed{\dot{Q}_{ambient} = 5782 \text{ KJ/min}}$$