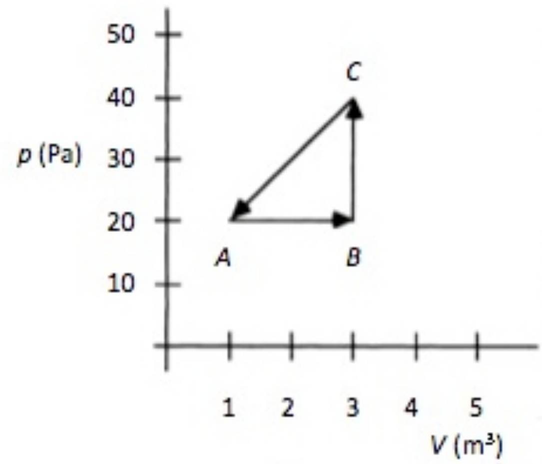
# Fundamentals of Physics in Engineering I

## Unit 5.- THERMODYNAMICS

**1.**-Indicate the signs of heat and work for the following processes: (a) An anvil is beaten by a hammer and then is cooled. (b) The $CO_2$ gas inside a rigid container is heated with temperature and pressure increasing. (c) A mixture of $H_2$ and $O_2$ in a cylinder with adiabatic walls explodes by the action of a spark and the piston moves, and so the gas volume increases. (d) A metal spring is compressed sharply.

**2.**-In a certain process, 500 cal and a mechanical work of 100 J are supplied to a system. Find the change in internal energy of the system.

**3.**-A thermodynamic system changes from an initial state A to an state B and then back again to A, via state C, as shows in the path A-B-C-A on the *pV*-diagram of the figure. (a) Complete the table of the figure indicating the appropriate sign (+) or (-) for the thermodynamic quantities in each process. (b) Calculate the numerical value of the work done by the system during the cycle A-B-C-A.




| | Q | W | ΔU |
|---|---|---|---|
| A ⟶ B | | | + |
| B ⟶ C | + | | |
| C ⟶ A | | | |

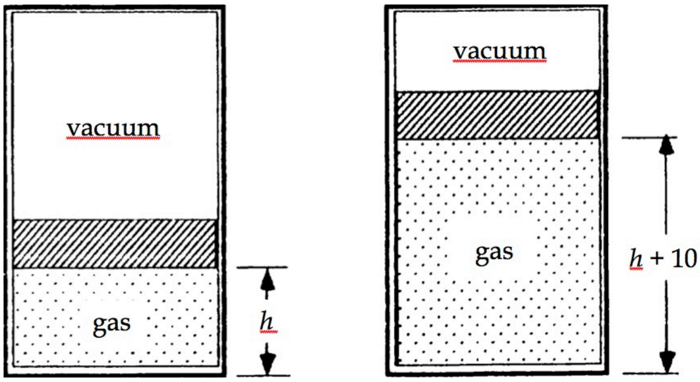
**4.-**The initial temperature and pressure of 1 mol of an ideal gas are 0ºC and 1 atm. The gas is compressed reversibly and adiabatically until its temperature rises to 10ºC. The gas is then expanded reversibly and isothermally until its pressure becomes 1 atm again. (a) Find the pressure after the adiabatic compression. (b) Calculate the total change in internal energy of the gas. (c) Calculate the heat and work for the complete process. Consider $C_p$ = 20.5 J $K^{-1}mol^{-1}$ and $R$ = 8.3 J $K^{-1}mol^{-1}$.

**5.-**One litre of oxygen ($O_2$) under normal pressure and temperature is expanded to a volume of 3 litres. (1) isothermally, (2) isobarically. Calculate, in each case: (a) The final pressure. (b) The final temperature. (c) The change in the internal energy. (d) The work done. (e) The heat supplied. ($C_p$ = 7 cal $K^{-1}mol^{-1}$).

**6.-** Demonstrate Reech's law: "the slope of the adiabatic curves is γ times greater than the slope of the isotherm curves".

**7.**-20 g of nitrogen gas ($N_2$**)** originally at a temperature of 27ºC are compressed reversibly and adiabatically from an initial volume of 17 litres to a final volume of 11 litres. Calculate the work done on the system and the change in its internal energy.

**8.-**0.1 moles of a diatomic ideal gas at an initial temperature of 273 K are in the bottom of the container of the figure. The piston has an area of 50 $cm^2$ and a mass of 100 kg and it is at a height *h*. The gas is heated and the piston moves up 10 cm. Calculate the value of the height *h*, the final temperature, the variation in internal energy of the gas and the heat supplied.




**9.-**200 $cm^3$ of dry air inside a cylinder, expand from a pressure of 10 to 1 atm. If the initial temperature of the dry air is 10ºC, calculate the final volume and the final temperature if the expansion is: (a) isothermal, (b) adiabatic. Calculate the work done in each case.
($C_v$ = 5 cal $K^{-1}mol^{-1}$).

**10.-**A heat engine operates between 127ºC and 27ºC with a heat input of 1200 J from the hot reservoir. The thermal efficiency of this heat engine is 80% of the one corresponding to a Carnot engine operating between the same temperatures. Calculate: (a) The work done per cycle. (b) The heat discarded to the cold reservoir per cycle. (c) The entropy change of the universe per cycle.

**11.-**A Carnot refrigerator is operating between two heat reservoirs at temperatures of 0ºC and 100ºC. In each cycle, the refrigerator receives 1 J of heat energy from the cold reservoir. (a) How much mechanical energy is required each cycle to operate the refrigerator? (b) During each cycle, how many joules of heat energy are discarded to the high-temperature reservoir?

**12.**-A system absorbs 300 cal from a reservoir at 300 K and 200 cal from a reservoir at 400 K. The system returns to its original state after doing a work of 100 cal and giving 400 cal to a third reservoir at a temperature *T*. (a) Calculate the entropy variation during each cycle and the thermal efficiency of this cycle. (b) If the cyclic process is reversible, what is the value of the temperature *T*?

**13.-**A ship engine operating through a Carnot cycle extracts heat from sea water at a temperature of 18°C and discards heat to a reservoir of dry ice at -78°C. If the engine has to develop a power of 8000 hp, how much dry ice will be consumed during the course of a day? Latent heat of sublimation of dry ice, $L_s$ = 137 cal/g. 1 hp (horsepower) = 736 W.

**14.-**Calculate the change in entropy when the equilibrium is reached if we mix 100 g of ice at 0ºC and 20 g of water vapour at 100ºC in an insulated container. The latent heats of melting and vaporization of ice and water vapour are $L_f$ = 80 cal/g and $L_v$ = 540 cal/g, respectively.

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