Heat – Calorimetry & Laws of Thermodynamics : Illustrations of Objective and Subjective Questions (Typical)

I-01	The amount of heat given to a body (ΔH) is expressed by $\Delta H = ms\Delta t$, where m is mass of the body, s is specific heat of the body and Δt is change in tempertaure of the body. Since, mass of the body is variable and dependes upon the body under consideration, while Δt is also variable can be different under different observations. While specific heat s of the body is characterstic to the material of the body. Therefore specific heat is also called Specific Heat caopacity of a body. **Hence, answer is (d)**
I-02	Water equivalent of a body in heat is the amount of water which will take heat equivalent to that required to raise temperature of a body and water by a 1 K., Therefore, for a body let $\Delta H_b = m_b s_b \Delta t_b \Rightarrow \frac{\Delta H_b}{\Delta t_b} = m_b s_b$ and for water $\Delta H_w = m_w s_w \Delta t_w \Rightarrow \frac{\Delta H_w}{\Delta t_w} = m_w s_w$. Thus for equal amonut of heat per degree change of temperature of body and the water is $\frac{\Delta H_b}{\Delta t_b} = \frac{\Delta H_w}{\Delta t_w} \Rightarrow m_b s_b = m_w s_w$. Thus water equivalent is $WE = m_w = \frac{m_b s_b}{s_w} = m_b\left(\frac{s_b}{s_w}\right)$. Here, the ratio of specific heat capacities is unit-less quantity and unit of water equivalent is same as that of mass i.e. kg. **Hence answer is (a).**
I-03	It is stated that hot liquid is mixed in cold liquid, there will be transfer of heat from hot liquid to cold liquid. Thus temperature of hot liquid would decrease, and temperature of cold liquid would increase, until temperature of mixture becomes constant. But, during the experiment or process the temperature observed would depend on how the bulb of the thermometer It leads to two possibilies – (i) If bulb is in contact with hot liquid being mixed – this will record abrupt rise of temperature approaching to temperature of hot liquid, and then decrease gradually till it becomes constant. (ii) If bulb continues to be immersed in cold liquid in which hot liquid is being mixed – this will record gradual rise of temperature untill it becomes constant. In the question densities of the Two liquids being mixed and position of the bulb is not defined to ascertain whether whether it is case of type (i) or (ii). **Therefore, option (a) and (b) are incorrect.** Since hot liquid being mixed cannot be infinte therefore, **option (c) is also invalid.** In absence of sufficient data change of temperature would remain undefined, but certainly on attaining thermal equilibrium temperature of the mixture will become nearly constant. Use of adjective 'nearly' is since attaining equilibrium is an exponential process and with increase of time rate of change of temperature $\frac{dT}{dt} \to 0$. **Thus answer is (d).** **N.B.:** In this question by creating insufficiency of data common sense has been challanged which would prompt to choose option (b), which is wrong.
I-04	For two units to represent same physical quantity they must be dimensionally same. In the question physical quantities being compared are : Kelvin, unit of temperature has dimension [K], Joule is unit of work or energy has dimension $[ML^2T^{-2}]$, Calories is unit of heat energy and as per law of conservation of energy it will have same dimension as Joule i.e. $[ML^2T^{-2}]$, Newton is unit of force and has dimension . $[MLT^{-2}]$. Thus dimensionally option (a) , (b) and C0 are incorrect, while option (d) is correct. **Hence, answer is Option (d).**
I-05	For two units to represent same physical quantity they must be dimensionally same. In the question physical quantities being compared are : Heat, it uis energy which has dimension $[ML^2T^{-2}]$, Tmperature is measure of hottness has dimnseion [K], Mole is amount of substance has dimension , work has same dimesion as eneregy

	having dimension [ML^2T^{-2}], specific heat has dimension $\frac{[ML^2T^{-2}]}{[MK]} = [L^2T^{-2}K^{-1}]$. Thus, dimensionally options (a), (b) and (d) are incorrect, and option (c) is correct. **Thus, answer is option (c).**
I-06	Amount of heat transferred to a body is $\Delta H = \Delta W + \Delta U$., ignoring component of mechanical energy. Here, ΔU is change in internal energy, ΔQ is amount of change in heat of the body, ΔW is work done. Thus when two bodies are at diffenernt temperatures mixed in a calorimeter their total internal energy remains conserved, while their temperatures change due to exchange of heat, **this makes option (a) incorrect**. Heat of the bodies is transient thermal energy and is transferred from one body to the other, **This makes option (b) incorrect**. Since, each body under goes change of temperature and physical state and hence each of them will individually undergo change in internal energy and hence **opion (d) is also incorrect**. But, the internal energy of the two bodies is sum of heat energy and kinetic energy which together for two bodies remainms conserved in the calorimeter. **Thus option (c) is correct**.
I-07	As per Mechanical Equivalent of heat (J) $W = JH$, here W is work i.e. energy equivalent to heat H (which too is also energy), while J is mechanical equivalent of heat. Thus, $J = \frac{W}{H}$ is a ration of two quantities having dimension of energy, which makes it a dimensionless quantity. **Thus correct option is (d).**
I-08	Amount of heat in a body is $H = msT$, here H is heat, m is mass of the body, s is specific heat of body and T is temperature. By definition heat capacity of a body is heat required per unit rise of temperature it leads to heat capacity of a body . Thus heat capacity is product of mass which is fixed i.e. option (c), and specific heat (s) which characterstic to material of the body i.e. option (d) are correct. Since heat given and temperature of the body are variables and hence options (a) and (b) are incorrect. **Thus, answer option (c) and (d) are correct.**
I-09	Heat capacity of body is $H_c = \frac{\Delta H}{\Delta T} = ms$, while molar heat capacity $H_{c-m} = Ms$, here is molar mass of substance Thus, the desired ratio is $\frac{H_c}{H_{c-m}} = \frac{ms}{Ms} = \frac{m}{M}$. Since mass of a given body is fixed hence $\frac{H_c}{H_{c-m}} \propto \frac{1}{M}$. Thus the ration depends on molar mass or molecular weight of the substance of the body. **Thus, answer is option (c).**
I-10	Heat supplied to a body may lead to rise in temperature in accoradnce with $\Delta H = ms\Delta T$, **this makes option (b) correct**. If on account of supply of heat there is change of state which is solid to liquid called melting process or **direct vapour called sublimation process at constant temperature such that** $\Delta H = \Delta mL$**,** this makes option (c) correct. Thus incertainity by stating 'may' in option invalid this **makes option (a) incorrect**. Further, on supply of heat to solid reduction of temperature is vilation of $\Delta H = ms\Delta T$, this makes **option (d) to be incorrect**. **Thus, answer is option (b) and (c)**
I-11	If temperature of a solid is constant there are following possibilities 1. $\Delta H = 0$, there would be $\Delta T = 0$ it leads to another two possibilities a. No heat is suplied – this makes it assertive and would thus rule out any other possibility, **thus option (c) is incorrect** b. No heat is extracted – this makes it assertive and would thus rule out any other possibility, **thus option (c) is incorrect** 2. $\Delta H \neq 0$ still for $\Delta T = 0$ the heat either absorbed or released it causes change in internal energy and in turn state of matter. It also has two possibilities a. $\Delta H > 0$ this is case of melting of solid, and b. $\Delta H < 0$ this is case of solidification. Thus, for constant temperature $\Delta H \geq 0$ I makes **option (a) correct** where heat may have been supplied..

