SHAMBHUNATH INSTITUTE OF ENGINEERING AND TECHNOLOGY

Subject Code: KOE-043 Subject: ENERGY SCIENCE AND ENGINEERING.

B.Tech. 4th SEMESTER

FIRST SESSIONAL SOLUTION, (2019-2020)

Branch: CIVIL ENGINEERING

SECTION – A

1. Attempt all questions in brief. (1*5 = 5)

Q N	QUESTION	Mars	CO	BL
a.	Define energy with it forms. **ANS.**Energy is defined as the ability to do work. Energy comes in various forms. Here are 10 common types of energy and examples of them 1. Mechanical Energy-Mechanical energy is energy that results from movement or the location of an object. Mechanical energy is the sum of kinetic energy and potential energy.**Examples:** An object possessing mechanical energy has both kinetic and potential energy, although the energy of one of the forms may be equal to zero. A moving car has kinetic energy. If you move the car up a mountain, it has kinetic and potential energy. A book sitting on a table has potential energy. 2. Thermal Energy-Thermal energy or heat energy reflects the temperature difference between two systems. **Example:** A cup of hot coffee has thermal energy. You generate heat and have thermal energy with respect to your environment. 3. Nuclear Energy-Nuclear energy is energy resulting from changes in the atomic nuclei or from nuclear reactions. **Example:** Nuclear fission, nuclear fusion, and nuclear decay are examples of nuclear energy. An atomic detonation or powers from a nuclear plant are specific examples of this type of energy. 4. Chemical Energy-Chemical energy results from chemical reactions between atoms or molecules. There are different types of chemical energy, such as electrochemical energy and chemiluminescence. **Example:** A good example of chemical energy is an electrochemical cell or battery. 5. Electromagnetic Energy-Electromagnetic energy (or radiant energy) is energy from light or electromagnetic waves. **Example:** Any form of light has electromagnetic energy, including parts of the spectrum we can't see. Radio, gamma rays, x-rays, microwaves, and ultraviolet light are some examples of electromagnetic energy. 6.Sonic Energy-Sonic energy is the energy of sound waves. Sound waves travel through the air or another medium. **Example**: A sonic boom, a song played on a stereo, your voice. 7-Gravitational Energy-Energy associated with gravity involves the attraction between two objects based on their mass. It can serve as a basis for mechanical energy, such as the potential energy of an object placed on a shelf or the kinetic energy of the Moon in orbit around the Earth. **Example**: Gravitational energy	**1**	**1**	**2**

	holds the atmosphere to the Earth. 8. Kinetic Energy-Kinetic energy is the energy of motion of a body. It ranges from 0 to a positive value. **Example**: An example is a child swinging on a swing. No matter whether the swing is moving forward or backward, the value of the kinetic energy is never negative. 9. Potential Energy-Potential energy is the energy of an object's position. **Example**: When a child swinging on a swing reaches the top of the arc, she has maximum potential energy. When she is closest to the ground, her potential energy is at its minimum (0). Another example is throwing a ball into the air. At the highest point, the potential energy is greatest. As the ball rises or falls it has a combination of potential and kinetic energy. 10. Ionization Energy-Ionization energy is the form of energy that binds electrons to the nucleus of its atom, ion, or molecule. **Example**: The first ionization energy of an atom is the energy needed to remove one electron completely. The second ionization energy is energy to remove a second electron and is greater than that required to remove the first electron.			
b.	Discuss the conversion between heat energy and mechanical energy. **ANS.**The **mechanical** equivalent of **heat** states that motion and **heat** are mutually interchangeable and that in every case, a given amount of work would generate the same amount of **heat**, provided the work done is totally converted to **heat energy**. A **heat** pump is the efficient way **to** "**convert**" **mechanical energy to heat energy**. A **heat** pump is just an air conditioner running backwards although usually you want a **heat** source other than the outside air - something warmer **in the** winter **to** take the **heat** from. SI unit of mechanical equivalent of heat is **Joules**/ calorie.	**1**	**1**	**2**
c.	What is energy quantization? **ANS. Quantization** is the process of constraining an input from a continuous or otherwise large set of values to a discrete set. The **quantization** of **energy** refers to the fact that at subatomic levels, **energy** is best thought of as occurring in discreet "packets" called photons. ... The red and blue photons are therefore "**quantized**" just as dollar bill denominations are "**quantized**". Each photon contains a unique amount of discreet **energy**. E=nhV Where h= Planck's constant and V= frequency of radiation. The **quantization** of **energy** refers to the fact that at subatomic levels, **energy** is best thought of as occurring in discreet "packets" called photons. ... The red and blue photons are therefore "**quantized**" just as dollar bill denominations are "**quantized**". Each photon contains a unique amount of discreet energy.	**1**	**1**	**1**
d.	Give the different statements of second law of thermodynamics. **Ans.** The **second law of thermodynamics** states that the entropy of a given closed system can never decrease. The **second law** can also be stated as 'It is impossible to build a perfect heat engine'.	**1**	**1**	**1**

