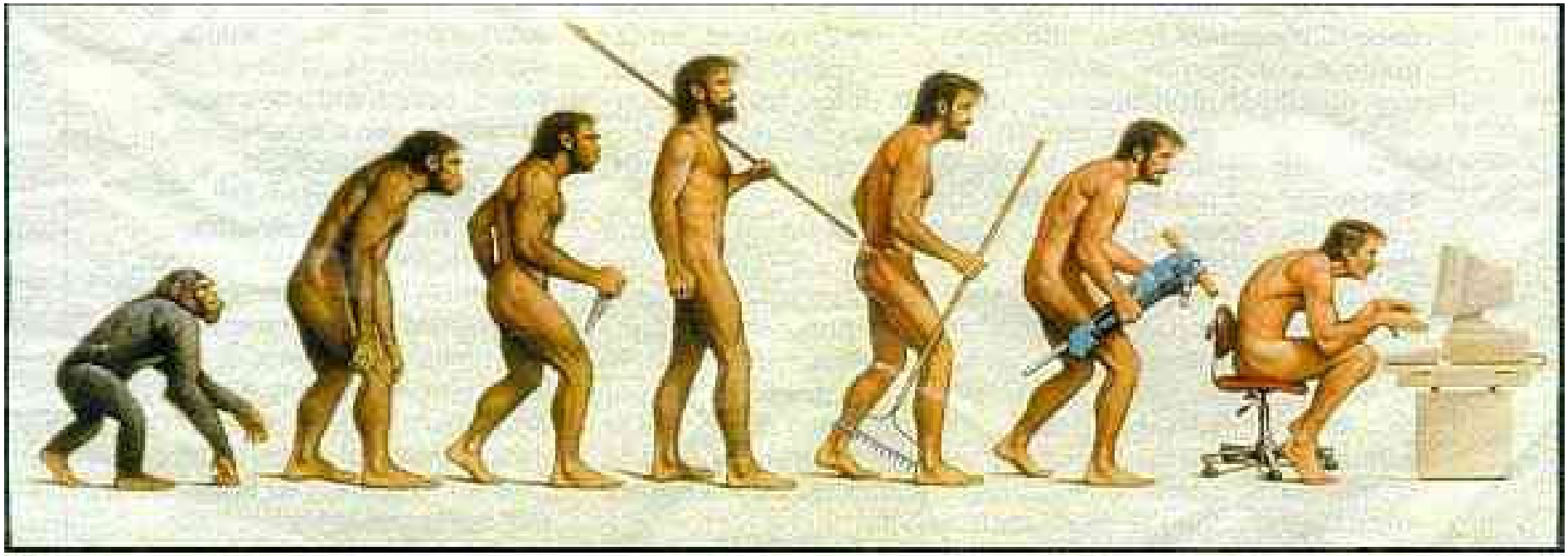
LAWS OF THERMODYNAMICS . . .



Somewhere, something went terribly wrong

LAWS OF THERMODYNAMICS…

Learned at CASINO – by R.J. Riggins (Rice University)

You can't win!

You can't break even!

And You can't even get out of the game!

Source: "Thermodynamics for two, please" by R. J. Riggins

LAWS OF THERMODYNAMICS – R.J. Riggins (Rice University)

The universe is a house (great casino). God is the great dealer, who controls the deck, and **always takes His percentage**, so that in the long run the player is broke, and his chips (his heat energy) is dissipated into the void, unrecoverable

1st Law – You cannot get something for nothing **(Energy is always balanced – cannot be created from nothing)**

2nd Law – You cannot get what you thought you could get **(You cannot avoid loss of energy – entropy is generated)**

Source: "Thermodynamics for two, please" by R. J. Riggins

ENERGY TRANSFER MODE (1)

- There are **2 types** of energy transfer:
  - Energy transfer due to **HEAT INTERACTION**
  - Energy transfer due to **WORK INTERACTION**
- There are **2 directions** of energy transfer:
  - Energy is **IN** to the system
  - Energy is **OUT** of the system