	Likewise, $\Delta H \le 0$ I makes **option (b) correct** where heat may have been extracted. Thus answer is option (a) and (b).
I-12	As per conservation energy $\Delta Q = \Delta W + U$, here component of mechanical energy is ignored. Temperature of a body can rise due to either supply of heat and/or adiabatic compression. Therefore, rise of temperature may be attributed to supply of heat; this makes option (c) as correct, and/or work done upon it is not isothermal; this makes option (d) as correct. But, stating certainty for rise of temperature due to supply of heat provided in **option (a) is incorrect**. Further, stating with certainty that heat is not supplied as provided in **option (b) is also incorrect.** **Thus, correct answer is option (c) and (d).**
I-13	Heat and Work are equivalent means that when either Heat is upplied or work is done upon a body its temperature would rise. Each of the option is being analysed separately – Options (a): It provides for exculsivity of supply of heat for rise of temperature of the body and hence **it is incorrect.** Option (b) : It provides for exculsivity of work done upon a body for rise of temperature of the body and hence **it is incorrect.** Oprion (c): By stating 'can' in the sytatement it provides for possibility of work done upon a body for rise of temperature of the body and hence **it is correct.** Option (d): As per Second Law of thermodynamics mechanical energy can be completely converted into work, but heat energy cannot be completely converted into mechanical energy. Statement in the option indicates complete convertibility heat energy into mechanical (kinetic) energy, hence **it is incorrect.** **Hence answer is Option (c).**
I-14	When hot iron block at 100^0C is put in water in a container in equilibrium at 20^0C, after some time the mixture will attain an equilibrium at temperatutre where all objects will be at T_{m-f}. As per law of conservation of energy $H_{v-w-i} + H_{Fe-i} = H_{v-i} + H_{Fe-i} \Rightarrow (m_v s_v + m_w s_w)T_i + m_{Fe} s_{Fe} T_{Fe-i} = (m_v s_v + m_w s_w + m_{Fe} s_{Fe})T_{m-f}$. Substituting the given data: $(0.5\times910 + 0.2\times4200)\times20 + 0.2\times470\times100 = (0.5\times910 + 0.2\times4200 + 0.2\times470)T_{m-f}$. It leads to $35300 = 1389\times T_{m-f} \Rightarrow T_{m-f} = \frac{35300}{1389} = 25.4^0\text{C}$. **Thus, considering SGs of temperature answer is** 25^0C
I-15	When hot iron block at T^0C is put in water in a container in equilibrium at 20^0C, after some time the mixture will attain an equilibrium at temperatutre where all objects will be at T_{m-f}. As per law of conservation of energy $H_{v-w-i} + H_{Fe-i} = H_{v-i} + H_{Fe-i} \Rightarrow (W_{e-c} + m_w)\times s_w \times T_i + m_{Fe} s_{Fe} T = ((W_{e-c} + m_w)\times s_w + m_{Fe} s_{Fe})T_{m-f}$. Here, water equivalent calorimeter is the amount of water which will require same amount of heat to raise its temperature by 10C as that required to do so with calorimeter. Therefore, water equivalent is added to masst of water in the calorimeterheat required tois added to mass of water. Substituting the given data: $(0.01 + 0.24)\times4200\times20 + 0.1\times470\times T = ((0.01 + 0.24)\times4200 + 0.1\times470)\times60$. It leads to $47\times T = 65820 - 21000 \Rightarrow T = \frac{44820}{47} = 953.6^0\text{C}$. **Thus, considering SGs of temperature answer is** 954^0C
I-16	Three liquids A, B and Ceach of mass m are at temperature $T_A = 12^0\text{C}$, $T_B = 19^0\text{C}$ and $T_C = 28^0\text{C}$, respectively. Let the liquids have specific heat capacities as s_A, s_B and s_C, respectively. Therefore, heat balance equation when liquid A and B are mixed shall be $m\times s_A \times T_A + m\times s_B \times T_B = m\times(s_A + s_B)\times T_{AB}$, here,

T_{AB} is temperature of mixture of liquids AB. It leads to $12\times s_A + 19\times s_B = 16\times\left(s_A + s_B\right) \Rightarrow \frac{s_A}{s_B} = \frac{3}{4}$. Likewise, when liquids B and C are mixed $m\times s_B \times T_B + m\times s_C \times T_C = m\times\left(s_B + s_C\right)\times T_{BC}$. On substituting the values it leads to $19\times s_B + 28\times s_C = 23\times\left(s_B + s_C\right) \Rightarrow \frac{s_B}{s_C} = \frac{5}{4}$. Therefore, when liquids A and B are mixed, let temperature of mixture is T_{AC}, then heat balance equation would be $12\times s_A + 28\times s_C = T_{AC}\times\left(s_A + s_C\right)$. It further leads to $T_{AC} = \frac{12\times s_A + 28\times s_C}{s_A + s_C}$. Dividing, numerator and denominator on RHS by we get $T_{AC} = \frac{12\times\frac{s_A}{s_C} + 28}{\frac{s_A}{s_C} + 1}$. From ratios of specific heat capacities determined above $\frac{s_A}{s_C} = \left(\frac{s_A}{s_B}\right)\times\left(\frac{s_B}{s_C}\right) = \frac{3}{4}\times\frac{5}{4} = \frac{15}{16}$.

Substituting this in final form of T_{AC} we get $T_{AC} = \frac{12\times\frac{15}{16} + 28}{\frac{15}{16} + 1} = \frac{\frac{45}{4} + 28}{\frac{31}{16}} = \frac{157}{4}\times\frac{16}{31} = 20.26^0\text{C}$. **Thus answer is** 20.3^0C.

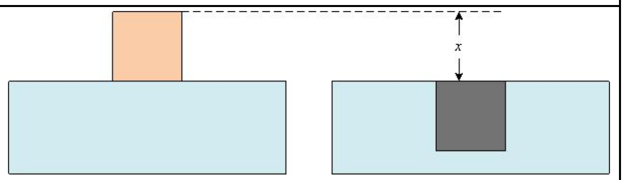
I-17

Mass of each ice cubes, as per given data, is $m_c = V_c \times \rho_c = \left(8\times 10^{-6}\right)\times 900 = 7.2\times 10^{-3}\,\text{kg}$. Therefore, mass of four ice cubes is $m_{c-4} = 4\times 7.2\times 10^{-3} = 28.8\times 10^{-3}\,\text{kg}$. Mass of drink, as per given data is $m_d = V_d \times \rho_c = \left(200\times 10^{-6}\right)\times 1000 = 200\times 10^{-3}\,\text{kg}$. At thermal equilibrium there are two possible condition – (a) Ice cubes take heat from the drink first to melt, and then continue to gain heat till thermal equlibrium of the mixture is attained at temperature T such that $0 < T < 10^0\text{C}$, (b) Part of the ice cubes take heat from the drink to melt till temperature of mixture reaches 0^0C. Beyond that there will be no transfer of heat as per Zeroth Lasw of Thermodynamics as both liquid mixture and ice are at 0^0C.

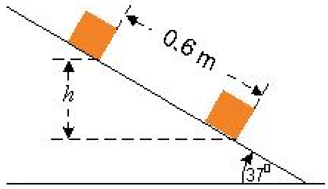
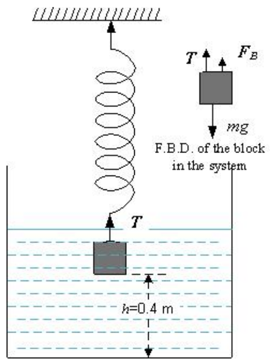
Taking first the case (a) : for analysis the heat balance equation will be heat gained by ice cubes and water created by meltingis equal to heat lost by the drink. Accordingly, $m_{c-4}\times L_f + m_{c-4}\times s_d \times T = m_d \times s_d \times\left(10 - T\right)$. On substituting values from the given data we get that $\left(28.8\times 10^{-3}\right)\times\left(3.4\times 10^5\right) + \left(28.8\times 10^{-3}\right)\times\left(4.2\times 10^3\right)\times T = \left(200\times 10^{-3}\right)\times\left(4.2\times 10^3\right)\times\left(10 - T\right)$. It leads to $97.92\times 10^3 + 0.12\times 10^3 \times T = 0.84\times 10^3\times\left(10 - T\right) \Rightarrow 97.92 + 0.12\times T = 8.4 - 0.84\times T \Rightarrow 0.96\times T = 8.4 - 97.92$. It further solves into $0.96T = -89.52 \Rightarrow T = \frac{-89.52}{0.96} = -93.3^0\text{C}$.This since leads to a (-)ve temperature of the mixture, which is not possible since essential condition $0 < T < 10^0\text{C}$ stated earlier is violated. **Thus it will lead to partial fusion of ice and temperature of mixture at equilibrium would be 0^0C. This is part (a) of the answer.**

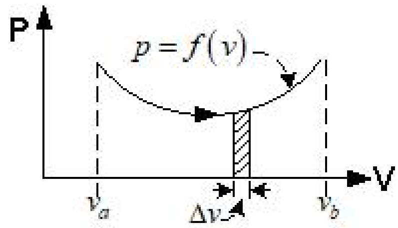
Extending rhe conclusion arrved at in case (a) to determine mass X of the ice that has melted as per case (b) and also desired in part (b) of the answer. In this case heat balance equation shall be $X\times L_f = m_d \times s_d \times\left(10 - 0\right) \Rightarrow X = \frac{0.2\times\left(4.2\times 10^3\right)\times 10}{3.4\times 10^5} = 2.47\times 10^{-2}\,\text{kg} = 24.7\text{ g}$. **Thus, considering SGs, the answer to part (b) is 25 g.**

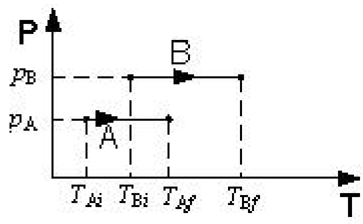
N.B.: Two parts of this question can be split in two sepearte questions.

