AQA A-Level Physics

11.2 Thermodynamics and engines

Flashcards

What is the first law of thermodynamics?

What is the first law of thermodynamics?

Conservation of energy in systems when cooling, heating and doing work.

$$Q = \Delta U + W$$

Q = Energy transferred by heating

U = Internal energy

W = Work done by system

A gas is compressed due to work being done on it, W is therefore positive. True or False?

A gas is compressed due to work being done on it, W is therefore positive. True or False?

False, work is done on a gas hence W is negative.

If a gas is cooled, Q is negative. True or False?

If a gas is cooled, Q is negative. True or False?

True, energy is removed hence Q is negative.

What assumptions are necessary when applying the 1st law to a closed (non-flow) system?

What assumptions are necessary when applying the 1st law to a closed (non-flow) system?

That the gas is an ideal gas so the internal energy is only dependent on temperature, work done causes a change in volume and the ideal gas law ($pV = nRT$) can be applied where n and R will both be constant.

What is an isothermal change?

What is an isothermal change?

A change that occurs at a constant temperature. This means internal energy stays constant so $Q = W$, meaning any transfer of energy would lead to work being done and vice versa. It obeys Boyle's Law: $PV = \text{constant}$

How do you calculate the work done on a isothermal change p-V diagram?

How do you calculate the work done on a isothermal change p-V diagram?

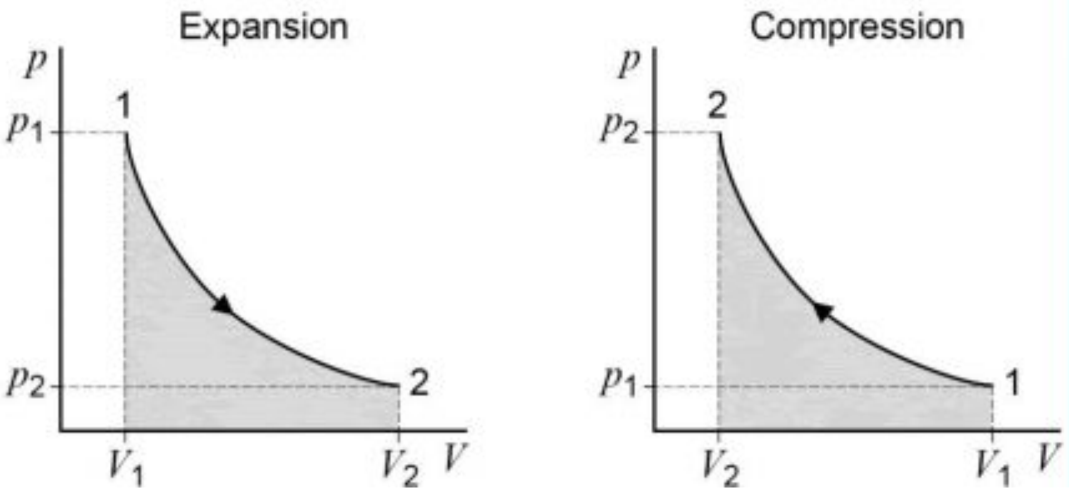


Image: AQA

The work done is the area under the graph, between the two points.

What is an adiabatic change?

What is an adiabatic change?

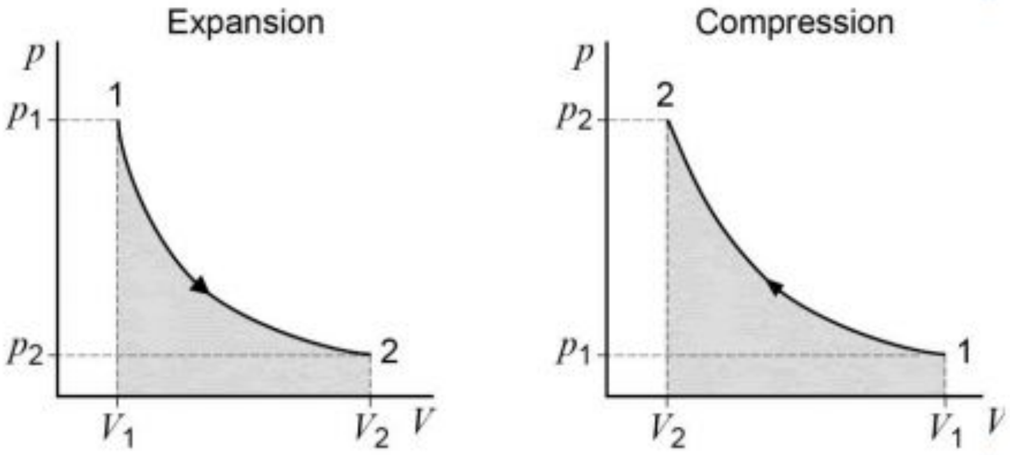
A change in which no heat passes in or out. $Q = 0$ and $W = -\Delta U$. If work is done by the system, W is positive and the internal energy will decrease.

