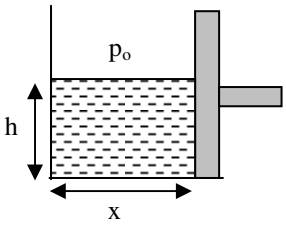
**ME –209 Basic Thermodynamics**

**Assignment -2**

NOTE: Use the value of $\gamma = 1.4$ for ideal gas wherever needed.

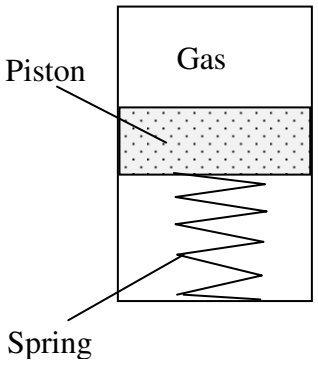
1. 2 kg of a substance undergoes the following changes in a cylinder piston arrangement. $P_1$=5 bar, $V_1$=0.1 $m^3$, $P_2$=2.0 bar, $V_2$=0.25 $m^3$
   (a) p varies as a linear function of V (Ans 52.5 kJ)
   (b) pV=Constant (Ans 45.8 kJ)
   (c) p remains constant till volume reaches 0.15 $m^3$ and $pV^n$ = Constant later (Ans 56.5 kJ)
2. An electric heater has a resistance of 40 Ohms. It is connected across a power supply of 240 V for a period of 1 hour. Determine the work done by the power supply on the heater. How many units of electricity are consumed. (5.18 MJ, 1.44 Units)
3. A system containing 5 kg of substance is stirred with a torque of 0.1 kgf-m, at a speed of 500 rpm for 24 hours. The system meanwhile expands from 1.5 $m^3$ to 2 $m^3$ against a constant prerssure of 5 kgf/$cm^2$. Determine the net work done by the system in kJ. (Ans -4191 kJ)
4. Evaluate the work done in the following processes. The system to be considered are underlined:
   (a) An <u>agent</u> slowly raises a <u>body</u> of mass 5 kg through a vertical distance of of 10 m in a gravitational field with g = 9.81 m/$s^2$ (Ans 490.5 J, -490.5 J)
   (b) A <u>body</u> of mass 10 kg is lowered by a crane slowly through a vertical distance of 30 kg in a gravitational field with g = 6 m/$s^2$ (1800 J, -1800 J)
   (c) A <u>body</u> of mass 10 kg falls freely through a vertical distance of 30 m in a gravitational field with g = 6 m/$s^2$ (neglect air resistance) (Ans 0 J)
   (d) A <u>body</u> of mass 10 kg falls freely through a vertical distance of 30 m in a gravitational field with g = 6 m/$s^2$. The <u>air</u> drag is 4 N ( Ans 120 J, -120 J)
   (e) A <u>rat</u> weighing 4 N climbs up a a stair of 0.3 m in height. (Ans 0 J)
5. The <u>electric motor</u> of a crane is supplied with a current of 14 A from a 200 V DC supply for a period of 15 s, while the crane lifts a <u>machine</u> of mass 2000 kg through a height of 2 m. The weight of the inextensible <u>cable</u> and the frictional resistance of the <u>pulleys</u> over which the cable passes are negligible. Evaluate the work done by the systems underlined. Assume g = 9.81 m/$s^2$. (Ans – 2760 J, -39240 J, 0 J, 0 J)
6. A ship's propeller is driven by a steam turbine through an 8:1 reduction gear. The mean resisting torque imposed by water on the propeller is 0.77 MN-m and the shaft power delivered by the turbine to the reduction gear unit is 15 MW at 1440 rpm. Evaluate:
   (a) The torque developed by the turbine, (99.5 kN-m)
   (b) The power delivered to the propeller shaft. (14.52 MW)
   (c) The net rate of work for the gear reduction unit. (-480 kW)
7. (a) The figure shows a channel of water supported by a piston. The width of the channel perpendicular to paper is b and pressure on the surface of water is $p_o$. Given that $\rho$ is the density of water, show that the force exerted on the piston is given by $F = \left( p_o + \frac{\rho g h}{2} \right) bh$

