**Type of infusion:**

**Patient-controlled infusion:**

It is done on-demand, usually with an already programmed ceiling to avoid intoxication of drugs. The rate of infusion is controlled by a pressure pad or button that can be activated by the patient himself. It is the method used for patient-controlled analgesia (PCA). This process includes repeated small doses of opioid analgesics which are delivered with the device that is programmed to stop delivery before a dose that may cause hazardous respiratory depression.

**A good infusion pump should be**

* electrically safe and portable
* accurate and consistent delivery of drugs
* easy to set up and use
* robust and reliable
* can be powered with battery and mains both
* proper use of alarms
* capable of detecting line occlusion
* should display rate of infusion and volume infused clearly.

**Types of Infusion Pumps:**

* Gravity controlled pumps
* Position displacement pumps

**Position Displacement Pumps:**

As the name suggests it provide a positive displacement of fluid with the help of a motor. The mechanism is such that it prevents infusion of large amount of air or subcutaneous infiltration. These pumps are based on the concept of peristaltic or piston motion. This pump uses linear or rotary methods. The rotator type peristaltic pump contains rollers on a wheel, as a result it compresses the tubing and hence the fluid can move towards the patient in the tube. The linear mechanism of peristalsis include finger like projections which compresses the tubing against a stationary back plate sequentially and causes a unidirectional flow of fluid.

**Types:**

* Drip rate pumps
* Volumetric pumps
* Syringe Pumps
* Multi-Channel Pumps
* Ambulatory pumps

**Volumetric Pumps:**

These types of pumps eliminate the drawback in drip rate pumps. It uses piston type action and peristaltic pumping type action. It uses infusion set which increases the cost of each infusion. It delivers accurate volume of infusion as it precisely regulates the set of flow rates. These pumps runs on ml per hour. Volumetric infusion pumps can calculate the amount of fluid going into the body. The volume can be calculated by microprocessor depending on the size of drop and the diameter of tubing. These pumps work on mains and also rechargeable batteries. It has an alarm and warning buzzer which work simultaneously when there is a bubble inside the tube. As a result the pump stops immediately. It has the alarms to show that infusion is completed. it also shows when the battery voltage is low. The occlusion in the flow can be detected. These pumps have the capability of delivering precise quantities of fluids at very slow and fast rates. They are more expensive than the drip rate pumps. They require special IV infusion sets of standard size. So, in a way they are actually costly but precise volume can be achieved.

**Syringe Pumps:**

These type of syringe pumps are most commonly used for delivery of intravenous drugs. This pump uses a gear reduction mechanism and lead screw for the flow of fluid. This pump doesn’t require any tubing and are extremely accurate. There have been pumps developed by which a nurse can set the weight of the patient, the drug concentration and the infusion rate in the mg per kg per minute. Then the calculator in pump calculates the infusion in ml per minute.

**Specifications of syringe pump include:**

* Microprocessor-controlled stepper motor should be used for accurate delivery.
* It should have capability of functioning on mains and rechargeable Ni-Cd batteries.
* It must have few controls as power switch, start switch and reset/stop switch
* It must have a range of 0.1-99.9 ml/hr with up-to 0.1 ml/hr increments
* It should display alarm/error messages, infused volume and infusion rate
* It should have alarms for dis-engagements of syringe clamp, any occlusion, when syringe becomes empty or plunger is out, low battery and mains power failure.

**Multi-Channel Pumps:**

These are those multi-channel pumps which allow delivery of drugs by 2 or 3 infusions simultaneously. The problem with this system is the probability of incompatible mixings.

**Ambulatory pumps:**

These are basically designed for those persons who needs to have it for longer period of time and they have a good alarm and display systems. It uses a linear peristaltic mechanism and have a fluid container that looks like a cassette. They are basically pocket-size pumps.

**Three Important components:**

* Insulin Reservoir
* Catheter system for transfer of fluid into human body
* Mechanism to drive the pump and to regulate infusion flow (Motor mechanism). The regulation is important for the body as it might cause under infusion or over infusion if not controlled properly. Both the process can cause serious toxic side effects.

**Simple Mechanism:**

* + A pump connected with a stepper motor is used to provide the force for the fluid to displace the contents into the volumetric chamber. Depending upon the stepper motor we can influence the flow uniformity. If the volume is not uniform, then we can control through the software. A processor or microcontroller with advanced GUI (graphical user interface) can be used for monitoring the patients. It also helps in detecting complications and generating an alarm.
  + Steppers motors are used to have a controlled flow rate. We can use DC motor with angular position sensors and Hall effect sensors. In this design the motor drive actuators drive the fluid depending upon revolution of the mechanism. The motor drive circuits can be fed onto closed –loop control system to reduce the power consumption and also to adjust the motor drive voltage. Different types of amplifiers, operational amplifiers, comparators and filters are used to make closed-loop control systems.

**Power supplies:**

Switch-mode voltage regulators are used to maximize battery life. Low drop-out linear regulators (LDOs) are used in those places where low efficiency can be tolerated or in those parts of circuit where the output voltage of LDO is not lower than the input voltage which results in high efficiency. Digital converters (DACs) are used in power supplies when on-the fly programmability is needed

**Battery management:**

Sometimes we need to transport patients while they still remain on the IV, there the infusion pump should be able to operate from battery for several hours. Rechargeable batteries should be used. The pump should not stop due to failure of battery power. For this an accurate battery fuel gauge is used.