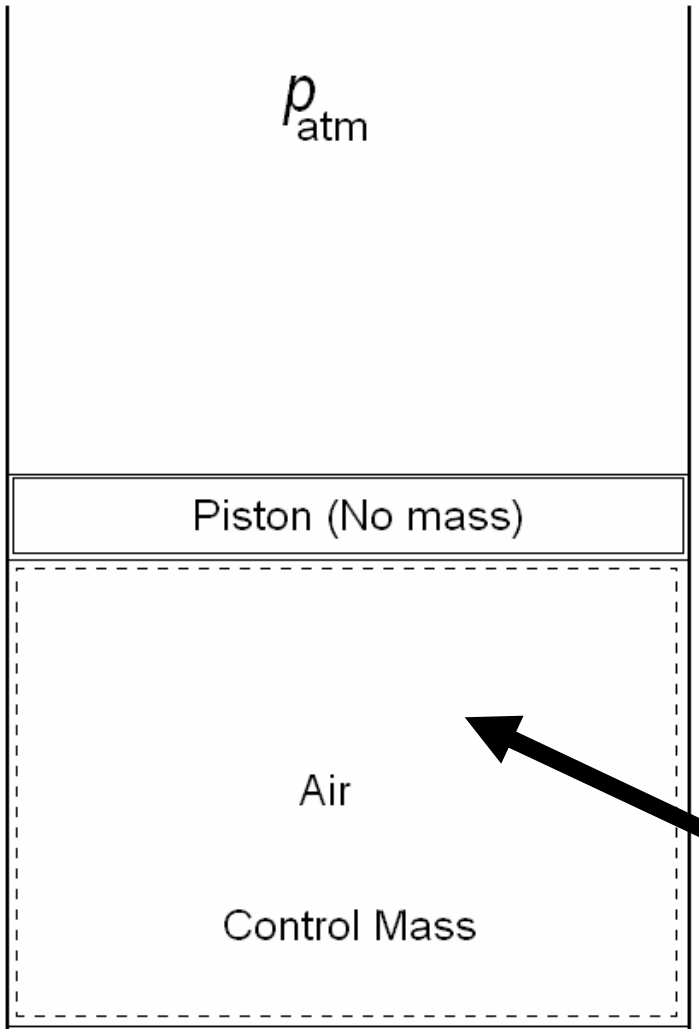
ENERGY TRANSFER MODE (2)

- **Heat Interaction** (due to temperature difference)
  - Energy **IN:** Q_{in} Energy **OUT:** Q_{out}
- **Work Interaction** (due to the work)
  - Energy **IN:** W_{in} Energy **OUT:** W_{out}

1ST LAW OF THERMODYNAMICS
at Embry-Riddle Aeronautical University

- The 1st law of thermodynamics derived & used at ERAU Prescott is significantly **DIFFERENT** from typical thermodynamics textbook
- This ALTERNATIVE 1st law was first developed and introduced by **Dr. Richard Felton** (associate dean) in early 1980's and adopted by many instructors
- The infamous sign convention of 1st law is completely eliminated (no longer necessary)
- At ERAU, this alternative approach has been employed over a decade in engineering courses