Obeys $pV^{\gamma} = \text{constant}$

(where γ is the adiabatic constant that depends on the type of gas)

How can you calculate the work done on a p-V diagram for adiabatic changes?

How can you calculate the work done on a p-V diagram for adiabatic changes?



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The work done is the area under the pressure volume graph.

What is a constant pressure change?

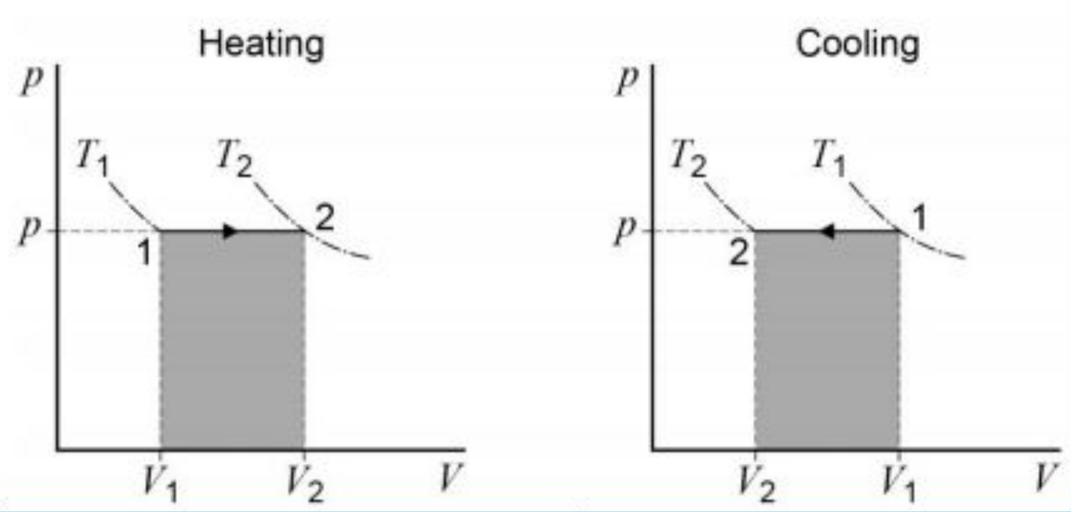
What is a constant pressure change?

If a gas is kept at a constant pressure, it will increase in volume when heated.

$$W = p\Delta V$$

How do you calculate the work done from a constant pressure change p-V diagram?

How do you calculate the work done from a constant pressure change p-V diagram?



The work done is the area under the graph.

Image: AQA

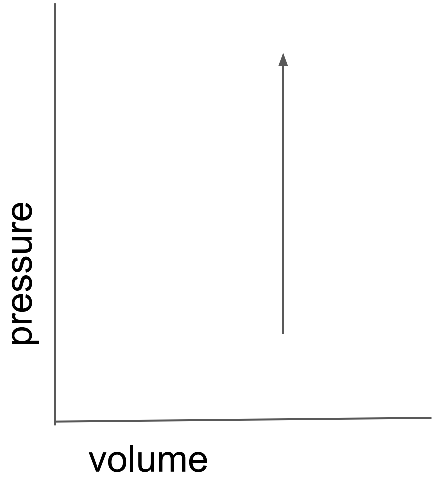
What is a constant volume change?

What is a constant volume change?

When heating gas in an enclosed space, volume stays constant. This leads to an increase in pressure, temperature and internal energy. $W = 0$ so $Q = \Delta U$. All the heat energy is transferred into internal energy.

Draw a constant volume change for heating on a p-V diagram

Draw a constant volume change for heating on a p-V diagram



No work is done as the volume doesn't change, the arrow points upwards as temperature has increased.