I-18	Rate of water seeping out of pitcher is $r = 0.2\,\text{g} = 2\times10^{-4}\,\text{kg.s}^{-1}$. Mass of water in the pitcher is $m = 100\,\text{kg}$. It is given that all the water that sees out take heat from water inside the pitcher. Therefore, rate of transfer of heat from water inside the pitcher is $R = r\times L_v = \left(2\times10^{-4}\right)\times\left(2.27\times10^{6}\right) = 4.54\times10^{2}\ \text{J.s}^{-1}$. Amout heat transfer to reduce temperature of water inside the pitcher by $\Delta T = 5^0\,\text{C}$ is $\Delta Q = m\times s\times\Delta T$. Accordingly, time taken to reduce temperature is $t = \frac{\Delta Q}{R}$. Substituting he given data and the above derived values $t_{\sec} = \frac{100\times4200\times5}{4.54\times10^{2}} = 462.6\sec \Rightarrow t_{\min} = \frac{462.6}{60} = 7.7\min$. **Thus, answer is 7.7 min.**
I-19	 Let cube at temperature T is of side of length x such that $V_c = x^3$. For the cube to sink mass of ice that melts is $m_i = V_c\times\rho_i$ and thus displaced is to immerce the ice block such that its upper surface just goes inside the ice. This is equlbrium position when ice block comes to the temperature of ice. Thus energy balance equation of the process would be: $\Delta Q_c + W_c = m_i\times L_f \Rightarrow V_c\times\rho_c\times s_c\times\left(T-0\right) + V_c\times\rho_c\times g\times x = V_c\times\rho_i\times L_f \Rightarrow \rho_c\times\left(s_c\times T + \rho_c\times g\times x\right) = \rho_i\times L_f$ The single equation in its final form has Two variables T and x, while only T has to be determined, and, therefore, which is not defined in the problem and in turn component of mechanical work done by cube in descending inside ice Mechanical Equivalent of heat (J) is ignored. Thus the energy balance equation reduces to heat balance equation $\rho_c\times s_c\times T = \rho_i\times L_f \Rightarrow T = \frac{\rho_i\times L_f}{\rho_c\times s_c}$. On substituting values from the given data $T = \frac{\left(900\right)\times\left(3.36\times10^{5}\right)}{\left(8\times10^{3}\right)\times\left(470\right)} = 80.4^0\text{C}$. **Thus, answer is 80^{0}C.** **N.B.:** It is important to decide extend of analysis based on given data and equations evolved., as done here.
I-20	In this problem ice gains heat to convert into water, and steam condenses to convert into water. Since latent heat of evaporation is sufficiently more than that of ice, the ice would fully melt and its temperature at equilibrium would be that of steam, but steam would condense partially. Thus heat balance equation would $m_i\times L_f + m_i\times s_w\times100 = m_s\times L_v \Rightarrow 1\times3.36\times10^{5} + 1\times4200\times100 = m_s\times2.26\times10^{6} \Rightarrow m_s = \frac{7.56}{22.6} = 0.335\,\text{kg}$ of steam would be utilized to melt the ice and raise itsperature to 100^{0}C. Thus total amount of **in the system water would be 1+0.335=1.335 kg**, and amount of un condenseded steam would be $1 - m_s = 1 - 0.335 =$ **0.665kg steam. Thus answer is 665 g of steam and 1.335 kg of water.**
I-21	It is a case of conversion of electrical energy into heat energy with different unit, involving Law of Conservation of Energy. Heat required to raise temperature is $\Delta H = m\times s\times\Delta t = 20\times4200\times\left(35-10\right) = 2.1\times10^{5}\,\text{J}$. While, effective power P_e of heater to produce heat is $P_e = P\times\eta$ is where $P = 1000$ W is power of heater and $\eta = 0.8$ is efficiency of heater. Heat equivalent of energy is $1\,\text{J} = 1\,\text{W}\times\text{S}$, therefore time to heat water as required is $t = \frac{\Delta H}{P_e\times60} = \frac{2.1\times10^{5}}{1000\times0.8\times60} = 43.75$. **Thus, considering significant digits answer is 44 min.**
I-22	Amount of heat in water in tap water above room temperature is $\Delta H = m_w s_w \Delta t$ J. Mass of water in tank of capacity 0.5 m^3 is $m_w = V\times\rho_w = 0.5\times1000 = 500\,\text{kg}$. It is stated that this heat is fully utilized to lift an object of mass m through a height h which requires work to be done $W = mgh$ N.m. Also 1 N.m=1 J. Therefore, as per

	law of conservation of energy $\Delta H = W \Rightarrow m_w s_w \Delta t = mgh \Rightarrow h = \frac{m_w s_w \Delta t}{mg} = \frac{500\times 4200\times(20-5)}{10\times 10} = 315,000$ m or 315 km. **Thus answer is 315 km.** **N.B.:** Such exapmles gives a realization of enormity of heqat energy
I-23	As per first law of thermo dynamics $\Delta Q = W + \Delta U$. In the instant case no heat is supplied to the system, therefore, $0 = W + \Delta U \Rightarrow \Delta U = -W$. Kinetic energy of the bullet is $KE = \frac{1}{2}mv^2 = \frac{1}{2}\times 0.02\times(40)^2 = 16$ J. When the bullet stops the entire kinetic energy reduces to ZERO . As per law of conservation of energy, this KE gets converted into internal energy of the bullet and wooden block. Thus change in internal energy $\Delta U = KE = 16$ J. **Hence, answer is 16 J.**
I-24	Kinetic energy of man is $KE = \frac{1}{2}mv^2 = \frac{1}{2}\times 50\times\left(\frac{18000}{60\times 60}\right)^2 = 625$ J, here speed of meter in kmph is converted in SI i.e. $m.s^{-1}$. Amount heat required to raise temperature of water by 10^0C is $\Delta H = m_w s_w \Delta T = m_w \times 4200\times 10 = 4.2\times m_w \times 10^4$. Equating the two as per given convertibility of energy $KE = \Delta H \Rightarrow 625 = 4.2\times m_w \times 10^4 \Rightarrow m_w = \frac{625}{42}\times 10^{-3} = 14.9$ g. **Thus answer, considering SGs, is 15 g.**
I-25	Total vertical distance travelled by the brick is $h = h_a + h_w = 2 + 1 = 3$ m. Thus potential energy of the brick converted into heat energy is $W_C = W\times\eta = (mgh)\times\eta = (4\times 10\times 3)\times 0.8 = 96$ J. Mechanical equivalent of heat is $J = 4.2$ J.cal^{-1}. Therefore , $H = \frac{W_C}{J} = \frac{96}{4.2} = 22.9$ cal. **Thus, considering SGs, answer is 23 Cal.**
I-26	Hechanical energy of the van is in the form of kinetic energy $KE = \frac{1}{2}mv^2 = \frac{1}{2}\times 1500\times\left(\frac{54000}{60\times 60}\right)^2 = 168750$ J. Speed of the van is converted in SI unit of $m.s^{-1}$. Given that all the KE is converted into heat in that case $H = \frac{KE}{J} = \frac{168750}{4.2} = 40178.6$. Since time taken in the process is 10 s, and hence average rate of production of thermal energy is 4018 cal.s^{-1}. **Thus, considering SGs from the data given in the problem, answer is 4000 cal.s^{-1}.**
I-27	Given that the initial speed $u = 10$ m.s^{-1} reduces to $u = 10$ m.s^{-1}while sliding on a rough horizontal surgace. Thus loss of kinetic energy of the block during sliding is $\Delta KE = \frac{1}{2}m(u^2 - v^2) = \frac{1}{2}\times 0.1\times(10^2 - 5^2) = 3.75$ J. Thus as per law of conservation of energy thermal energy developed is 3.75 J and is in accordance with SGs**. Hence, answer is 3.75 J.**
I-28	Given that collision bodies moving in opposite directions is completely elastic where momentum of the two bodies is conserved and accordingly $\vec{p}_1 + \vec{p}_2 = \vec{p} \rightarrow m_1\vec{v}_1 + m_2\vec{v}_2 = (m_1 + m_2)\vec{v}$. Thus taking opposite sign of the pre collision velocities of the two block final velocity van be determined. Accordingly, from the given data $10\times 10 + 20\times(-20) = (10+20)v \Rightarrow 30v = -300 \Rightarrow \lvert v\rvert = 10$ m.s^{-1}. Thus during collision change in kinetic energy is $\Delta E = \frac{1}{2}\left((m_1 v_1^2 + m_2 v_2^2) - (m_1 + m_2)v^2\right) = \frac{1}{2}\left(m_1(v_1^2 - v^2) + m_2(v_2^2 - v^2)\right)$. On substituting values