Derivation of Governing Equation:
1st Law of Thermodynamics

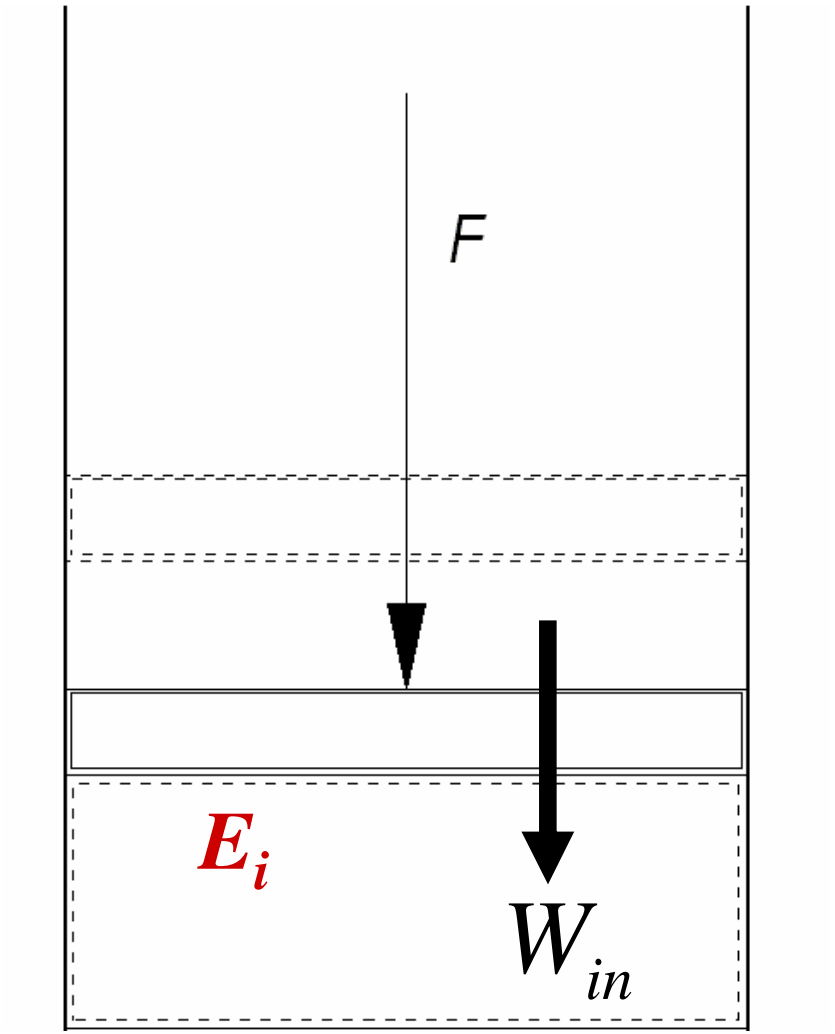


A Cylinder & Piston System

Initial energy content of the system:

E_i

Work Interaction: Energy "IN" W_{in}

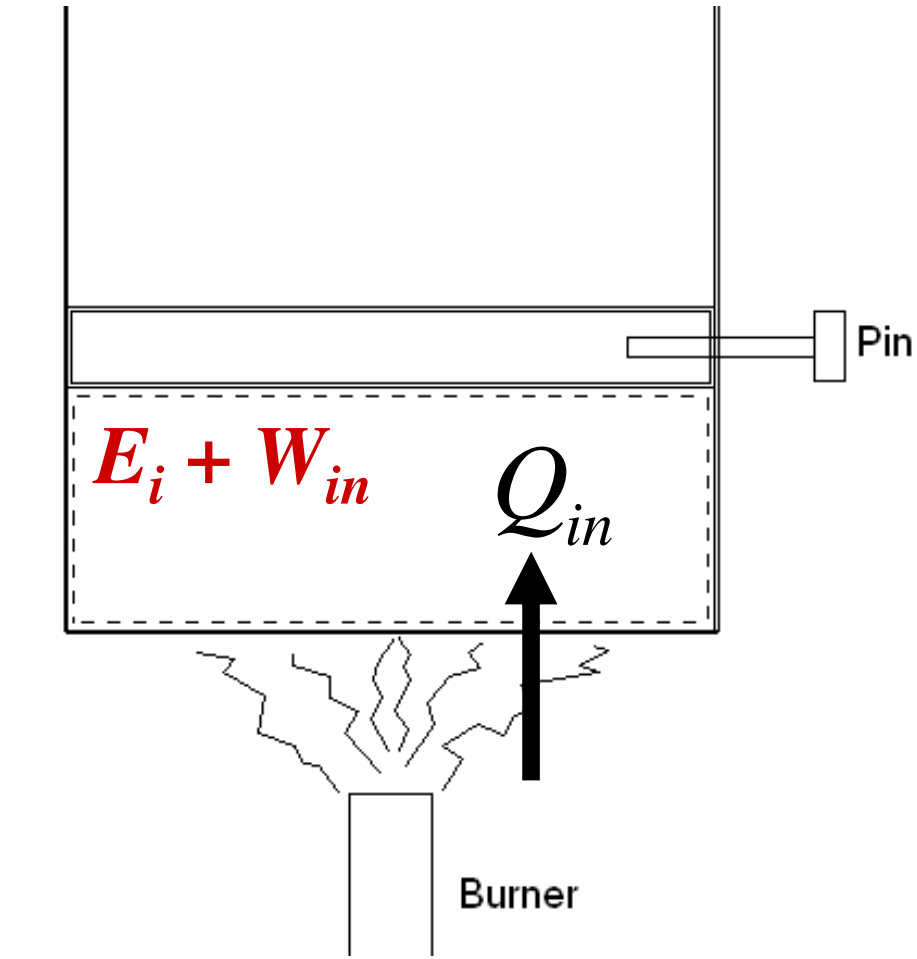


Piston is compressed by the externally applied force (Energy is **in** to the system)

Energy content of the system after this work interaction:

$$E_i + W_{in}$$

Heat Interaction: Energy "IN" Q_{in}



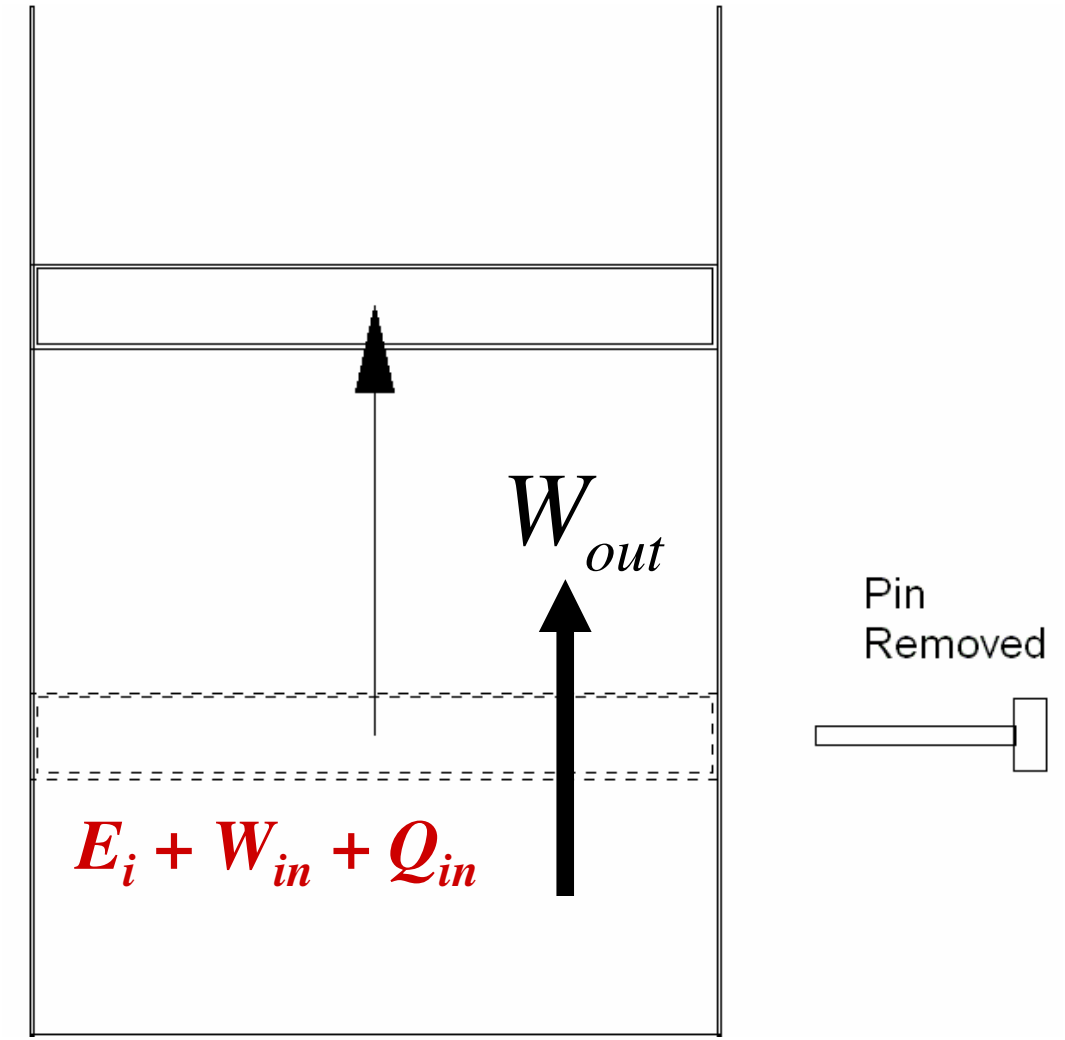
Cylinder is heated up by the externally applied heat source (Energy is **in** to the system)

