Syllabus:
1. Mean free path
2. Adiabatic Processes for an Ideal Gas, inadequacies of the first law, the second law
3. Heat engines and heat pumps/refrigerators, COP of heat pump/refrigerator

1 Mean free path of the molecules of a gas depends on absolute temperature T as:

T A
T^(-1)
T^2
T^3
T^4

Solution:
l= 1/( sqrt(2) pi d^2 n_V), here n_V = number density of molecules = (number of molecules)/volume
Then n_V depends on temperature inversely, because we have, n_V = N/V = P/kT . Hence l varies as T

$$l = \frac{kT}{P\sqrt{2}\pi d^2}$$

2 If the mean free path of atoms is increased by 50% then the pressure P of gas will become
P/2
2P
3P/2
2P/3 A
4P
sqrt(2)P
Solution: We have

$$l = \frac{kT}{P\sqrt{2}\pi d^2}$$

Hence l -> (1+50%)l = (3/2)l which implies we have imposed P-> (2/3)P

3 At a temperature of 20 degree Celsius and a pressure of 750 torr, the mean free path of the Ar gas is $\lambda_{Ar} = 9.9 \times 10^{-6}$cm. What will be the mean free path at 20 degrees Celsius and 150 torr of pressure?

990 nm
120 nm
300 nm
495 nm A
50 nm

Solution: We know the mean free path is

$$\lambda = \frac{kT}{P\sqrt{2}\pi d^2}$$

Hence, at the same temperature: $\lambda_1 P_1 = \lambda_2 P_2$
Hence, $\lambda_2 = \lambda_1\,(P_1/P_2) = \lambda_1(750/150) = 5\lambda_1 = 4.95 \times 10^{-5}$cm

4 Consider two gases under identical conditions of temperature, pressure and volume. Their molecular diameters are 10 nm and 20 nm, respectively. The ratio of the mean free paths l_1 : l_2 of the molecules of two gases is:

1:2
1:4
2:1
4:1 A
1:sqrt(2)

Solution: Mean free path $l \propto 1/d^2$ Hence, $l_1 : l_2 = d_2^2 : d_1^2 = (20/10)^2 = 4 : 1$

5 Certain Ideal gas is found to be obey PV^(3/2)=Constant during an adiabatic process.If such a gas at initial temperature T is adiabatically compressed to half the initial volume.Its final temperature will be

T
sqrt(2) T A
2 T
2 sqrt(2) T
4 T

Solution: T V^(gamma-1) = constant => T V^(1/2) = constant
T2 = T1 (V1/V2)^(1/2) = T (1/(1/2))^(1/2) = sqrt(2) T

6 Meteorologists use the first law of thermodynamics in its adiabatic form (i.e. Q = 0). The temperature of the gas in a rising cloud falls as:

it goes to higher altitudes because:
we are away from the warm surface of the earth
the air pressure decreases with altitude, and the cloud expands A
the internal energy of the cloud decreases due to reduced pull of gravity
the air pressure decreases with the altitude, and the cloud contracts
the radiation from the gas molecules increases at higher altitudes

7 If two-thirds of the energy added to an engine as heat is removed to the engine's surroundings as heat, what is the efficiency of the engine?

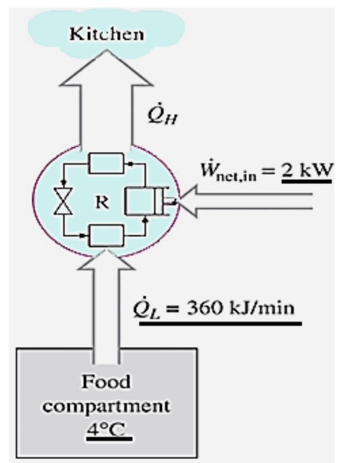
1/4
1/5
1/6
1/2
1/3 A

Solution: Given, Qc = (2/3)Qh, Eff = 1- (Qc/Qh) = 1 - (2Qh/3)/Qh = 1-(2/3) = 1/3

8  A heat engine that in each cycle does positive work and loses energy as heat, with no heat energy input, would violate:
the zeroth law of thermodynamics
the first law of thermodynamics A
the second law of thermodynamics
the third law of thermodynamics
Newton's first law of motion

9 Heat is transferred to a heat engine from a furnace at a rate of 80 MW. If the rate of waste heat rejection to a nearby river is 50 MW. The thermal efficiency for this heat engine is:
47.5 %
27.5 %
37.5 % A
57.5 %
none of the others

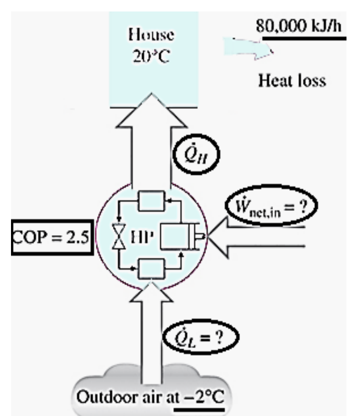
10 The food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2kW, the coefficient of performance of the refrigerator is:
Figure:




5
4
3 A
2
1

Explanation: COP = (360/2)(1/60) = 3.

11  A heat pump is used to meet the heating requirements of a house and maintain it at 20°C. On a day when the outdoor air temperature drops to 2°C, the house is estimated to lose heat at a rate of 80,000 kJ/h. The heat pump under these conditions has a COP of 2.5. The power consumed by the heat pump is:
Figure:




31 MJ/h
32 MJ/h A
33 MJ/h
34 MJ/h
35 MJ/h

Solution: Explanation: W = Q/COP = 80000 kJ/h / 2.5 = 32000 kJ/h

12  In a cryogenic experiment we need to keep a container at -125°C although it gains 100 W due to heat transfer. The smallest power of a motor that we require as a heat pump absorbing heat from the container and rejecting heat to the room at 20°C is:

95 kW
96 kW
97 kW
98 kW A
99 kW

Solution: COP = 1.022 and thus power required = 100/1.022 = 97.84 kW.