In a cyclic process, the work done per cycle on a graph is the...

In a cyclic process, the work done per cycle on a graph is the...

Area of the loop.

(the difference between the work done by the system and work done on the system).

What are indicator diagrams?

What are indicator diagrams?

A p-V diagram for engines that allows identification of the different processes in the system.

It may vary depending on speed, timing and load.

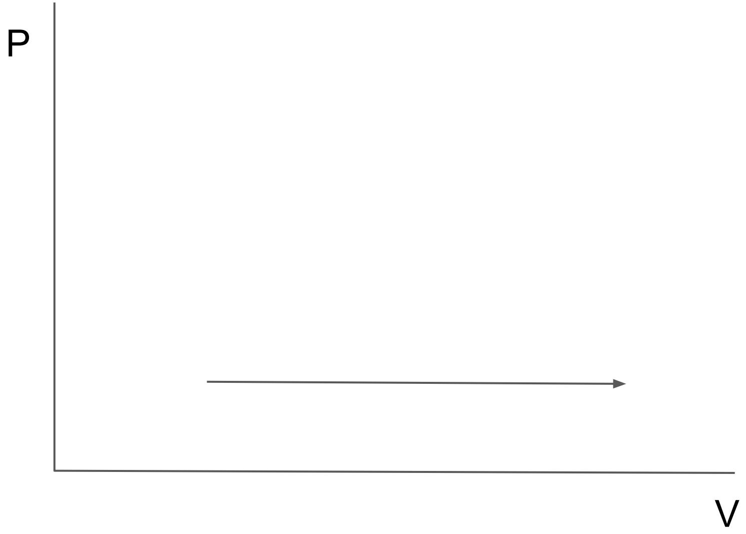
What are the key stages of induction in the four stroke petrol engine cycle?

What are the key stages of induction in the four stroke petrol engine cycle?

- The piston moves down the cylinder increasing the volume of gas above it.
- Air and petrol vapour are drawn into the cylinder through the open inlet valve.
- Pressure stays constant, volume increases.

Draw the indicator diagram for induction.

Draw the indicator diagram for induction.



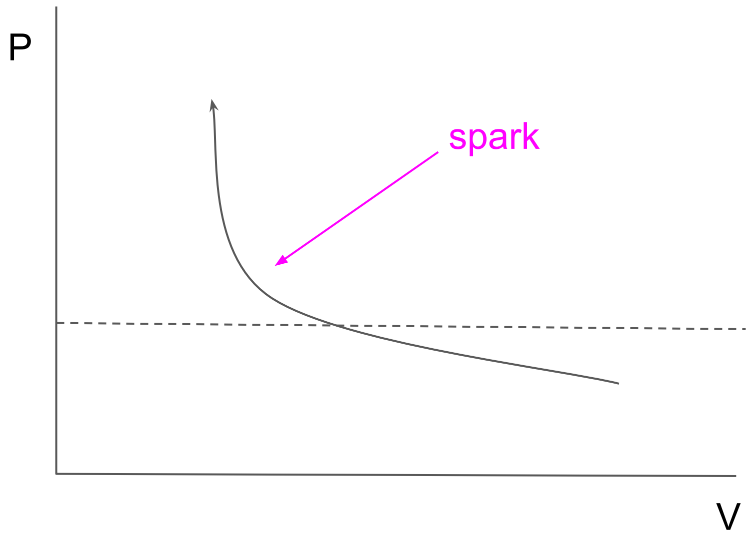
What are the key stages of compression in the four stroke petrol engine cycle?

What are the key stages of compression in the four stroke petrol engine cycle?

- The valves are closed.
- Piston moves back up cylinder, volume decreases, pressure increases (work is done).
- Near the end of the stroke, the spark plug ignites air/fuel mix causing an increase in temperature and pressure. Minimal volume change.

Draw the indicator diagram for compression.

Draw the indicator diagram for compression.



What are the key stages of expansion in the four stroke petrol engine cycle?