Energy content of the system after this heat interaction:

$$E_i + W_{in} + Q_{in}$$

Work Interaction: Energy "OUT" W_{out}

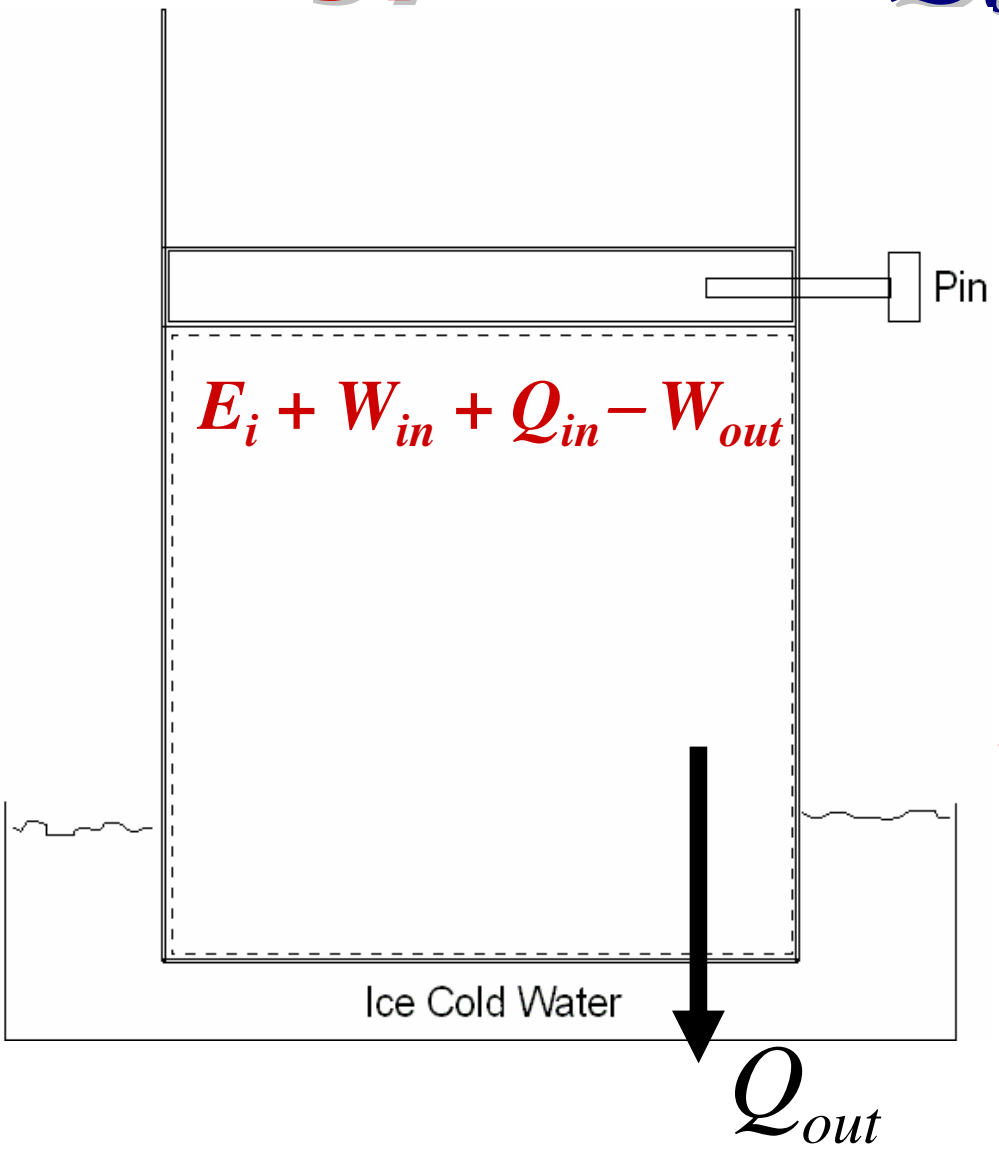
Piston pin is removed and piston moves up as a result (Energy is **out** from the system)