	Clausius statement of the **second law** is: “It is not possible to construct a device that operates in a cycle and whose sole effect is to transfer heat from a colder body to a hotter body.” **Kelvin–Planck statement-second law of thermodynamics** states that it is impossible to devise a cyclically operating heat engine, the effect of which is to absorb energy in the form of heat from a single thermal reservoir and to deliver an equivalent amount of work.			
e.	Name the fundamental forces in universe with their relative strength and range. **ANS.** The Four **Fundamental Forces** of Nature are Gravitational **force**, Weak Nuclear **force**, Electromagnetic **force** and Strong Nuclear **force**. The weak and strong **forces** are effective only over a very short **range** and dominate only at the level of subatomic particles. Gravity and Electromagnetic **force** have infinite **range**.	**1**	**2**	**2**

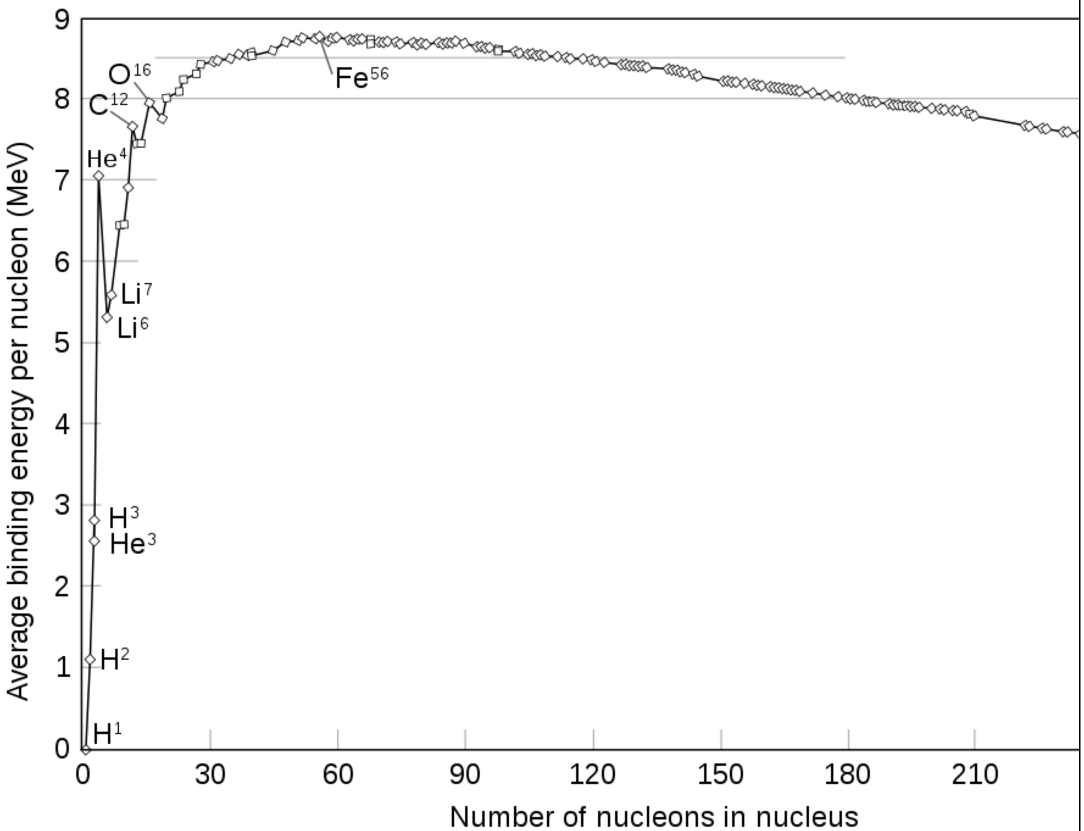
Fundamental Forces

Force	Associated Property	Effect	Range	Carrier Particle	Re Str
Gravitational	Mass	All masses attract each other	Infinite but weakens with distance	Graviton	
Electromagnetic	Electric charge	Opposites attract, likes repel	Infinite but weakens with distance	Photon	
Strong	Color charge	Three colors combine to make neutral combinations	≈ 10^{-15} meters (distance between protons in atomic nucleus)	Gluon	
Weak	Weak charge	Massive particles decay to lower mass particles	≈ 10^{-18} meters (1/1000th proton diameter)	W & Z	