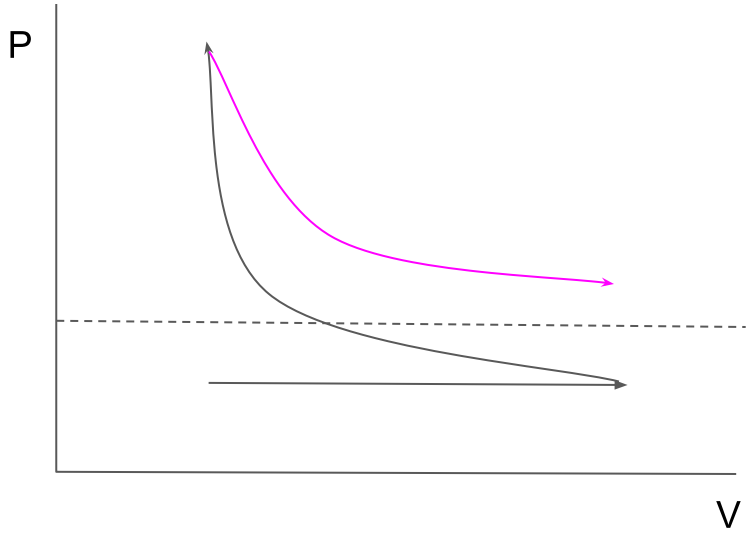
What are the key stages of expansion in the four stroke petrol engine cycle?

- Valves are closed, expanded ignited gas moves piston down.
- Work done by the expanding gas is more than the work done to compress the gas, net output of work.
- Near the end of the stroke, the exhaust valve opens to reduce pressure to near atmospheric.

Draw the indicator diagram for expansion.

Draw the indicator diagram for expansion.

The pink line shows expansion, the other lines are the previous stages.



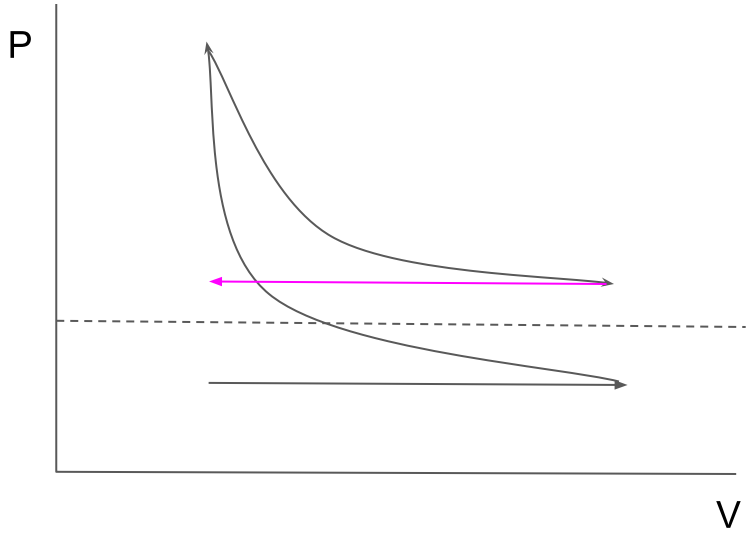
What are the key stages of the exhaust stroke in the four stroke petrol engine cycle?

What are the key points of the Exhaust stage in the four stroke petrol engine cycle?

- The piston moves back up, getting rid of the burnt air through the exhaust.
- Pressure just above atmospheric.

Draw the indicator diagram for the exhaust stroke

Draw the indicator diagram for the exhaust stroke



What assumptions are made for theoretical indicator diagrams of diesel and petrol engines?

What assumptions are made for theoretical indicator diagrams of both diesel and petrol engines?

- Pure air is continuously cycled.
- Pressure and temperature changes can be instant.
- The heat source is external.
- The engine is frictionless.

What 4 processes make up the theoretical cycle of a 4 stroke petrol engine?

What 4 processes make up the theoretical cycle of a 4 stroke petrol engine?

1. The gas is adiabatically compressed so no heat is transferred.
2. Volume stays constant as heat is supplied.
3. Gas cools adiabatically.
4. System cools at constant volume.

