CONCEPT: THE CARNOT CYCLE

● Remember: The Second Law says no heat engine can *EVER* have an efficiency of 100%.

- The **Carnot Cycle** is an ideal "reversible" cycle that has the ______________ possible efficiency: e_{Carnot} = 1 – ——

- An engine is "reversible" if processes happen infinitely slowly and without frictional forces dissipating energy.

● The Carnot Cycle has 4 steps:

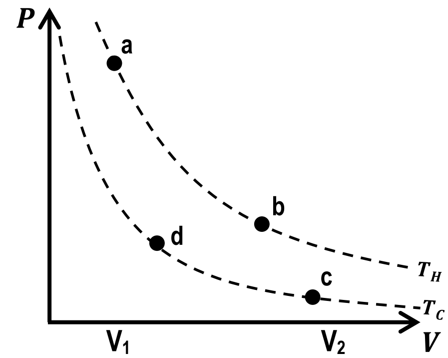
(1) $(a \to b)$ Isothermal Expansion at T_H, absorbing heat (Q_H)

(2) $(b \to c)$ Adiabatic Expansion from T_H to T_C $(Q = 0)$

(3) $(c \to d)$ Isothermal Compression at T_C, releasing heat (Q_C)

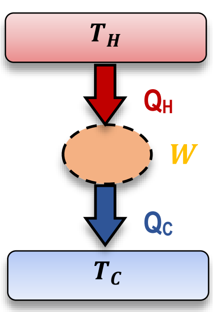
(4) $(d \to a)$ Adiabatic Compression from T_C to T_H $(Q = 0)$

- Because (__) & (__) are adiabatic, heat transfer only happens during (__) & (__)



● The heat released & absorbed depends on temperatures of the Cold & Hot reservoirs: —— = ——

EXAMPLE: You build a Carnot engine operating between 520K and 300K. The engine takes in 6.45 kJ of heat from the hot reservoir. **a)** Calculate the maximum theoretical efficiency between these two reservoirs. **b)** How much waste heat does the engine expel each cycle? **c)** How much mechanical work does the engine produce?



HEAT ENGINES
$\Delta E_{int} = 0$
$\lvert W \rvert = \lvert Q_H \rvert - \lvert Q_C \rvert$
$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$

PROBLEM: A theoretical heat engine in space could operate between the Sun's 5500°C surface and the –270.3°C temperature of intergalactic space. What would be its maximum theoretical efficiency?

A) 99.98%
B) 95.1%
C) 99.95%

HEAT ENGINES
$\Delta E_{int} = 0$
$\lvert W \rvert = \lvert Q_H \rvert - \lvert Q_C \rvert$
$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$
$e_{Carnot} = 1 - \frac{T_C}{T_H}$

PROBLEM: A Carnot engine with an efficiency of 70% is cooled by water at 10°C. What temperature must the hot reservoir be maintained at?

A) 33.3 K
B) 404.3 K
C) 943.3 K
D) 14.3 K

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$\lvert W \rvert = \lvert Q_H \rvert - \lvert Q_C \rvert$
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$e_{Carnot} = 1 - \frac{T_C}{T_H}$

PROBLEM: A Carnot engine operates between reservoirs at 182°C and 0°C. If the engine extracts 25J of energy from the hot reservoir, how many cycles will it take to lift a 10kg mass a height of 8m?

HEAT ENGINES
ΔE_{int} = 0
$\lvert W \rvert = \lvert Q_H \rvert - \lvert Q_C \rvert$
$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$
$e_{Carnot} = 1 - \frac{T_C}{T_H}$
$\left\lvert \frac{Q_C}{Q_H} \right\rvert = \left\lvert \frac{T_C}{T_H} \right\rvert$ (Carnot only)

PROBLEM: Your friend claims they have a design for a reversible heat engine that can operate between the freezing and boiling temperatures of water that has an efficiency of 30%. Is this possible?

- **A)** No
- **B)** Yes
- **C)** Not enough information

HEAT ENGINES
ΔE_{int} = 0
$\lvert W \rvert = \lvert Q_H \rvert - \lvert Q_C \rvert$
$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$
$e_{Carnot} = 1 - \frac{T_C}{T_H}$