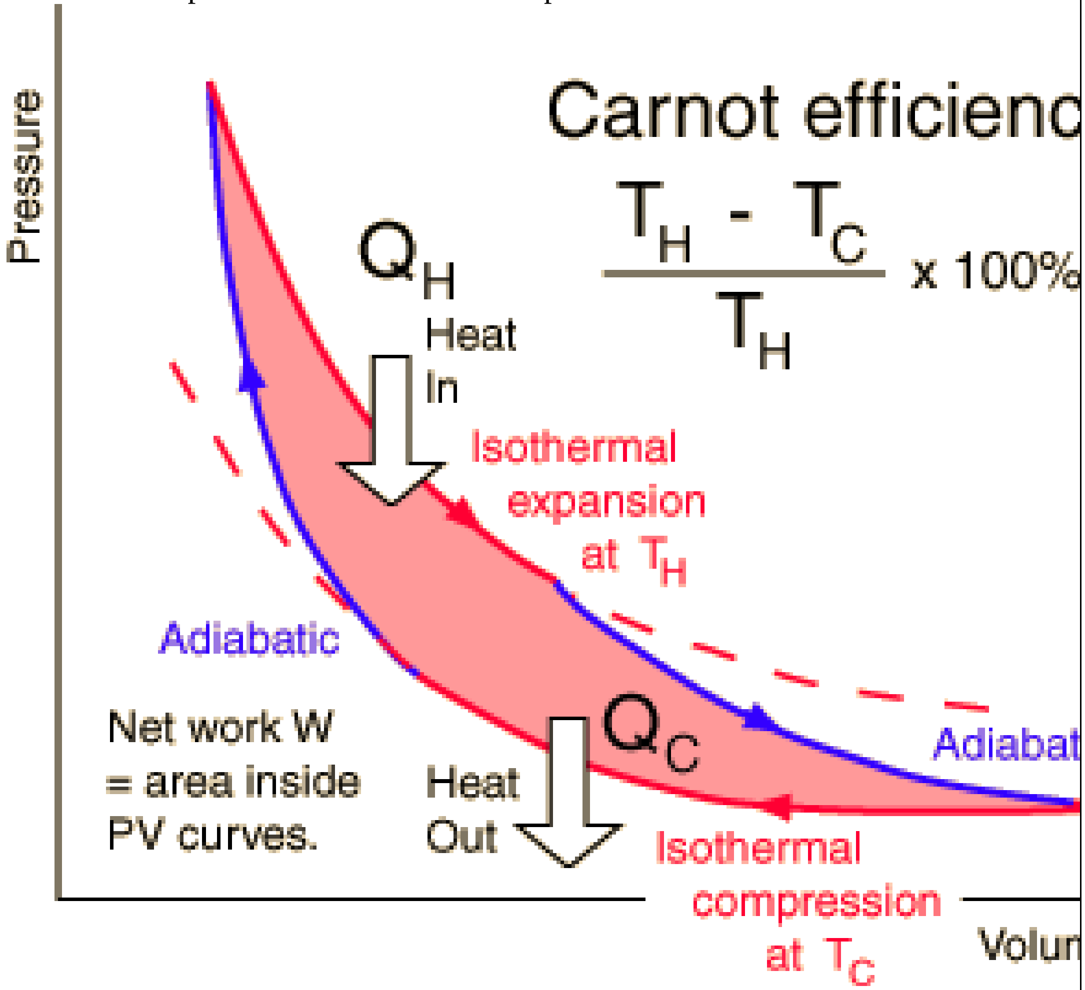
SECTION - B

2. Attempt any <u>TWO</u> of the following. (2*5 = 10)

Q N	QUESTION	Marks	CO	BL
a.	What is nuclear binding energy? Illustrate from the binding energy curve, the various information you got. **ANS.** **Nuclear binding energy** is the *minimum* energy that would be required to disassemble the nucleus of an atom into its component parts. These component parts are neutrons and protons, which are collectively called nucleons. The binding	**5**	**2**	**4**

	energy is always a positive number, as we need to spend energy in moving these nucleons, attracted to each other by the strong nuclear force, away from each other. The mass of an atomic nucleus is less than the sum of the individual masses of the free constituent protons and neutrons, according to Einstein's equation $E=mc^2$. This 'missing mass' is known as the **mass defect**, and represents the energy that was released when the nucleus was formed.  The actual **mass** is always less than the sum of the individual masses of the constituent protons and neutrons because energy is removed when when the nucleus is formed. ... This **mass**, known as the **mass** defect, is missing in the resulting nucleus and represents the energy released when the nucleus is formed. B.E./N for hydrogen like nuclei is very small. B.N./N. increases rapidly upto mass number 20 with peak corresponding to $\mathbf{{}_2He^4, {}_6C^{12}, {}_8O^{16}}$. Which indicates that these nuclei are much stable than its neighboring nuclei. After Mass number 20 B.E./N. increases gradually and for mass number(40-120) curve is almost flat and B.E./N. is approximately B.E./N. 8.5MeV. After mass number120 B.E./N decreases and reach up to 7.6MeV for uranium. This value for heavier atom to be unstable in comparison to Colombian forces and uranium atom exhibit alpha, beta particle and gamma radiation.			
b.	Gives the different operations of Carnot's cycle. How does it account for the efficiency of a heat engine? **ANS.** The Carnot cycle is a theoretical thermodynamic cycle. It is the most efficient cycle for converting a given amount of thermal energy into work, or conversely, creating a temperature difference (e.g. refrigeration) by doing a given amount of work. A Carnot cycle acting as a heat engine. The cycle takes place between a hot reservoir at temperature T_H and a cold reservoir at temperature. It is not a practical engine cycle because the heat transfer into the engine in the	**5**	**1**	**3**

isothermal T_C process is too slow to be of practical value.