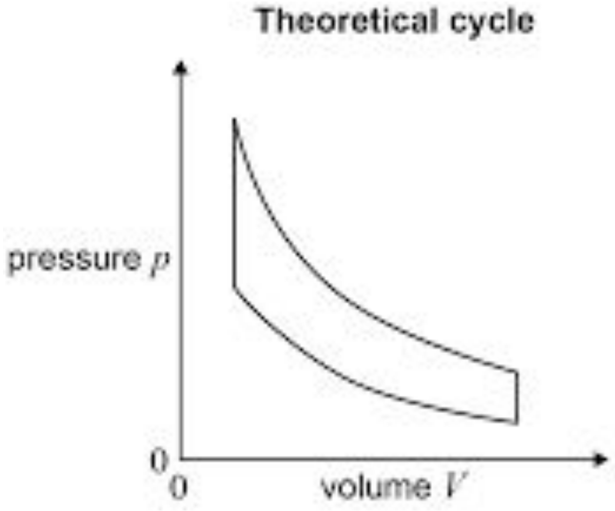
What 4 processes make up the theoretical cycle of a 4 stroke **diesel** engine?

What 4 processes make up the theoretical cycle of a 4 stroke **diesel** engine?

1. Gas is adiabatically compressed.
2. Heat is supplied, pressure stays constant.
3. Gas cools adiabatically.
4. System cools at constant volume.

Describe the difference between the theoretical and real four-stroke petrol engine cycle on a p-v graph.

Draw the difference between the theoretical and real four-stroke petrol engine cycle on an indicator diagram.



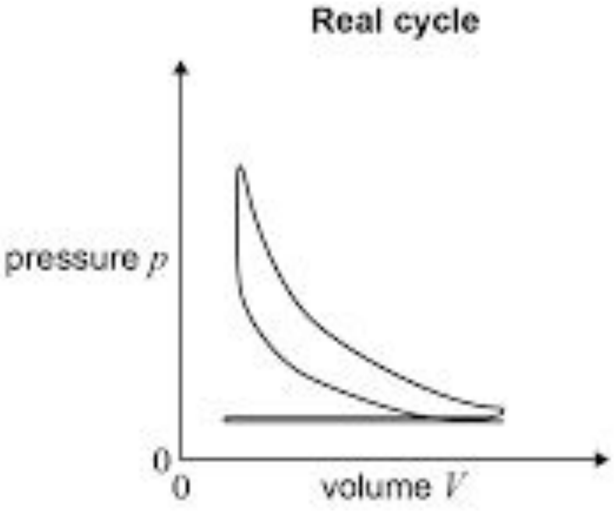


Image: AQA

Describe a four stroke **diesel** engine cycle induction stroke.

Describe a four stroke diesel engine cycle induction stroke.

- Inlet valve opens.
- Air is drawn into cylinder (no fuel).
- Volume increases, pressure stays constant.

Describe a four stroke diesel engine cycle compression stroke.

Describe a four stroke diesel engine cycle compression stroke.

- Inlet valve closed.
- Piston moves in, air is compressed.
- Temperature increases, air becomes hot enough to ignite fuel.
- Diesel is sprayed into cylinder and ignites.

Describe a four stroke diesel engine cycle expansion and exhaust stroke .

Describe a four stroke diesel engine cycle expansion and exhaust stroke.

- Gas expands, moving the piston down.
- Net output of work.
- Exhaust valve opens and removes heat and burnt gas.
- Piston moves in, expelling more gas.

What is the difference between petrol and diesel engine indicator diagrams?

What is the difference between petrol engine and diesel engine indicator diagrams?

The petrol engine diagram has a sharper peak at the start of the expansion stroke than diesel engines (due to spark).

Why are corners rounded on actual indicator diagrams?

Why are corners rounded on actual indicator diagrams?

It's theoretically assumed that the same air is used constantly but actually the valves need time to open and close.

Why doesn't heating take place at a constant volume in a real engine?

Why doesn’t heating take place at a constant volume in a real engine?

The increase in pressure and temperature isn’t instantaneous in a real engine.

Why don’t theoretical indicator diagrams include the negative work done between the exhaust and induction lines?

Why don’t theoretical indicator diagrams include the negative work done between the exhaust and induction lines?

It assumes the same air continuously cycles round the system.

Why do theoretical indicator diagrams have a higher peak than actual diagrams?

Why do theoretical indicator diagrams have a higher peak than actual diagrams?

The temperature rise from burning the gas isn’t as large as predicted as the fuel isn’t completely burnt, so maximum pressure isn’t achieved (hence lower peak).

Why is the area within the indicator diagram loop smaller for real engines than theoretical engines?

Why is the area within the indicator diagram loop smaller for real engines than theoretical engines?