Energy content of the system after this work interaction:

$$E_i + W_{in} + Q_{in} - W_{out}$$

Heat Interaction: Energy "OUT" Q_{out}



Cylinder is cooled down by dipping into the ice cold water (Energy is **out** from the system)

Energy content of the system after this heat interaction:

$$E_i + W_{in} + Q_{in} - W_{out} - Q_{out}$$

$$= E_f$$ **Final Energy Content**

Governing Equation for the 1st Law of Thermodynamics

Energy content of the system after all interactions:

$$E_f = E_i + W_{in} + Q_{in} - W_{out} - Q_{out}$$

1st Law of Thermodynamics is therefore:

$$E_i + W_{in} + Q_{in} = E_f + W_{out} + Q_{out}$$

For a **control mass** (steady-state)

Advantages of this Method

$\Delta E = E_f - E_i = Q - W$ (typical textbook equation)

Need **sign convention** (often very confusing)

$Q > 0$: heat transfer to the system

$Q < 0$: heat transfer from the system **(negative heat?)**

$W > 0$: work done by the system

$W < 0$: work done on the system **(negative work?)**

$$E_i + Q_{in} + W_{in} = E_f + Q_{out} + W_{out}$$

Advantages of this Method (2)

$$E_i + Q_{in} + W_{in} = E_f + Q_{out} + W_{out}$$

- **No sign convention required:** just keep track of what's "in" and what's "out" energy is always positive (physically makes more sense)
- **Equation is symmetrical:** students need to memorize only one of them (either RHS or LHS of equation) and actually makes more sense in terms of conceptual 1st law idea of "energy must be balanced"

1st Law of Thermodynamics in Control Mass - Summary (1)

$$\Delta E = (E_f - E_i) = (Q_{in} + W_{in}) - (Q_{out} + W_{out})$$

Change in energy content of the system

Energy transfer **in**to the system, due to heat and/or work interaction

Energy transfer **out** from the system, due to heat and/or work interaction

(Steady Control Mass)

1st Law of Thermodynamics in Control Mass - Summary (2)

Time rate of change in energy contents (POWER):

$$\frac{dE}{dt} = \frac{d}{dt}(Q_{in} + W_{in}) - \frac{d}{dt}(Q_{out} + W_{out})$$

$$\frac{dE}{dt} = (\dot{Q}_{in} + \dot{W}_{in}) - (\dot{Q}_{out} + \dot{W}_{out})$$

$$\boxed{\frac{dE}{dt} = \sum(\dot{Q}_{in} + \dot{W}_{in}) - \sum(\dot{Q}_{out} + \dot{W}_{out})}$$