	from the given data $\Delta E = \frac{1}{2}\left(10\left(10^2 - 10^2\right) + 20\left(20^2 - 10^2\right)\right) = 3000$ J. Therefore, thermal energy developed in the process is $H = \Delta E = 3000$ J. **Hence, answer is 3000 J.**
I-29	A ball of mass dropped from height h_1 after collision with the floor rises to height $h_2 < h_1$. Therefore, loss of energy in collision $\Delta E = mg\Delta h$. It is given that 40% of is converted into heat i.e. $\Delta H = 0.4 \times \Delta E$. Then, rise of temperature of the ball $\Delta T = \frac{\Delta H}{H_c}$, here H_c is heat capacity of the ball, therefore, $\Delta T = \frac{0.4 \times mg\Delta h}{H_c}$. On substituting given data $\Delta T = \frac{0.4 \times 1 \times 10 \times (2 - 1.5)}{800} = 2.5 \times 10^{-3}$. **Hence, answer is** $2.5 \times 10^{-3}\ ^0\text{C}$
I-30	Given that the slope inclined at an angle $\theta = 37^0$ through which copper block slides is of length $L = 0.6$ m. Thus decrease in height $h = L\sin\theta$. Given that the cube is sliding at a constant speed it implies that there is no change in kinetic energy i.e. $KE_1 = KE_2$. Thus as per conservation of energy $KE_1 + PE_1 + H_1 = KE_2 + PE_2 + H_2$. Therefore, $\Delta H = PE_1 - PE_2 = mgh$. Accordingly, rise of temperature of the copper cube is $\Delta H = ms\Delta T \Rightarrow \Delta T = \frac{\Delta H}{ms} = \frac{mgh}{ms} = \frac{gL\sin\theta}{s}$. On substituting the fgiven data  $\Delta T = \frac{10 \times 0.6 \times \sin 37^0}{420} = \frac{6 \times 0.6}{420} = 8.57 \times 10^{-3}\ ^0\text{C}$., **Thus, consudering SGs from the given data, answer is** $8.6 \times 10^{-3}\ ^0\text{C}$. **N.B.:** Solving problem algebraically eliminates mass of metal block from final results. Nevertheless it is useful if intermediate values are determined arithmetically
I-31	The metal block when suspended through a spring is in equilibrium such that $mg = T + F_B \Rightarrow T = mg - F_B = mg - (V\rho_W)g = mg - \left(\frac{m}{\rho_m}\rho_w\right)g = mg\left(1 - \frac{\rho_w}{\rho_m}\right)$.  When spring breaks, the spring tension T which keep the block in equilibrium disappears and block starts descending in the water with resultant force , since density of block is greater than that of water $\rho_m > \rho_w$. Work done by the block in descending to bottom is $W = mg\left(1 - \frac{\rho_w}{\rho_m}\right) \times h$. As per Law of conservation of energy, this work done during fall of the body would be absorbed in increase of temperature of water and block such that $\Delta H = (m \times s_m + m_w \times s_w) \times \Delta T$. Here, mass of water is , $m_w = (V\rho_W) = \left(\frac{m}{\rho_m}\rho_w\right)$. Accordingly, heat gained is $\Delta H = \left(m \times s_m + \left(\frac{m}{\rho_m}\rho_w\right) \times s_w\right) \times \Delta T = m\left(\frac{s_m \times \rho_m + \rho_w \times s_w}{\rho_m}\right) \times \Delta T$. As per law of conservation of energy $\Delta H = W \Rightarrow m\left(\frac{s_m \times \rho_m + \rho_w \times s_w}{\rho_m}\right) \times \Delta T = mg\left(1 - \frac{\rho_w}{\rho_m}\right) \times h \Rightarrow \Delta T = \frac{g\left(\frac{\rho_m - \rho_w}{\rho_m}\right)h}{\left(\frac{s_m \times \rho_m + \rho_w \times s_w}{\rho_m}\right)} = gh\left(\frac{\rho_m - \rho_w}{s_m \times \rho_m + \rho_w \times s_w}\right)$.

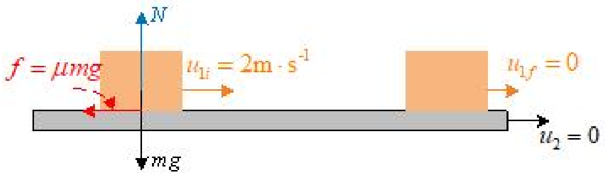
	On substituting the given data in the final algebraic form $\Delta T = 10 \times 0.4\left(\frac{6000-1000}{250\times 6000+4200\times 1000}\right) = 4\times\frac{5}{1500+4200} = 3.5\times 10^{-3}\ {}^{0}C$. **Thus, answer is $3.5\times 10^{-3}\ {}^{0}C$**. N.B.: Solving problem algebraically eliminates mass of metal block from final results. Nevertheless, it is useful if intermediate values are determined arithmetically to avoid algebraic statement, if considered helpful by student.
I-32	First law of thermodynamics is about convertibility of energy and is mathematically expressed as $Q = W + \Delta U$, i.e amount heat energy (Q) given to a system is absobed in doing work (W) and change of internal energy (ΔU) of the system. Thus it a statement of conservation of energy. **Thus answer is option (d).**
I-33	As per ideal gas equation $pv = nRT$. In an isothermal process temperature ***T*** is constant, number of gram-mioles ***n*** is constant for a given sample of gas and **R** is unversal gas constant. Thus as long as temperature is constant internal energy of the gas is constant or $\Delta U = 0$. Therefore, as per FLT, $Q = W$. Heat supplied to a system Q is (+) and therefore workdone W as a consequence of it will also be (+)ve. **Hence, answer is option (b).**
I-34	The processes in the question are shown on P-V diagram and hence temperature is constant i.e the processes are isothermal and hence $\Delta U = 0$. Therefore, area under the curve in process A is $Q_A = W_A = \int p_A dv$ and in the process B is $Q_B = W_B = \int p_B dv$. The area under the loop formed by two processes is $W_{AB} = \oint pdv$ which is always (+)ve. Since work done by the two processes is (+)ve and from inspection of the given figure $W_A = W_B + W_{AB}$, hence $W_A > W_B$. Thus, applying FLT $\Delta Q_1 > \Delta Q_2$. **Thus, answer is option (a).**
I-35	The processes in the question are shown on P-V diagram and hence temperature is constant i.e the processes are isothermal and hence $\Delta U_A = \Delta U_B = \Delta U = 0$. **Hence, answer is option (b).**
I-36	The processes in the question are shown on P-V diagram and hence temperature is constant i.e the processes are isothermal and hence $\Delta U = 0$. Since work done in the process, as shown in the figure, is $W = \int_{v_a}^{v_b} pdv$. Though pressure ***p*** is decreasing, yet it is always (+)ve and all long the process as pressure can never be (-)ve. Accordingly, Δv is monotonously (+)ve. Hence work done in the process would increase continuously. **Thus, answer is option(a).** 
I-37	As per First law of thermodynamics $Q = W + \Delta U$. If the process is isothermal then $\Delta T = 0$. Thus rise of temperature is not mendatory and is dependent on the nature process being undertaken. **This makes statement (A) wrong.** Thus, in this equation FLT reduces to $Q = W$. Further, as per ideal gas equation $pv = nRT$, where, in given sample of gas, ***n*** is constant, and ***R*** is unversal gas constant. This leads to $pv = \text{Constant}$. Thus amount heat added ***Q*** is equal to work done $W = \int pdv$. Since, heat given to the system is (+)ve and therefore, to satisfy the reduced form of equation as per FTL, workdone W must be positive. Since pressure cannot be negative, which can only happen when in the process $\Delta V > 0$.e. volume increases. **This makes statement (B) correct.** Thus analytical conclusions of statements (A) and (B) matches with the option (c). **Hence answer is Option(c).**
I-38	The process as shown in the figure is $p = f(T)$. Therefore, volume of the gas is constant i.e. $\Delta v = 0$. As per definition of work $\Delta w = p\Delta v$, i.e. dispalcement would be caused only in case of change in volume. Therefore,

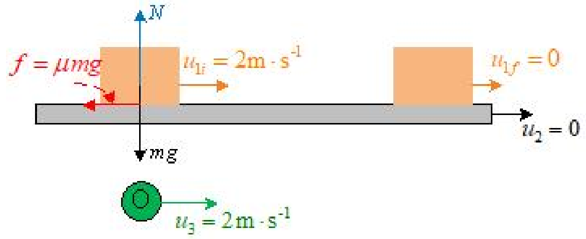
	elemental work done by gas during the process $\Delta w = 0 \Rightarrow W = \int dw = 0$. **Thus correct answwer is option (c).**
I-39	The question states that at initial states in two processes is $v_{Ai} = v_{Bi}$ and at final states in two processes is $v_{Af} = v_{Bf}$. In both the processes A and B pressures are different yet constant $p_A = \text{Constant}$ and $p_B = \text{Constant}$. Thus the two processes are isobaric processes. Therefore, as per ideal gas equation $pv = nRT$, the effective equation for the processes would be $v = \frac{nRT}{p}$. Therefore work  done in process A is $\Delta W_1 = p_A\left(\frac{n_A RT_{Af}}{p_A} - \frac{n_A RT_{Ai}}{p_A}\right) = n_A R\left(T_{Af} - T_{Ai}\right) = n_A R\Delta T_A$. Likewise in process B it would be $\Delta W_2 = n_B R\left(T_{Bf} - T_{Bi}\right) = n_B R\Delta T_B$. Using these two equations $\frac{\Delta W_1}{\Delta W_2} = \frac{n_A R\Delta T_A}{n_B R\Delta T_B} = \frac{n_A \Delta T_A}{n_B \Delta T_B}$. Since, the two processes are carried out on a system and hence $n_A = n_B$ it leads to $\frac{\Delta W_1}{\Delta W_2} = \frac{\Delta T_A}{\Delta T_B}$ From figure it is evident that $\Delta T_A < \Delta T_B \Rightarrow \frac{\Delta T_A}{\Delta T_B} < 1$, therefore, $\frac{\Delta W_1}{\Delta W_2} < 1 \Rightarrow \Delta W_1 < \Delta W_2$. **From this analysis, correct answer is (c).**
I-40	As per FLT $Q = W + \Delta U$. Since the process is carried out suddenly it is an adiabtic process where $Q = 0 \Rightarrow W = -\Delta U$. Since, work is done on the system, and not by the system hence $-W = -\left(-\Delta U\right) = \Delta U$. The (+)ve value of ΔU is indicative of increase in internal energy and in accordance with IGE, it would be increase in temperature. Let post compression parameters of the gas be n, p_1, v and T_1 The gas is contained in metallic cylinder which is good conductor of heat. As the time passes heat would dissipate into the environment and there would be fall of temperature, while the volume and mass of gas contant at n and v remians constant. Let, after some time the gas parameters are n, p_2, v and T_2. Therefore, for same mass of gas as per ideal gas equation, $pv = nRT$ in the two cases $\frac{p_1 v}{p_2 v} = \frac{nRT_1}{nRT_2} \Rightarrow \frac{p_1}{p_2} = \frac{T_1}{T_2} \Rightarrow p \propto T$. Therefore, when temperature falls after some time pressure of the gas would also fall. **Thus answer is (b).**
I-41	As per ideal gas equation $pv = nRT$. Given that in a process $p_i < p_f$ and $v_i < v_f$. Therefore, $\frac{p_f v_f}{p_i v_i} = \frac{nRT_f}{nRT_i} \Rightarrow \frac{p_f v_f}{p_i v_i} = \frac{T_f}{T_i} > 1$. Thus total internal energy of the gas has increased. As per FLT, $Q = W + \Delta U \Rightarrow \Delta U = Q - W$. Thus for to increase in ΔU there are three possibilities – (a) either (+)ve quantity increases $Q \to T = \frac{Q}{ms} \Rightarrow T \propto Q$ i.e.supply of heat increases temperature of the system,. **This provided in option (c)** or **(b)** W the(-)ve quantity decreases i.e. work is done by the system; this is accordance with Mechanical Equivalent of heat (J), or **(c)** both (a) and (b) occur together. **Hence, answer is option (b) and (c).**
I-42	Given that in a process $p_i = p_f$ and $v_i = v_f$ and, therefore, $p_i v_i = p_f v_f$. As per ideal gas equation $pv = nRT$, thus $\Delta T = 0$ as provided in the **option (a)** correct and internal energy of the system $\Delta U = 0$ **as provided in the option (b) as correct**.. As per FLT $Q = W + \Delta U \Rightarrow Q = W$ hence it not necessary for $Q = 0$ making **option (c) incorrect** and $W = 0$ **making option (d) incorrect**. .Thus, **answer is option (a) and (b).**