The net work done by an actual engine is less than for a theoretical engine as energy is needed to overcome friction in the engine’s moving parts.

What is the input power of an engine?

What is the input power of an engine?

Input power = calorific value of fuel x fuel flow rate

The amount of heat energy per unit time it could gain from fuel.

How can you calculate the work done on the gas during the compression phase of an indicator diagram?

How can you calculate the work done on the gas during the compression phase of an indicator diagram?

The area underneath the curve during the compression phase.

How can you calculate the work done by the gas during the expansion phase of an indicator diagram?

How can you calculate the work done by the gas during the expansion phase of an indicator diagram?

The area underneath the curve during the expansion phase.

How can you calculate the net work done during the cycle?

How can you calculate the net work done during the cycle?

The area enclosed by the loop, which is work done on the gas during compression minus the work done by the gas during expansion.

How can you predict the engine’s indicated power?

How can you predict the engine's indicated power?

The area enclosed by the loop x number of cycles per second x number of cylinders.

It is the net work done by the engine cylinder in one second.

Why would the output power be less than the indicated power?

Why would the output power be less than the indicated power?

Some power is used when overcoming frictional forces, this power is called frictional power.

How can you calculate output/brake power ?

How can you calculate output/brake power ?

Brake power is the power delivered to the crankshaft of the engine.

$$P = T\omega$$

In this case P is the output/brake power, T is the engine torque and ω is the angular velocity of the crankshaft.

How can frictional power be calculated?

How can frictional power be calculated?

Frictional power = Indicated power - brake power

How do you calculate the overall efficiency?

How do you calculate the overall efficiency?

Brake power / input power

How do you calculate the thermal efficiency ?

How do you calculate the thermal efficiency ?

Indicated power / input power

How do you calculate the mechanical efficiency?

How do you calculate the mechanical efficiency?

Brake power / indicated power

Why can’t an engine work using only the 1st Law of thermodynamics?

Why can’t an engine work using only the 1st Law of thermodynamics?

Even with the most theoretically efficient engine, some energy is lost to overcoming friction, hence the heat energy can’t all be transferred to work.

What is the Second Law of thermodynamics?

What is the Second Law of thermodynamics?

The heat energy inputted to an engine is equal to the useful work done by the engine and the heat lost to the sink.

Heat cannot be completely converted to work without some being lost in heating a colder body (sink).

Heat engines must operate between a heat source and a heat sink.

What is the consequence of the second law of thermodynamics for a heat engine?

What is the consequence of the second law of thermodynamics for a heat engine ?

A heat engine needs to work between a (hot) source and a (cold) sink.

Why are CHP plants useful for places such as green houses and schools?

Why are CHP plants useful for places such as green houses and schools?

Heat engines have an efficiency of around 35% , they transfer over twice as much energy to the surroundings as is used for useful work. The waste heat can be used for thermal heating in buildings (limiting energy waste).

What is a reversed heat engine?

What is a reversed heat engine?

An engine that transfers heat from a colder to a hotter place, these places are reservoir spaces.

What is a heat pump?

What is a heat pump?

A heat pump provides maximum energy per joule of work to the hot reservoir.

It is an engine used to heat places.

What is a refrigerator?

What is a refrigerator?

A refrigerator removes the maximum energy per joule of work from a cold reservoir.

It is used for air conditioning.

For a refrigerator and a heat pump, is work done onto the system or by the systems?

For a refrigerator and a heat pump, is work done onto the system or by the systems?

Work needs to be done on the systems, as both systems need inputted energy to operate.

Why can't we use the term efficiency when considering the effectiveness a heat pump and refrigerator?

Why can we use the term efficiency when considering the effectiveness a heat pump and refrigerator?

The coefficient of performance (COP) is used instead, as it often exceeds 1 greatly, whilst efficiency can never exceed 1.

How can you calculate the COP of a refrigerator?

How can you calculate the COP of a refrigerator?

$$COP_{ref} = Q_C / W \text{ or } T_C / T_H - T_C$$

How can you calculate the COP of a heat pump?

How can you calculate the COP of a heat pump?

$$COP_{hp} = Q_H / W \text{ or } Q_H / (Q_H - Q_C)$$

The maximum theoretical COP is:

$$T_H / (T_H - T_C)$$