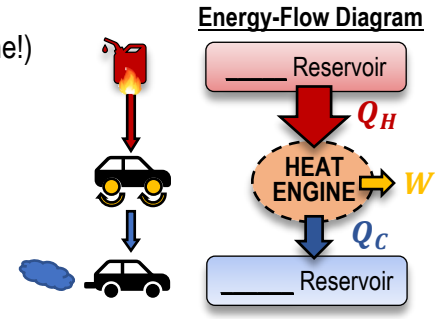
CONCEPT: INTRO TO HEAT ENGINES

● **Heat Engine:** Machine that converts _____ into useful _____ (e.g. a car engine!)

Hot Reservoir: Source of heat energy (Q_H) going *INTO* engine (burning gasoline)

Work: Usable energy (W) *produced BY* engine (turning wheels of car)

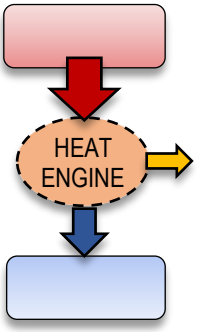
Cold Reservoir: Wasted heat energy (Q_C) *expelled OUT* from engine (exhaust pipe)



● Remember: $\Delta E_{int} = Q - W$, and in cyclic processes, $\Delta E_{int} = 0$, so $W_{cyc} = Q_{cyc}$

- Heat Engines are ALWAYS cyclic, and heat flows IN and OUT over a cycle: ____ = ____ = _____

EXAMPLE: A heat engine takes in 500J of heat and does 300J of work. How much waste heat is expelled from the engine?



PROBLEM**:** An aircraft engine takes in 9 kJ of heat and expels 6.4 kJ of heat each cycle**.** How much mechanical work does the engine do each cycle?

A) 15.4 kJ
B) 2.6 kJ
C) 2.6 J
D) 6.4 kJ

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

PROBLEM**:** A gasoline engine takes in 1.6×10^4 J of heat from gasoline combustion and does 3700 J of work per cycle**.** Gasoline has a latent heat of combustion L_C = 4.6×10^7 J/kg**. a)** How much heat is expelled each cycle? **b)** What mass of fuel is burned each cycle? **c)** If the engine completes 60 cycles/sec (3600 RPM), what is its power output in kW?

HEAT ENGINES
$\boldsymbol{\Delta E_{int} = 0}$
$\boldsymbol{\lvert W\rvert = \lvert Q_H\rvert - \lvert Q_C\rvert}$
$\boldsymbol{Q = mL}$

PROBLEM**:** A heat engine uses a tank of ice water as a cold reservoir**.** The engine takes in 8 kJ of heat from the hot reservoir, and the heat expelled melts 18g of ice in the tank**.** How much work does this engine do?

A) 14,012 J
B) 6012 J
C) 1,988 J
D) 8000 J

HEAT ENGINES
$\Delta E_{int} = 0$
$\lvert W \rvert = \lvert Q_H \rvert - \lvert Q_C \rvert$
$Q = mL$
$L_f = 3.34 \times 10^5$ J/kg

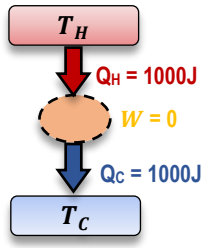
CONCEPT: THERMAL EFFICIENCY AND THE SECOND LAW OF THERMODYNAMICS

- Remember: Heat engines produce Work using heat energy flowing from the Hot reservoir to the Cold Reservoir.

-The engine's **thermal efficiency** (__) is how _____ it is at producing Work from Heat: $e = \frac{\quad}{\quad}(\times 100\%) = 1 - \frac{\quad}{\quad}$

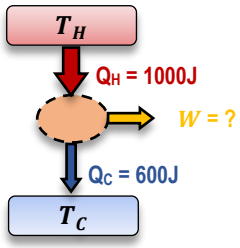
EXAMPLE: For the following examples below, calculate the missing variable(s).

a)



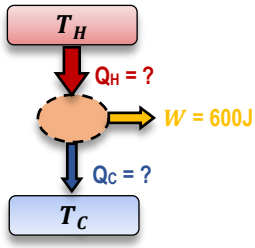
e = ?

b)



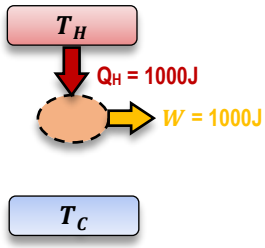
e = ?

c)



e = 0.3

d)



e = ?

- The Second Law of Thermodynamics has multiple "statements".

Second Law of Thermodynamics – Kelvin / "Engine" Statement

- It is _____ to convert $Q_H \rightarrow W$ with 100% efficiency. Engines **must** expel waste heat to the cold reservoir.

PROBLEM: A steam turbine takes in 75g of water and boils it as heat energy to run a 40% efficient engine. How much work does this engine do per cycle?

A) 67,800 J
B) 1.695×10^5 J
C) 10,020 J
D) 4.24×10^5 J

HEAT ENGINES
$\Delta E_{int} = 0$
$\lvert W\rvert = \lvert Q_H\rvert - \lvert Q_C\rvert$
$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$
$Q = mL$
$L_f = 3.34 \times 10^5$ J/kg
$L_v = 2.26 \times 10^6$ J/kg

PROBLEM: A nuclear power plant produces 250 MW of power, and expels 550 MW out to the surrounding environment. What is the thermal efficiency of this power plant?

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

- The efficiency equation does *not* depend on time, so you can use it when given units of power [**W**] instead of energy [**J**].