I-43	As per First law of thermodynamics $Q = W + \Delta U \Rightarrow Q - W = \Delta U$, Accordingly, to take the system from state-1 to state-2 in the process-1, $\Delta Q_1 - \Delta W_1 = \Delta U_1$ and likewise in the process-2, $\Delta Q_2 - \Delta W_2 = \Delta U_2$. Further, as per IGE, $pv = nRT = U$, which is dependent on the state of the system i.e. *p* and *v*. Therefore, $p_1 v_1 = U_1$ and $p_2 v_2 = U_2$. Accordingly, in transition from state-1 to state-2 $U_2 - U_1 = \Delta U$ and it is independent of the process. Therefore, $\Delta U = \Delta U_1 = \Delta U_2$. Accordingly, $\Delta Q - \Delta W$ is independent of the process. **Thus, answer is option (d).**
I-44	As per FLT $Q = W + \Delta U$ and in process-A, $Q_1 = W_1 + \Delta U_1 \Rightarrow \Delta U_1 = Q_1 - W_1$ and in process-B, $Q_2 = W_2 + \Delta U_2 \Rightarrow \Delta U_2 = Q_2 - W_2$. Since the after completing the process the system returns to its initial opearing point, i.e. it is a closed process. Therefore, as per Mechanical Equivalent of heat (J) $W_{net} = \Delta Q - \Delta W$. **Thus, Option (a) is correct.** Accordingly, $W_{net} = (\Delta Q_1 + \Delta Q_2) - (\Delta W_1 + \Delta W_2)$. Accordingly $W = (\Delta Q_1 - \Delta W_1) + (\Delta Q_2 - \Delta W_2) = \Delta U_1 + \Delta U_2$ **Thus option (c) is correct**. **Thus answer is option (a) and (c).**
I-45	As per FLT $Q = W + \Delta U$. Given that $\Delta U = -W$, it is possible only when $Q = 0$ i.e. **process is adiabatic as per option (a).** Since work is done by the system, therefore as per Law of Conservation of Energy, required energy to perform the work will be supplied by Internal Energy in turn U will decrease.. As per IGE, $pv = nRT \Rightarrow U \propto T$. Therefore, in the process **temperature would also decrease as per option (d). Thus, answer is options (a) and (d).**
I-46	As per FLT $Q = W + \Delta U$. Further, in the process described in problem there is neither any source of heat nor sink and hence there is no transfer of heat i.e. $Q = 0$. This part (a) of the answer. This part (a) leads to reduced form of FLT as $\Delta U = -W$ Further from the given data heat generated in the process is absorbed in increase of internal energy $\Delta U = H = (m_v s_v + m_w s_w) \times (T_f - T_i)$. Thus on substituting the given data in this equation $\Delta U = H = (0.1 \times 420 + 0.2 \times 4200) \times (17 - 15) = 1764$ J. **Thus part (c) of the answer is 1764 J**. Using answer of part (c) in the reduced form of FLT work done on the system is $-W = 1764$ J, Thus part (b) of the answer is 1764 J. **N.B.:** In the question time of shaking is given to be 15 minutes. But this information is not required in solving the problem.
I-47	As per FLT $Q = W + \Delta U$. Further, in the process described in problem the container is adibatic which does not allow any transfer of heat hence there is no transfer of heat i.e. $Q = 0$. Therefore, **heat given to the liquid is zero, and this part (a) of the answer.** Next part of the problem is loss of potential energy of a mass of 12 kg falling through a height 0.7 m. Thus $\Delta PE = mgh = 12 \times 10 \times 0.7 = 84$ J. This loss of PE is transferred through a string passing over frictionless pulley to the paddle. Therefore work done by the paddle is $W = \Delta PE = 84$ J. **This is part (b) of the answer**. As per Mechanical Equivalent of heat (J) $W = H = H_c \Delta T$ C. Thus $\Delta T = \frac{W}{H_c} = \frac{84}{4200} = 0.02^0$ **This is part (c) of the answer.**
I-48	As per law of friction frictional force between the block and the joprizontal belt is $f = \mu \times N = \mu \times (mg)$. This frictional force would create a retardation on the block having initial velocity $u = 2$ m.s^{-1}. Thus, retardation

experienced by the block on the belt is $a=-\frac{f}{m}=-\frac{\mu mg}{m}=-\mu g$.

Initial kinetic energy of the block the block is $KE_i=\frac{1}{2}mv^2=\frac{1}{2}\times100\times2^2=200$ J. Final kinetic energy of the block when it comes to rest is $KE_f=0$ J. Hence change in mechanical energy in case (a) is $W_a=KE_f-KE_i=0-200=-200$ J. In the system no transfer of heat from an external source is stated and hence $Q=0$. Accordingly as per FLT $Q=0=W+\Delta U\Rightarrow\Delta U=-W=-(-200)=200$ **Thus change in internal energy of the block-belt sytem is 200 J. This form part (a) of the answer.**



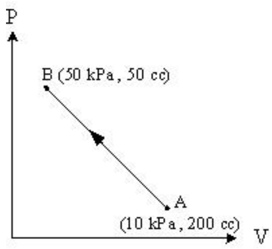


In part (b) of the problem belt remains static and initially an observer and the block are moving in same direction with velocities $u_{1i}=u_3=2\,\text{m}\cdot\text{s}^{-1}$ Therefore, relative velocity ob block w.r.t. observers $v_{b-o-i}=v_{1i}-v_3=2-2=0\,\text{m.s}^{-1}$. As block is placed on the static belt, it exercises friction on the block and it reads to come at rest w.r.t. belt as in case (a). But, final velocity of block w.r.t. observer is $v_{b-o-f}=v_{1i}-v_3=0-2=-2$ m.s^{-1}. Therefore, change in kinetic energy of the block w.r.t. observer in case (b) is $\Delta KE_b=\frac{1}{2}m\left(v_{b-o-f}{}^2-v_{b-o-1}{}^2\right)=\frac{1}{2}100\left(2^2-0^2\right)=200$ J. **Thus part (b) of the answer is 200 J increase in kinetic energy of the block.**

In part (c) it is desired to find work done done by external force in holding the belt w.r.t. frame. The block, before being placed on the belt was having Zero relative velocity w.r.t. the observer. All the changes in energy occur when the block is placed on the belt. Thus, sum of this energy would be provided by external force on the belt and it is $W=U+\Delta KE_b=200+200=400$ J. **Thus, part (c) of the answer is 400 J.**

I-49 As per FLT $Q=W+\Delta U$. Given that heat supplied to the gas is $Q=100$ J, while the gas is kept in a rigid cylinder which will not undergo any expansion on supply of heat and hence $W=0$. Thus, as per FLT change in internal energy of the gas $\Delta U=Q=100$ J. **Thus, answer is 100 J.**

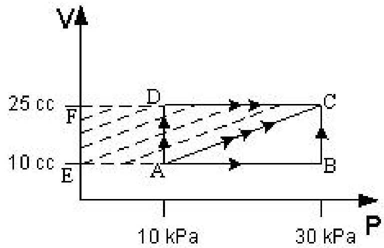
I-50 The P-V variation is given to be linear and hence equation of line AB representing the process is $\left(p-p_a\right)=\frac{p_a-p_b}{v_a-v_b}\times\left(v-v_a\right)$. On substituting the given data it comes to $\left(p-10\right)=\frac{10-50}{200-50}\times\left(v-200\right)\Rightarrow p=-\frac{4}{15}v+\frac{4}{15}\times200+10$. It simplifies into $p=-\frac{4}{15}v+\frac{190}{3}$. As per definition of work $dw=p\cdot dv\Rightarrow W=\int_{v_a}^{v_b}\left(-\frac{4}{15}v+\frac{190}{3}\right)dv$.