   (b) Calculate the work done by the water on the piston and by atmosphere on water, when the chamber length is slowly increased from $x_1$ to $x_2$

(Ans $W_{w-p} = \left[ p_o x_1 h_1 \ln\frac{x_2}{x_1} - \frac{\rho g h_1^{\,2} x_1^{\,2}}{2}\left(\frac{1}{x_2} - \frac{1}{x_1}\right)\right] b, \quad W_{aw} = p_o x_1 h_1 \ln\frac{x_2}{x_1}$ )

8 Consider a leak-proof, frictionless cylinder piston arrangement as shown in the figure. The initial pressure and volume of the gas in the cylinder are 500 kPa and 0.01 $m^3$ respectively. For simplicity the space on the spring side of the piston may be assumed evacuated. The gas from its initial state of equilibrium, expands quasistatically to a new final state where the pressure and volume are 100 kPa and 0.05 $m^3$ respectively. The process followed by the gas may be assumed to be $pV^n$ = constant. Calculate the work done for the following systems: (a) The gas, (b) the piston and (c) the spring
(Ans8.047 kJ, 0., -8.047 kJ)




9. A system executes a quasi-static process from an initial state 1 to a final state 2, absorbing 80 kJ of heat and expanding from 2 $m^3$ to 2.25 $m^3$ against a constant pressure of 2 bar. The system is brought back to its initial state by a non-quasi-static process, during which it rejects 120 kJ of heat. What is the work done in the second process? [-90 kJ]
10. 3 kg of air in a rigid container changes its state from 5 bar and 60°C to 15 bar while it is being stirred. The heat absorbed is 200 kJ. Assume air to be ideal gas with $C_V$ = 0.714 kJ/kg-K. Determine the final temperature, change in internal energy and work done. [999.4 K, 1427 kJ, -1227kJ]
11. 2.5 kg of air at 2 bar, 26°C forms a closed system,. It undergoes a constant pressure process with a heat addition of 650 kJ. Compute (a) final temperature, (b) change in enthalpy, (c) change in internal energy and (d) work done. Assume air to be ideal gas with a MM (Molecular Mass) of 29 kg/kmol and $C_V$ = .714 kJ/kg-K. [559K, 650 kJ, 464 kJ, 186 kJ]
12. A perfectly insulated system contains 0.05 $m^3$ of hydrogen at 25 °C and bar. It is stirred at constant pressure until the temperature reaches 50 °C. Determine (a) heat transferred, (b) change in internal energy, (c) stirrer work and (d) net work. For hydrogen MM = 2 kg/kmol, $\gamma$ = 1.4. Treat hydrogen as an ideal gas.[0, 5.24 kJ, -7.34 kJ, -5.24 kJ]
13. Air initially at 0.75 bar 1000 K, and occupying a volume of 0.12 $m^3$ undergoes two processes. The air is first compressed isothermally until the volume is halved. Then it undergoes a constant pressure process until the volume is halved again. Assuming ideal gas behaviour, (a) sketch the process on a p-V diagram, (b) determine the total work done and (c) determine the heat transferred. [sketch, -10.74 kJ, -21.95 kJ]
14. A piston cylinder assembly contains 1 kg of nitrogen gas. it expands from an initial state of 5 bar, 700 K to final state of 2 bar. During the process the path followed by the gas may be represented by $pV^{13}$ = constant. Assuming ideal gas behaviour compute the heat transfer during the process. [33 kJ].
15. Two well insulated rigid tanks with carbon monoxide (CO) gas are connected by a valve. In tank A, 1 kg of gas is stored at 100 kPa and 330 K where as in tank B, 5 kg of gas is stored at 500 kPa and 870 K. The valve is opened and the contents of the two tanks are allowed to mix until equilibrium is achieved. Assuming ideal gas behaviour determine, (a) volume of each tank, (b) the final temperature, and (c) the final pressure. [0.9798 $m^3$, 2.583 $m^3$, 780 K and 388 kPa]