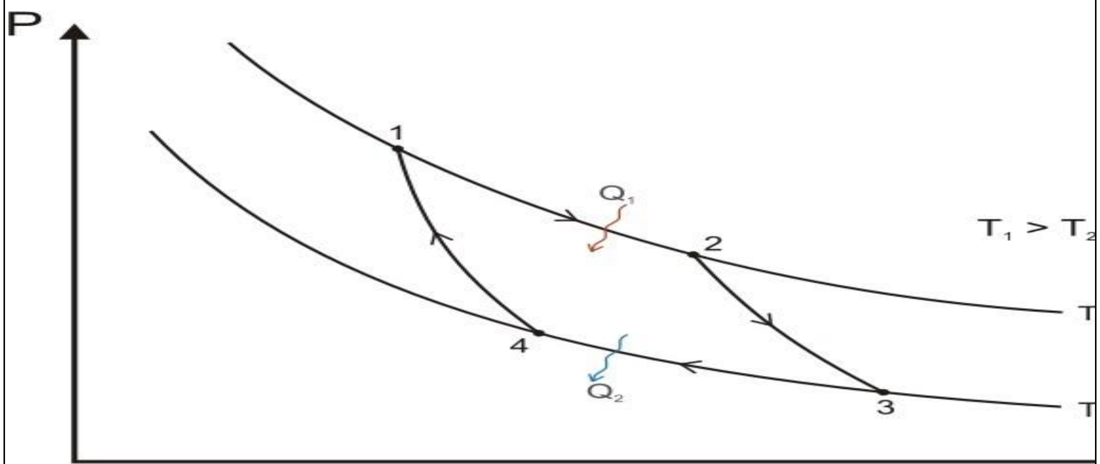


Carnot Cycle

Reversible isothermal expansion of the gas at the "hot" temperature, T_H (isothermal heat addition or absorption). During this step (1 to 2 P-V diagrams) the expanding gas makes the piston work on the surroundings. The gas expansion is propelled by absorption of quantity Q1 of heat from the high temperature reservoir. Carnot Cycle

Reversible adiabatic expansion of the gas. For this step (2 to 3 on P-V diagram) the piston and cylinder are assumed to be thermally insulated, thus they neither gain nor lose heat. The gas continues to expand, working on the surroundings. The gas expansion causes it to cool to the "cold" temperature, T_C .

Reversible isothermal compression of the gas at the "cold" temperature, T_C . (Isothermal heat rejection) (3 to 4 on P-V diagram). Now the surroundings do work on the gas, causing quantity Q2 of heat to flow out of the gas to the low temperature reservoir.

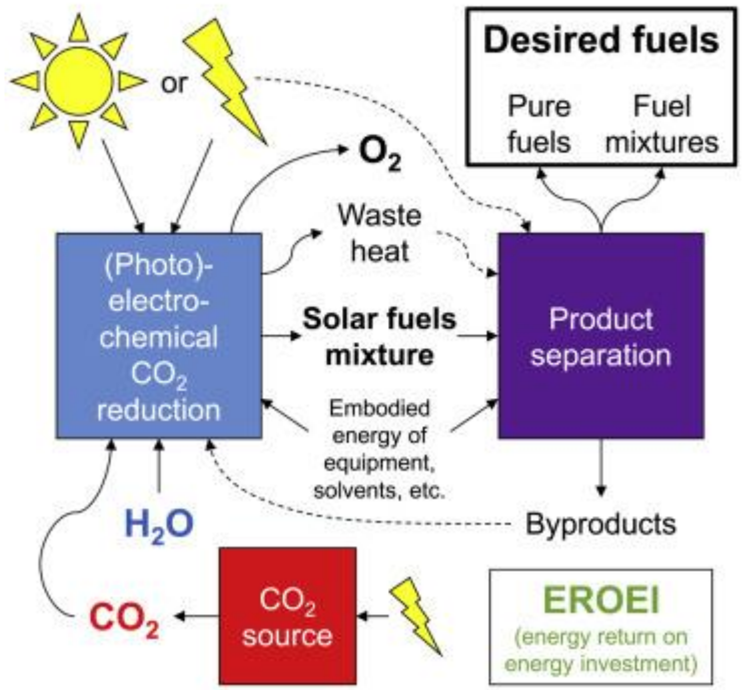
	Reversible adiabatic compression of the gas (4 to 1 on P-V diagram) Once again the piston and cylinder are assumed to be thermally insulated. During this step, the surroundings do work on the gas, compressing it and causing the temperature to rise to TH . At this point the gas is in the same state as at the start of step 1.  **Adiabatic – complete combustion of fuel**; no lingering ΔQ input in other parts of cycle (no exchange of heat with surroundings) **Isothermal – no heat loss to walls;** no turbulence of fluids; no friction; heat transfer is done very slowly in order to retain isothermal quality Efficiency of Carnot's heat engine (η) = $1 - \frac{Tc}{Th}$			
c.	A Carnot's engine whose temperature of source is 400K takes 200 calories of heat at this temperature and rejects 150 calories heat to sink. What is the temperature of sink? Also calculate the efficiency of the engine. **Ans.** **Carnot's theorem speaks** $\frac{Qh}{Th} = \frac{Qc}{Tc}$ $\frac{200}{400} = \frac{150}{Tc}$ **= Tc =** $\frac{400x150}{200}$ **= 300K** **Efficiency of Carnot's heat engine (η) =** $1 - \frac{Tc}{Th} = 1 - \frac{300}{400} = \frac{1}{4}$ **=0.25 or 25%**	**5**	**1**	**3**
d.	Calculate the binding energy per nucleon of $_{17}Cl^{35}$ nucleus. Given Mass of $_{17}Cl^{35}$ is 34.9800U; Mass of Proton ($_{1}p^{1}$) is 1.008665U and Mass of neutron ($_{0}n^{1}$) is1.007825U. **ANS. Given Mass of $_{17}Cl^{35}$ is 34.9800U;** **Mass of Proton ($_{1}p^{1}$) is 1.008665U** **and Mass of neutron ($_{0}n^{1}$) is1.007825U.** **Calculated mass of $_{17}Cl^{35}$={(17x1.008665)+(18x 1.007825)}** **={17.133025+18.14085}** **=35.273875U** **Now Mass Defect=35.273875U-34.9800U=0.293875U** **Binding Energy= Mass Defect x 931 MeV** **= 0.293875x931 MeV=273.597625 MeV** **Now binding energy/ N=273.597625/35=7.817 MeV. Ans.**	**5**	**2**	**3**

P.T.O.