**User interface**

These user interfaces are used to program the flow rate. It also helps in displaying parameters such as amount of fluid being infused, patient information, the life of battery remaining, different types of error messages, alarm conditions. Flow rates are designed for a wide range from 0.01ml/hr to 999ml/hr. There may be errors due to the programming so sophisticated software should be used

**Self-test and system monitoring:**

All infusion pumps should undergo power –on self-test (POST). This includes tests for all processors, circuitry, indicators, displays and functionality of alarm. Microcontrollers must be held in reset until all power supplies are stable. Analog to digital converters (ADC) are used for sensor readings such as temperature, motor loading, IV-line pressure and battery voltage. After POST we must ensure that pump is operating properly during patient use. These pumps show high efficiency so fans are not needed. These pumps must be splash proof so it is difficult to put them in openings for airflow.

**Alarms:**

The infusion pumps require alarm that can be heard and seen properly. Audible alarms are basically simple beepers. Bicolour/tricolour (red/orange/green) LEDs are used as visual indicators.

**Time keeping:**

As the patient care is critical so every event has to be done in a perfect time. A small lapse in time may lead to problems to the patient. Every change of configuration like pump door opening or closing, AC power disconnect, battery error etc, every key press, every start and end of infusion and every fault condition reported should be logged and time stamped.

**Electrostatic discharge:**

While keeping the patient in hospital there is a chance for electrical leakage to the patient. To avoid this the developers needs to meet the requirements of the IEC 60601-1 product safety standard for electrical medical equipment

**Stepper Motor:**

A stepper motor is an electromechanical device that is used to have discrete mechanical movements. It converts electrical pulses in form of voltages to step wise mechanical movements. When the electrical pulses are applied in a proper sequence, the shaft of motor rotates in steps and causes increment in steps. The direction of motor shaft rotation depends proportionally on the sequence of the applied pulses. The length of rotation is directly proportional to number of input pulses given. The frequency of input pulses determines the speed of the motor shaft rotation.

**Advantages of stepper motor:**

* The degree of rotation is directly proportional to the input pulse.
* It gives an excellent output to starting or stopping or reversing.
* It is very much reliable as there are no brushes in the motor. So, the life of motor is long and depends on life of bearing.
* We can obtain a wide range of speeds as speed depends on frequency of input pulses.
* The response of motor towards digital input pulses provides open loop control which makes the motor simpler and less costly to control.
* Low speed synchronous rotation can be achieved with a load that is couple to the shaft directly.
* In standstill position the motor has full torque.
* There is a precise and repeated movement of motor which increases the accuracy.

**Disadvantages of stepper motor:**

* These are not easy to operate at extremely high speeds.
* The resonances have to be controlled otherwise it might affect the motor.

**Open loop operation:**

It has characteristics of accurately controlling in open loop system. It means no feedback information is needed about the position. It eliminates the use of optical encoders which are basically the feedback devices and the need for expensive sensing. The position can be known by keeping the track of input pulses.

**Types of Stepper Motor:**

* Permanent magnet type stepper motor.
* Variable reluctance type stepper motor.
* Hybrid type stepper motor

**Permanent magnet type stepper motor:**

It is sometimes referred as a “tin can” or “can stock” motor. It is a low cost and low-resolution type motor with typical angles of 7.5◦ to 15◦. These have permanent magnet in the motor structure. It doesn’t have the teeth like the VR motor. As a result, the rotor is magnetized. These are magnetized with alternating north and south poles which are placed in a straight line parallel to rotor shaft. These motors have improved torque characteristics as compared with the VR type because these rotor poles provide increased magnetic flux intensity

**Variable reluctance type stepper motor:**

This type of motor has been used for a long period of time. It has a structure which is one of easiest to understand. It contains a soft iron multi toothed rotor and a wound stator. When the stator windings are given the DC current, the poles get magnetized. When the rotor teeth are attracted to the energized stator poles, the rotation occurs.

**Hybrid type stepper motor:**

This type of motor is costlier than the permanent magnet stepper motor. It provides better performance than permanent magnet stepper motor with respect to step resolution, torque and speed. The degree of rotation ranges from 3.6° to 0.9°(100−400 steps of revolution). this is basically the hybrid of VR and PM type stepper motor. The rotor is similar to VR motor, basically multi toothed, has an axially magnetized concentric magnet at its shaft. Thus, it provides a better path which helps in having magnetic flux at preferred locations in air gap thereby increasing the detent, holding and dynamic characteristics of motor as compared to VR and PM motors. PM and hybrid are most commonly used. For an application first use PM motor otherwise use the hybrid one. It provides low inertia and an optimized magnetic flow path with no coupling between the windings.

**To know:**

The stepper motor can be classified in terms of size and power. For example, size 11 stepper motor has a body diameter of approx. 1.1 inches. Similarly, a size 23 stepper motor has a body diameter of 2.3inches. The length of the body varies from motor to motor. The available torque output from the motor of précised size will be incremented with an increase in body length. Power required for this type of stepper motor range from 10-20 watts .to calculate this we use PE = V x EI. The motor is always rated at power dissipation level where the motor case rises 65◦C. The motor should be used at its maximum power dissipation so that it becomes efficient from size/output power/cost point of view.