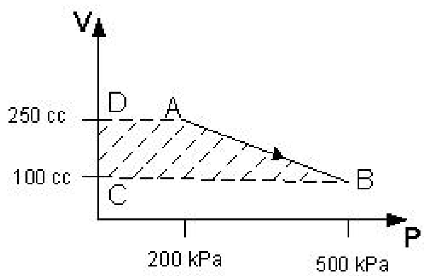


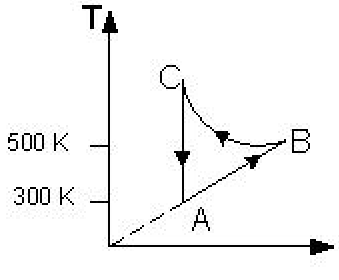
It leads to $W=\left[-\frac{4}{15}\cdot\frac{v^2}{2}+\frac{190}{3}\cdot v\right]_{200}^{50}\times10^{-3}=\left[-\frac{2}{15}\cdot\left(50^2-200^2\right)\times10^{-12}+\frac{190}{3}\cdot\left(50-200\right)\times10^{-6}\right]\times10^{-3}=-4.5$ J.

Since pressure is given kPa i.e. 10^3 Pa and volume is given in cc i.e. in 10^{-6} m^3 , hence unit of product $\boldsymbol{pv}$ in SI unit would be 10^{-3} J and is used accordingly with given quantities. Since, change in pressure of the gas is stated to be occurring without mention of external force therefore work is done by the gas. Thus, **part (a) of the answer is -4.5 J.**

As regards part (b) which states no heat is supplied i.e. $Q=0$ then change in internal energy as per FLT

	$Q = 0 = W + \Delta U \Rightarrow \Delta U = -W = -(-4.5) = 4.5$. **Thus, part (b) of the answer is 4.5 J.**
I-51	As per IGE $pv = nRT$, and it is given that $\frac{p}{T} = \text{Constant}$. Thus applying this condition to the IGE, it leads to $v = nR \cdot \frac{T}{P} = \frac{nR}{\text{Constant}}$. Since, for given sample of gas in a process number of moles ***n*** is constant, ***R*** is universal gas constnat, and a third constant in the denominator, thus volume is constant. This implies that there is no volumetric change i.e. $\Delta v = 0$. Since work done in a process $\Delta w = p\Delta v + v\Delta p = 0$. **Hence, net work done by the gas is Zero.**
I-52	Work done in a process in gas $\Delta W = \Delta(pv) = p\Delta v + v\Delta p = p\Delta v$ since as per definition of work $v\Delta p$ despite force there has to be displacement, which is zero in case of constant volume. Coordinates of four vertices in the process diagram for points A,B,C, D, E and F are $(p_a, v_a), (p_b, v_b), (p_c, v_c), (p_d, v_d), (p_e, v_e)$ and (p_f, v_f) respectively. Further total work done when volume is changing is area under P-V curve. Since pressure is given kPa i.e. 10^3 Pa and volume is given in cc i.e. in 10^{-6} m^3, hence unit of product ***pv*** in SI unit would be 10^{-3} J and is used accordingly with given quantities.  (a) Thus taking process AB $W_{AB} = \left(\frac{p_c + p_a}{2}\right)(v_c - v_a) = \left(\frac{10+30}{2}\right) \times (25-10) = 0.30$ J.**Thus part (a) of the answer is 0.30 J.** (b) Taking process ABC, it is split in two parts process AB under constant volume $v_e = 10$ cc, and hence $W_{ab} = 0$ and $W_{bc} = p_b \cdot \Delta v_{bc} = 30 \times (25-10) \times 10^{-3} = 0.45$ J. Thus $W_{abc} = W_{ab} + W_{bc} = 0 + 0.45 = 0.45$ J. **Thus part (b) of the answer is 0.45 J.** (c) Taking process ADC, $W_{adc} = W_{ad} + W_{dc}$, $W_{dc} = 0$ since it at constant volume 25 cc, while $W_{ad} = p_a \cdot (v_d - v_a) = 10 \times (25-10) = 0.15$ J. Thus, $W_{adc} = W_{ad} + W_{dc} = 0.15 + 0 = 0.15$ J. **Thus part (c) of the answer is 0.15 J.** **N.B.:** In this direction of the path is important which will affect sign of the results.
I-53	As per FLT, $Q = W + \Delta U$. The two process on a system have transition from point a to c, as per ideat gas equatin $pv = nRT \propto U$. Since it is PV process and hence temperature remains constant, irrespective of the process path. Therefore, change in internal energy $\Delta U_{ac} \propto (p_c \cdot v_c - p_a \cdot v_a) \Rightarrow \Delta U_{ac} = 0$. Further, it is given that in process abc, $Q_{abc} = 80$ J and $W_{abc} = 30$, whereas in process adc, $W_{adc} = 10$. Using FLT, $\Delta U_{ac} = Q_{abc} - W_{abc} = Q_{adc} - W_{adc}$. On substituting the values $80 - 30 = Q_{adc} - 10 \Rightarrow Q_{adc} = 50 + 10 = 60$ J. **Hence, answer is 60 J.**
I-54	As per FLT, $Q = W + \Delta U$. The two process on a system have transition from point a to c, as per ideat gas equatin $pv = nRT \propto U$. Since it is PV process where temperature remains constantand hence change in internal energy $\Delta U_{ac} \propto (p_c \cdot v_c - p_a \cdot v_a) = 0$. Further, it is given that in process abc, $Q_{abc} = 50\text{cal} = 50 \times J = 50 \times 4.2 = 210$ J. As regards work done $W_{abc} = W_{ab} + W_{bc} = W_{ab}$, since in part BC of the process $W_{bc} = 0$, as it is at a constant volume of 400 cc.. Further,

	$W_{ab} = \int_{v_a}^{v_b} p_a dv = p_a\left(v_b - v_a\right) = \left(50\times10^3\right)\times\left(400-200\right)10^{-6} = 10$ J. Thus $W_{abc} = W_{ab} = 10$ J, using this together with given value of Q_{abc}, FLT leads to $\Delta U_{abc} = Q_{abc} - W_{abc} = 210 - 10 = 200$ J. Now in the process ADC, $\Delta U_{adc} = \Delta U_{abc}$, since P,V values of the terminal states A,C are same for two processes. As regards work done in process ADC, on the lines of W_{abc} is $W_{adc} = W_{ad} + W_{dc} = W_{dc} = \int_{v_d}^{v_c} p_d dv = p_d\left(v_d - v_c\right) = \left(155\times10^3\right)\times\left(400-200\right)10^{-6} = 31$ J. Therefore, as per FLT $Q_{adc} = W_{adc} + \Delta U_{adc} = 31 + 200 = 231$ J. Thus, as per Mechanical Equivalent of heat (J) equivalent heat in calories $Q = \frac{Q_{adc}}{J} = \frac{231}{4.2} = 55\,\text{cal}$. **Thus, answer is 55 cal.**
I-55	Given that the process is cylic and, therefore, $\Delta U = 0$, since system returns to the same P-V state. Further as per FLT $Q = W + \Delta U \Rightarrow Q = W$. Since work done in a process. $W = \oint pdv$. In the figure the giver process path is circular with radius $r = 100\text{kPa} = 100\text{cc}$. Thus are under the curve is $W = \pi\times\left(100\right)^2\times10^3\times10^{-6} = 31.4$ J. Hence, as per reduced form of FLT for a closed process $Q = W = 31.4$ **J, is the answer.**
I-56	ABCA is a closed process starting from A and terminating at A, therefore, $\Delta U = 0$. As regards workdone in the ABCA process is area inside the cycle $W = \frac{1}{2}\left(\left(200-100\right)\times10^3\right)\times\left(\left(700-500\right)\times10^{-6}\right) = 10$ J. It is given that to perform the process heat given in the process is H = 2.4 cal. As [pper Mechanical Equivalent of heat (J) $W = JH \Rightarrow J = \frac{W}{H} = \frac{10}{2.4} = 4.166\,\text{J.cal}^{-1}$. **Thus answer considering SGs the answer is 4.2 J.cal^{-1}.**
I-57	In the process abc work done $W = W_{ab} + W_{bc} = p_a\left(v_b - v_a\right) + 0 = \left(200\times10^3\right)\times\left(0.05-0.02\right) = 6\times10^3$ J. Given that $\Delta U = 5\times10^3$ J and $H = 2.625\times10^3$ Cal. As per FLT $Q = W + \Delta U$ and as per Mechanical Equivalent of heat (J) $Q = JH$. Combining these jwo Laws $JH = W + \Delta U \Rightarrow J = \frac{W + \Delta U}{H}$. Substituting the values $J = \frac{6000+5000}{2625} = 41.9\text{J.cal}^{-1}$. **Hence answer is 4.19 J.cal^{-1}**
I-58	As per FLT $Q = W + \Delta U$ and as per Mechanical Equivalent of heat (J) $Q = JH$. Combining the the laws $JH = W + \Delta U$. In the process $H = -70$ cal since heat is extracted from the gas in the process. Further, workdone in the process $W = \int_{v_b}^{v_a} pdv =$ Area in the cycle ABCDA $= \frac{1}{2}\left(p_a + p_b\right)\times\left(v_b - v_a\right)$ Using given data  $W = \frac{1}{2}\left(\left(200+500\right)\times10^3\right)\times\left(\left(100-250\right)\times10^{-6}\right) = -52.5$J. Value of Mechanical Equivalent of heat is $J = 4.2\,\text{J}\cdot\text{Cal}^{-1}$. Using these values in the combined equation $4.2\times\left(-70\right) = -52.5 + \Delta U \Rightarrow \Delta U = -294 + 52.5 = -241.5$J. . **Thus as per principles of SGs answer is -240 J**