SECTION – C

3. Attempt any ONE part of the following: (1*5 = 5)

Q N	QUESTION	Marks	CO	BL
a.	What is entropy? Discuss flow of carbon dioxide cycle and give its relation with Entropy. **ANS. Entropy**, the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work. Because work is obtained from ordered molecular motion, the amount of **entropy** is also a measure of the molecular disorder, or randomness, of a system. The **Second Law of Thermodynamics** states that the state of **entropy** of the entire universe, as an isolated system, **will** always increase over time. The **second law** also states that the changes in the **entropy** in the universe **can** never be negative. All of the vital processes of plants, including the synthesis of complex organic substances, the building of their complicated structures, and the maintenance of a high level of organization, are because of the continuous influx of negative entropy. This influx is provided by the energy flux that passes through the plant. The entering energy flux of solar radiation has an effective temperature on the order of 2000–6000 K. The energy flux leaving the plant is almost the same in magnitude, but its effective temperature is much lower at about 300 K. Thus, the energy flux loses its high degree of negative entropy, and from this loss the plant performs all kinds of useful work necessary for its vital activity. In other words, the incoming energy flux brings little entropy to the plant, whereas the flux leaving withdraws much more entropy. Thus, the energy flux that passes through the plant continuously “pumps” entropy out of it. The entropy deficit originated in this way compensates for the entropy produced by irreversible	**5**	**1**	**4**



b.	Discuss internal combustion engine by taking its types and parts with the suitable diagram. What are advantage and disadvantage of IC engine? ANS. **INTERNAL COMBUSTION ENGINES-**An Engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this thermal energy to produce mechanical work. Engines normally convert thermal energy into mechanical work and therefore they are called heat engines. Heat engines can be broadly classified into : i) External combustion engines (E C Engines) ii) Internal combustion engines (I C Engines) Internal combustion engines can be classified as Continuous IC engines and Intermittent IC engines.In continuous IC engines products of combustion of the fuel enters into the prime mover as the working fluid. For example: In Open cycle gas turbine plant. Products of combustion from the combustion chamber enter through the turbine to generate the power continuously . In this case, same working fluid cannot be used again in the cycle. ADVANTAGES OF INTERNAL COMBUSTION ENGINES 1. Greater mechanical simplicity. 2. Higher power output per unit weight because of absence of auxiliary units like boiler , condenser and feed pump 3. Low initial cost DISADVANTAGES OF INTERNAL COMBUSTION ENGINES 1. I C engines cannot use solid fuels which are cheaper. Only liquid or gaseous fuelof given specification can be efficiently used. These fuels are relatively more expensive. 2. I C engines have reciprocating parts and hence balancing of them is problem and they are also susceptible to mechanical vibrations. **CLASSIFICATION OF INTERNAL COMBUSTION ENGINES.** There are different types of IC engines that can be classified on the following basis. **1. According to thermodynamic cycle**	5	1	2

i) Otto cycle engine or Constant volume heat supplied cycle.
ii) Diesel cycle engine or Constant pressure heat supplied cycle
iii) Dual-combustion cycle engine

2. According to the fuel used:
i) Petrol engine ii) Diesel engine iii) Gas engine

3. According to the cycle of operation:
i) Two stroke cycle engine ii) Four stroke cycle engine

4. According to the method of ignition:
i) Spark ignition (S.I) engine ii) Compression ignition (C I) engine

5. According to the number of cylinders.
i) Single cylinder engine ii) Multi cylinder engine

INTERNAL COMBUSTION ENGINE PARTS

1. Cylinder-it is a container fitted with piston, where the fuel is burnt and power is produced.

2. Cylinder Head/Cylinder Cover:-One end of the cylinder is closed by means of cylinder head. This consists of inlet valve for admitting air fuel mixture and exhaust valve for removing the products of combustion.

3. Piston:- Piston is used to reciprocate inside the cylinder. It transmits the energy to crankshaft
through connecting rod.

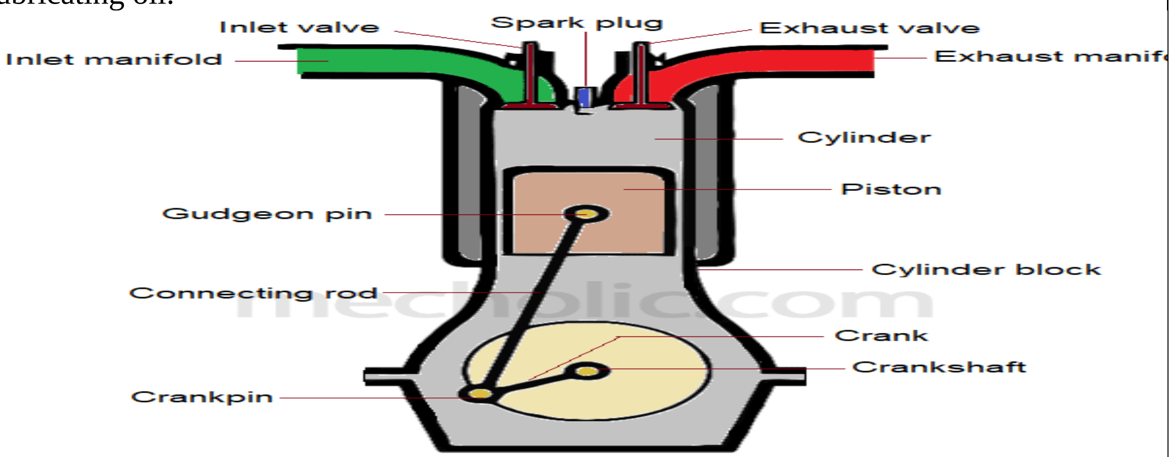
4. Piston Rings:- These are used to maintain a pressure tight seal between the piston and cylinder walls and also it transfer the heat from the piston head to cylinder walls.

5. Connecting Rod:- One end of the connecting rod is connected to piston throughpiston pin while the other is connected to crank through crank pin. It transmits the reciprocatory motion of piston to rotary crank.

6. Crank:- It is a lever between connecting rod and crank shaft.

7. Crank Shaft:- The function of crank shaft is to transform reciprocating motion in to arotary motion.

8. Fly wheel:- Fly wheel is a rotating mass used as an energy storing device.**9. Crank Case:-** It supports and covers the cylinder and the crank shaft. It is used to store the lubricating oil.



4. Attempt any ONE part of the following: **(1*5 = 5)**

Q N	QUESTION	Marks	CO	BL
a.	Discuss the operation of Otto engine in detail. **Ans.** Otto cycle	**5**	**1**	**4**

The **Otto Cycle**, describes how heat engines turn gasoline into motion. Like other thermodynamic cycles, this cycle turns chemical energy into thermal energy and then into motion. The Otto cycle describes how internal combustion engines (that use gasoline) work, like automobiles and lawn mowers.

Application

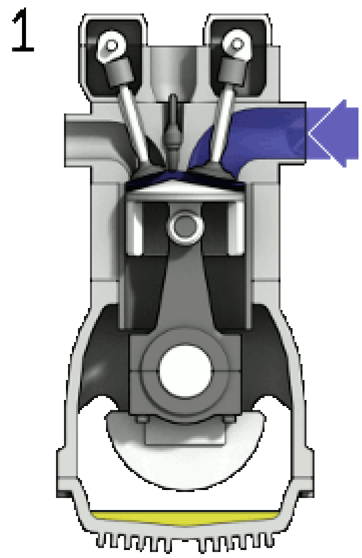


Figure 1. A four stroke engine

The engines' pages will provide details on their unique mechanisms, and an explanation on how they use the Otto Cycle, which is slightly modified.

The Ideal Otto Cycle

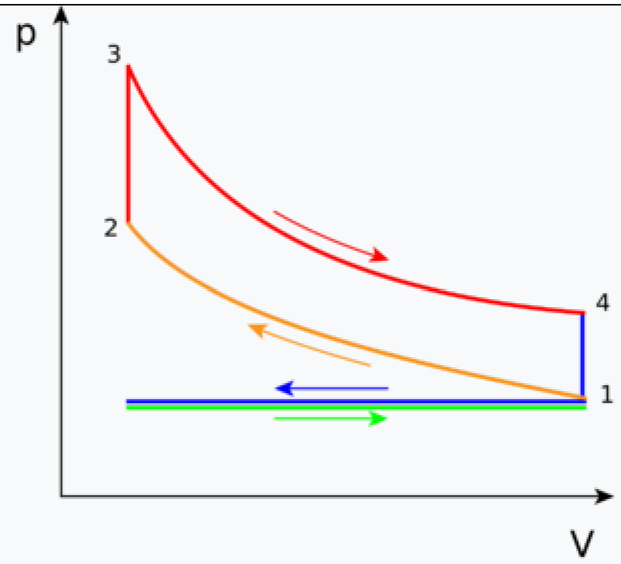


Figure 2. The pressure-volume diagram of an ideal Otto Cycle process. It consists of two isochoric, two adiabatic and two isobaric processes (for intake and exhaust)

The PV diagram (pressure-volume diagram) of the ideal Otto cycle is shown in Figure 3. This diagram models how the changes in pressure and volume of the working fluid (gasoline and air fuel) change due to the combustion of hydrocarbons which powers the movements of a piston, creating heat, to provide motion for a vehicle. There are expansion (increased volume chamber) piston motions—caused when the thermal energy is released from combustion—inducing work being done *by the gas* and *on the piston.* In contrast, when the piston does *work on the gas*, the engine chamber is being compressed (decreasing in volume).[5]