	N.B.: Arithmatically area ABCDA is (+)ve but direction of process shall define sign of the value, in the intant case W is (-)ve.
I-59	As per FLT $Q = W + \Delta U$, and initial internal energy is $U_i = 1.5 \times \left(1.0 \times 10^5\right) \times \left(100 \times 10^{-6}\right) = 15$ J and final internal energy is $U_f = 1.5 \times \left(1.0 \times 10^5\right) \times \left(200 \times 10^{-6}\right) = 30$ J. Therefore, change in internal energy is $\Delta U = U_f - U_i = 30 - 15 = 15$ J. Work done by the gas at constant pressure $W = p\left(v_f - v_i\right) = \left(1.0 \times 10^5\right) \times \left((200-100) \times 10^{-6}\right) = 10$ J. Using these values in the equation of FLT $Q = 10 + 15 = 25$ J. **Hence, answer is 25 J.**
I-60	As per FLT $Q = W + \Delta U$. Given that gas is enclosed in the cylindrical vessel of cross-sectioanl are $A = 4 \times 10^{-4}$ cm^2. On supply of heat pistom under atmospheric pressure $p = 100 \times 10^3$ Pa moves out by a distance $d = 0.1$ m. Thus work done by the gas is $W = p\Delta v = p \times (A \times d) = \left(100 \times 10^3\right) \times \left(4 \times 10^{-4}\right) \times 0.1 = 4$ J.. Thus using FLT equation $10 = 4 + \Delta U \Rightarrow \Delta U = 10 - 4 = 6$ J. **Hence answer is 6 J.**
I-61	The process defined in the problem states that gas is brought back to initial state it implies $\Delta U = 0$. Accordingly energy balance equation as per FLT would be $Q = W + \Delta U \Rightarrow Q = W$. P-V diagram of the complete process is shown in figure as ABCA having three parts – (a) Constant pressure process AB. (b) Constant volume process BC (c) Return to original state CA. Thus work done in the process is area of the trianble ABC and is $W = \frac{1}{2} \times (AB) \times (BC) = \frac{1}{2} \times (2.5 - 2) \times \left((200-100) \times 10^3\right) = 25 \times 10^3$ J. Thus. as per reduced form of FLT work done by the system in the process of returning to initial state heat is extracted from the gas. **Accordingly, answer to the part (a) is extracted.** Further, heat supplied to the process is $Q = W = 25 \times 10^3 \text{ J} = 25 \text{ kJ}$. **Thus answer to thepart (b) is 25 kJ.**
I-62	The process is cyclic and therefore there is no change in internal energy of the system as it return to original state after completing the process, hence $\Delta U = 0$. As per FLT $Q = W + \Delta U \Rightarrow Q = W$, here given that $Q = 1200$ J and hence $W = 1200$ J. As regards cycle ABCA work done is $W = W_{AB} + W_{BC} + W_{CA}$. Taking each part seperately –  (a) The cycle is shown in V-T diagram is on a constant pressure and part CA is $\Delta v = 0 \Rightarrow W_{CA} = 0$ (b) Part AB of the cycle linear variation of V-T is also at constant pressure. In this part terminal temperatures T_A and T_B are defined but not the volume v_A and v_B. Therefore internal energy of the gas at any point, in this part can, be defined with IGE $pv = nRT$. Accordingly, $W_{AB} = p\Delta v = nR\Delta T = nR\left(T_B - T_A\right)$. Here n= 2 mol and universal gas constant $R = 8.31$. Accordingly, $W_{AB} = 2 \times 8.31 \times (500 - 300) = 3324$ J. Substituting values in equation of total work done $-1200 = 3324 + W_{BC} + 0 \Rightarrow W_{BC} = -1200 - 3324 = -4524$ J. **Thus, answer is -4524 J.**

<table>
<tr><td>I-63</td><td>As per ideal gas equation $U = pv = nRT$, here $n = 2.0$, number of moles of gas is constant for asample of gas and R is Universal Gas constant . Acoordingly, $U \propto T$ In the given cycle abcda part ab and cd are at constant internal energy and therefore both these parts are isothermal provess. Further, IGE can be rframed as $p = \frac{nRT}{v}$ work done in a thrmodynamic process is $\Delta W = p\Delta v = \frac{nRT}{v}\Delta v \Rightarrow W_{rs} = nRT\int_{v_r}^{v_s}\frac{dv}{v} = nRT\ln\left(\frac{v_s}{v_r}\right)$.
Accordingly, taking work in each part
(i) Part 'ab': workdone is $W_{ab} = nRT_b \log\left(\frac{v_b}{v_a}\right) = nRT_b \log\left(\frac{2v_0}{v_0}\right) = nRT_b \ln 2$, given that $T_b = 500$ K
(ii) Part 'bc': work done in this part $W_{ab} = 0$, since this is a constant volume process and therefore it does not involve any displacement, a necessary requirement for work
(iii) Part 'cd': $W_{cd} = nRT_c \ln\left(\frac{v_d}{v_c}\right) = nRT_c \ln\left(\frac{v_0}{2v_0}\right) = -nRT_c \ln 2$, given that $T_c = 300$ K
(iv) Part 'da': work done in this part $W_{ab} = 0$, since this is a constant volume process and therefore it does not involve any displacement, a necessary requirement for work
Thus total work done in the process is $W = W_{ab} + W_{bc} + W + W_{da}$. Substituting the values derived and then given data $W = nRT_b \ln 2 + 0 - nRT_c \ln 2 + 0 = nR_b \ln 2\left(T_b - T_b\right) \Rightarrow W = 2\times 8.31\times 0.693\times\left(500-300\right) = 2303.5$ J. Here in the calculations natural log of 2 is $\ln 2 = 0.693$ and has been used. Thus, considering SGs, answer is 1200 J.</td></tr>
<tr><td>I-64</td><td>Change in internal energy of water in rise of temperature from 0^0C to 4^0C involves two processes –
a. Change of density from ρ_0 to ρ_4, , here $\rho_4 > \rho_0$. It implies that work is done by atmospheric pressure in reducing volume. Thus $W_a = p\Delta v = p\left(v_f - v_i\right) = p\left(v_4 - v_0\right) = p\left(\frac{m}{\rho_4} - \frac{m}{\rho_0}\right) = pm\left(\frac{1}{\rho_4} - \frac{1}{\rho_0}\right)$ J. On substituting the given data $W_a = -10^5 \times 2\times\left(\frac{1}{1000} - \frac{1}{999.9}\right) = -0.02$. Here, W_a is work done by atmospheric pressure on the water and therefore for the purpose of FLT work done by the water is $W = -W_a = -(-0.02) = 0.02$ J.
b. Amount of heat given to mass of water raise the temperature $W = ms\Delta T = 2\times 4200\times\left(4-0\right) = 33600$ J.
As per FLT $Q = W + \Delta U \Rightarrow \Delta U = Q - W$. Thus using values derived above change in internal energy of the waterr is $\Delta U = 33600 - 0.02 = \left(33600 - 0.02\right)$ J. Thus answer is (33600 - 0.02) J.</td></tr>
<tr><td>I-65</td><td>When water of mass $m = 0.01$ kg at 0^0C is converted to steam at 100^0C having density $\rho_s = 0.6$ kg.m^{-3} , it under goes two processes –
(a) Absorption of heat in raising temperature 0^0C to 100^0C $Q_1 = m\times s_w \times \Delta t = 0.01\times 4200\times\left(100-0\right) = 4200$ J
(b) Amount of heat in converting water into vapour state $Q_2 = m\times s_v = 0.01\times\left(2.25\times 10^6\right) = 2.25\times 10^4$ J
(c) Amount of work done in expansion of volume of water from density 1000 kg-m^{-3} to 0.6 kg.m^{-3}, under atmospheric pressure p = 100 kPa is $W = p\left(v_f - v_i\right) = p\left(\frac{m}{\rho_f} - \frac{m}{\rho_i}\right) = pm\left(\frac{1}{\rho_f} - \frac{1}{\rho_i}\right)$. On substituting values $W = \left(100\times 10^3\right)\times 0.01\times\left(\frac{1}{0.6} - \frac{1}{1000}\right) = 1666.5$.</td></tr>
</table>