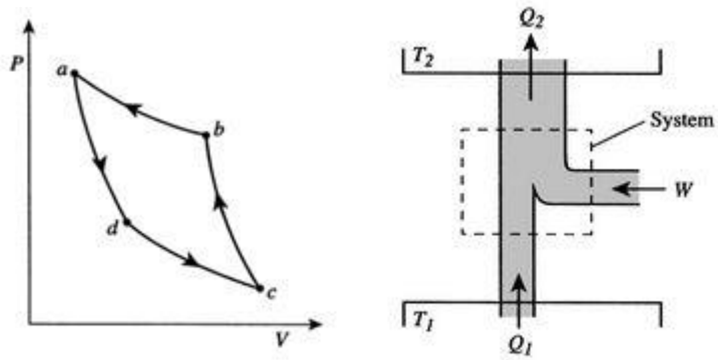
It is important to note that Figure 3 depicts an *ideal* process for any engine using the Otto cycle. It describes the basic working steps in a gasoline engine. The slight modification which depicts a more realistic situation of the Otto Cycle's PV diagram for a two stroke and four stroke engine is explained on their respective pages. The work done by the engine can be calculated by solving the area of the closed cycle.

The following describes what occurs during each step on the PV diagram, in which the combustion of the working fluid—gasoline and air (oxygen), changes the motion in the piston:

Green line: Referred to as the *intake phase*, the piston is drawn down to the bottom to allow the volume in the chamber to increase so it can "intake" a fuel-air mixture. In terms of thermodynamics, this is referred to as an isobaric process.

Process 1 to 2: During this phase the piston will be drawn up, so it can compress the fuel-air mixture that entered the chamber. The compression causes the mixture to increase slightly in pressure and temperature—however, no heat is exchanged.

	In terms of thermodynamics, this is referred to as an adiabatic process. When the cycle reaches point 2, that is when the fuel is met by the spark plug to be ignited. **Process 2 to 3:** This is where combustion occurs due to the ignition of fuel by the spark plug. The combustion of the gas is complete at point 3, which results in a highly pressurized chamber that has a lot of heat (thermal energy). In terms of thermodynamics, this is referred to as an isochoric process. **Process 3 to 4:** The thermal energy in the chamber as a result of combustion is used to do work on the piston—which pushes the piston down—increasing the volume of the chamber. This is also known as the *power stoke* because it is when the thermal energy is turned into motion to power the machine or vehicle. **Purple line (Process 4 to 1 and *exhaust* phase):** From process 4 to 1, all waste heat is expelled from the engine chamber. As the heat leaves the gas, the molecules lose kinetic energy causing the decrease in pressure.[6] Then the *exhaust phase* occurs when the remaining mixture in the chamber is compressed by the piston to be "exhausted" out, without changing the pressure.			
b.	Explain the working principle of Heat pump with suitable diagram. Derive the formula for coefficient of performance. **ANS. Heat Pumps:** The Carnot cycle has been used for power, but we can also run it in reverse. If so, there is now net work into the system and net heat out of the system. There will be a quantity of heat Q_2 rejected at the higher temperature and a quantity of heat Q_1 absorbed at the lower temperature. The former of these is negative according to our convention and the latter is positive. The result is that work is done on the system, heat is extracted from a low temperature source and rejected to a high temperature source. The words ``low" and ``high" are relative and the low temperature source might be a crowded classroom on a hot day, with the heat extraction being used to cool the room. The cycle and the heat and work transfers are indicated in Figure 3.6. In this mode of operation the cycle works as a refrigerator or heat pump. ``What we pay for" is the work, and ``what we get" is the amount of heat extracted. A metric for devices of this type is the coefficient of performance, defined a $$\text{Coefficient of performance} = \frac{Q_1}{-W} = \frac{Q_1}{-(Q_1+Q_2)}.$$	**5**	**1**	**4**

	 **Figure 3.6:** Operation of a Carnot refrigerator For a Carnot cycle we know the ratios of heat in to heat out when the cycle is run forward and, since the cycle is reversible, these ratios are the same when the cycle is run in reverse. The coefficient of performance is thus given in terms of the absolute temperatures as $$\text{Coefficient of performance} = \frac{T_1}{T_2 - T_1}.$$ This can be much larger than unity. The Carnot cycles that have been drawn are based on ideal gas behavior. For different working media, however, they will look different.			

5. Attempt any ONE part of the following: **(1*5 = 5)**

Q N	QUESTION	Marks	CO	BL
a.	What are the nuclear forces? How do they differ from electrostatic and gravitational forces? Enumerates their silent characteristics. ANS. The ***nuclear force*** is a ***force that*** acts between the protons and neutrons of atoms. Neutrons and protons, both nucleons, ***are*** affected by the ***nuclear force*** almost identically. Work (energy) is required to bring charged protons together against their electric repulsion. This energy is stored when the protons and neutrons are bound together by the nuclear force to form a nucleus. The mass of a nucleus is less than the sum total of the individual masses of the protons and neutrons. The difference in masses is known as the mass defect, which can be expressed as an energy equivalent. Energy is released when a heavy nucleus breaks apart into two or more lighter nuclei. This energy is the electromagnetic potential energy that is released when the nuclear force no longer holds the charged nuclear fragments together. This repulsive force is responsible. for size of nucleus. The size of atom lies lies in order of few angstroms and one laces time larger than size of atom. Between o.7F to 2.5F Colombian force becomes insignificant i.e. strong force is much larger than Colombian force. Colombian force becomes significant after 2.5F.	5	2	4