	As per FLT $Q = W + \Delta U \Rightarrow \Delta U = Q - W = (Q_1 + Q_2) - W = (4.2\times10^3 + 22.5\times10^3) - 1.67\times10^3 = 24.03\times10^3$. **Thus, as per SGs the answer is** 2.5×10^4 **J.**
I-66	Given that- (i) the cylindrical tube has adiabatic walls, it implies that no heat will be dissipate into the environment. (ii) The tube is divided by a fixed wall a. in two equal parts i.e. $v_1 = v_2 = v$ b. the dividing wall is diathermic it implies heat transfer across the walls in both the directions. (iii) Internal energyof the gas (IEG) $U = 1.5nRT$ (iv) System is left to reach in thermal equilibrium say at temperature *T*. Taking this data each part of the problem is being analysed – **Part (a):** Since the dividing wall is fixed and hence there will be no change in volume hence work done by the gas in both the parts is zero. **Hence answer of part (a) is Zero.** **Part (b & c):** Both these parts are interdependent and hence taken together. As per IGE, $p_1v = n_1RT_1 \Rightarrow n_1 = \frac{p_1v}{RT_1}$, on the similar lines $n_2 = \frac{p_2v}{RT_2}$. On reaching the temperature T, pressure in left part would be $p_{1f} = n_1\times\frac{RT}{v} = \frac{p_1v}{RT_1}\times\frac{RT}{v} = \frac{p_1T}{T_1}$ and on similar lines $p_{2f} = \frac{p_2T}{T_2}$. Here, T is unknown and is required to be determined in part (c) of the problem; it shall be dentermined from energy balance equation $U = U_{1i} + U_{1i} = U_{1f} + U_{1f}$. Taking each component seperately - (i) $U_{1i} = 1.5\times p_1\times v$ (ii) $U_{2i} = 1.5\times p_2\times v$ (iii) $U_{1f} = 1.5\times p_{1f}\times v = 1.5\times\frac{p_1T}{T_1}$ and (iv) $U_{2f} = 1.5\times p_{2f}\times v = 1.5\times\frac{p_2T}{T_2}$. Using these values in energy balance equation we get- $1.5\times p_1\times v + 1.5\times p_2\times v = 1.5\times\frac{p_1T}{T_1}\times v + 1.5\times\frac{p_2T}{T_2}\times v \Rightarrow p_1 + p_2 = \left(\frac{p_1}{T_1} + \frac{p_2}{T_2}\right)T \Rightarrow T = \frac{T_1T_2(p_1+p_2)}{p_1T_2 + p_2T_1}$, **this is part (c) of the answer**. Using this value of equilibrium temperature, final pressure on left part is $p_{1f} = \frac{p_1T}{T_1} = \frac{p_1}{T_1}\times\frac{T_1T_2(p_1+p_2)}{p_1T_2+p_2T_1} = \frac{p_1T_2(p_1+p_2)}{p_1T_2+p_2T_1}$ and on the right part is $p_{2f} = \frac{p_2T}{T_2} = \frac{p_2}{T_2}\times\frac{T_1T_2(p_1+p_2)}{p_1T_2+p_2T_1} = \frac{p_2T_1(p_1+p_2)}{p_1T_2+p_2T_1}$. **This part (b) of the answer**. Part (d) : Amount of heat flown from right part of the gas to the left part $U_{2i} - U_{2f} = 1.5p_2v - 1.5p_{2f}v = 1.5\times v\times(p_2 - p_{2f}) = 1.5\times v\times\left(p_2 - \frac{p_2T_1(p_1+p_2)}{p_1T_2+p_2T_1}\right) = 1.5\frac{p_1p_2(T_2-T_1)}{p_1T_2+p_2T_1}$ Since half volume of the tube $v = \frac{V}{2}$, using this value, transfer of energy is $\frac{3}{2}\times\frac{p_1p_2(T_2-T_1)}{p_1T_2+p_2T_1}\times v = \frac{3}{2}\times\frac{p_1p_2(T_2-T_1)}{p_1T_2+p_2T_1}\times\frac{V}{2} = \frac{3}{4}\times\frac{p_1p_2(T_2-T_1)V}{p_1T_2+p_2T_1}$. **This is part (d) of the answer.** Taking $p_1T_2 + p_2T_1 = \lambda$, since it is repeating in **answers (b) to (d) the answers can be rewritten as –** (b) $\frac{p_1T_2(p_1+p_2)}{\lambda}$ on the left and on the right part $\frac{p_2T_1(p_1+p_2)}{\lambda}$, taking $\lambda = p_1T_2 + p_2T_1$

(c) $\dfrac{T_1T_2\left(p_1+p_2\right)}{\lambda}$

(d) $\dfrac{3p_1p_2\left(T_2-T_1\right)V}{4\lambda}$

I-67 Given that-

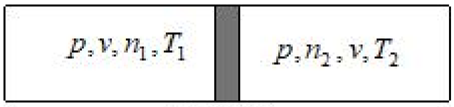
(i) the cylindrical tube has adiabatic walls, it implies that no heat will be dissipate into the environment.

(ii) The tube is divided by a fixed wall

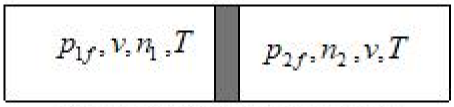
a. in two equal parts i.e. $v_1=v_2=v=\dfrac{V}{2}$, where V is volume of tube

b. the dividing wall is diathermic it implies that heat transfer across the walls in both the directions

c. pressure in two parts is $p_1=p_2=p$.



Initial State



Final State: Thermal Equlibrium

(iii) Internal energyof the gas (IEG) $U=1.5nRT$

(iv) Gas in left part is $n_1=1\,\text{mol}$ and $n_2=2\,\text{mol}$

(v) System is left to reach in thermal equilibrium say at temperature *T*.

Taking this data each part of the problem is being analysed –

Part (a): Since the dividing wall is fixed and hence there will be no change in volume hence work done by the gas in both the parts is zero. **Hence answer of part (a) is Zero**.

Part (b): Both these parts are interdependent and hence taken together. As per IGE, $pv=n_1RT_1\Rightarrow T_1=\dfrac{pv}{n_1R}$, on the similar lines $T_1=\dfrac{pv}{n_2R}$. Thus substituting values $T_1=\dfrac{p\frac{V}{2}}{1\times R}=\dfrac{pV}{2R}$ and $T_2=\dfrac{p\frac{V}{2}}{2\times R}=\dfrac{pV}{4R}$. These two values are part (b) of the answer.

Part (c): On reaching the temperature T, pressure in left part would be $p_{1f}=n_1\times\dfrac{RT}{v}$ and on similar lines $p_{2f}=n_2\times\dfrac{RT}{v}$. Here, T is unknown and is required to be determined in part (c) of the problem; it shall be dentermined from energy balance equation $U=U_{1i}+U_{1i}=U_{1f}+U_{1f}$. Taking each component seperately -

(ii) $U_{1i}=1.5\times p\times v$ (ii) $U_{2i}=1.5\times p\times v$ (iii) $U_{1f}=1.5\times p_{1f}\times v=1.5\times\dfrac{n_1RT}{v}$ and

(iv) $U_{2f}=1.5\times p_{2f}\times v=1.5\times\dfrac{n_2RT}{v}$. Using these values in energy balance equation we get-

$$1.5\times p\times v+1.5\times p\times v=1.5\times\frac{n_1RT}{v}\times v+1.5\times\frac{n_2RT}{v}\times v\Rightarrow 3pv=1.5\left(n_1+n_2\right)RT\Rightarrow T=\frac{2pv}{n_1+n_2}=\frac{2p\frac{V}{2}}{1+2}=\frac{pV}{3R}$$

, **this is part (c) of the answer**.

Part (d) : Heat given in right part $\Delta U_R=U_{f2}-U_{i2}=1.5n_2R\left(T-T_2\right)=\dfrac{3}{2}\times 2\times R\times\left(\dfrac{pV}{3R}-\dfrac{pV}{4R}\right)=\dfrac{pV}{4}$. , this is part (d) of the answer.

Part (e): increase in internal energy of gas on the left, heat gained by it $\Delta U_L=U_f-U_i$. Accordingly,

	$\Delta U_R = U_{f1} - U_{i1} = 1.5 n_1 R\left(T - T_1\right) = \frac{3}{2} \times 1 \times R \times \left(\frac{pV}{3R} - \frac{pV}{2R}\right) = -\frac{pV}{4}$. **This is part (e) of the answer.**

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