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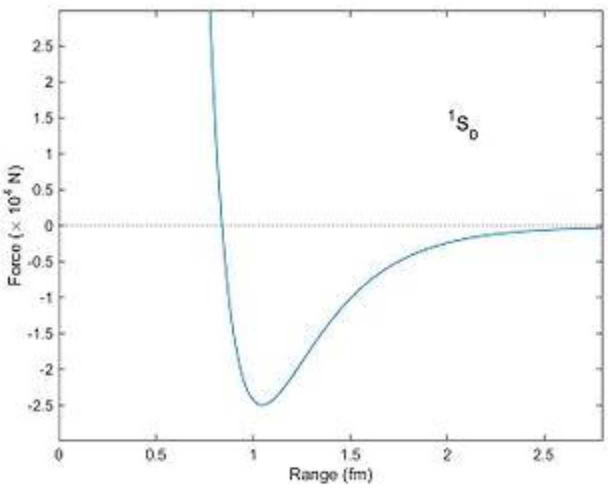
<td>Nuclear force is spin dependent i.e. this force is strong for particles for their spins are allied than particles are anti allied. It is according idea of Pauli exclusive principle.
Nuclear forces are saturated forces i.e. they do not vary inside the nucleus.
Nuclear forces are non central forces. it does not depends upon line joining the nucleons but depends upon orientation of spin of nocleons.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.</td>
<td>Discuss quantum mechanical properties of nucleus. Evaluate packing fraction.
ANS. Nuclei have an intrinsic angular momentum. This angular momentum is referred to as the “spin.”
Parity is the fundamental property and is considered to be more important than the nuclear spin.it is closely associated to angular momentum.
For odd a nuclei, the spin J is half integer. (1/2,3/2, etc.) For even A nuclei, the spin J is integer. (0, 1,2,etc.).
Electric moments are measures of the distribution of electric charge. Magnetic moments measure the distribution of electric currents.

The ratio of the total volume of a set of objects packed into a space to the volume of that space. The difference between the isotopic mass of a nuclide and its mass number, divided by its mass number. The packing fraction is often interpreted as a measure of the stability of the nucleus.
A negative packing fraction means isotopic mass is less than actual mass number. This difference is due to the transformation of mass into energy in the formation of nucleus.
A nucleus having positive packing fraction has its mass M greater than its mass number A. It means that the loss of mass due to B.E. arrangement in this nucleus is less than for carbon.</td>
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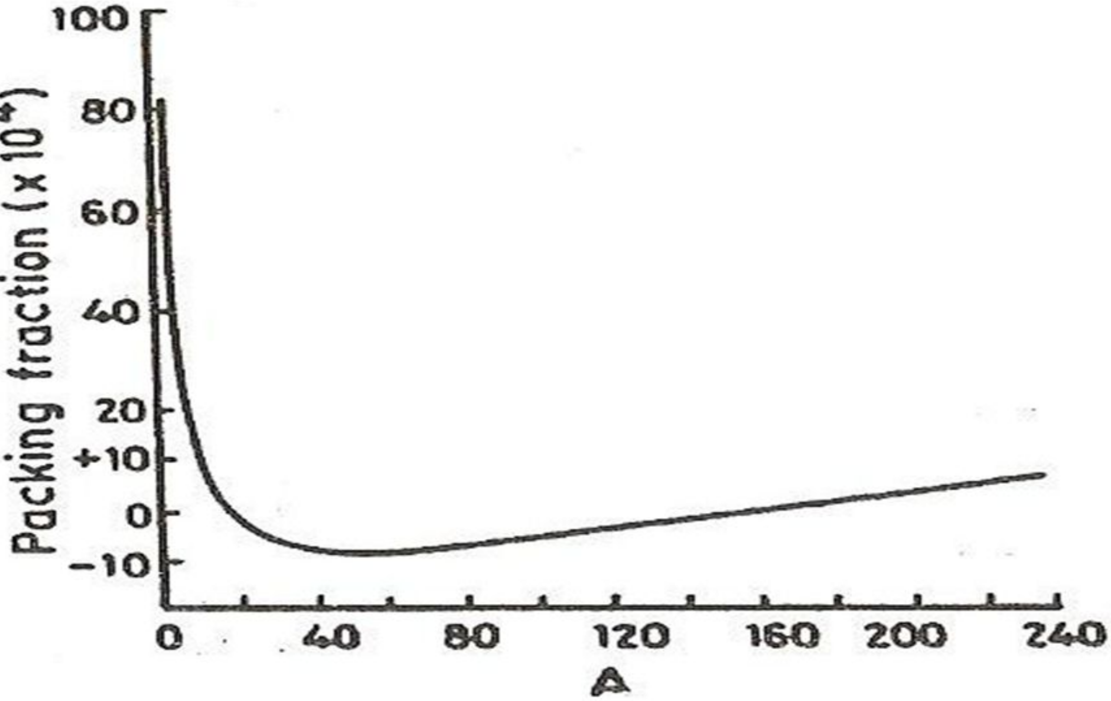

Fig. 2.1. Packing fraction curve.