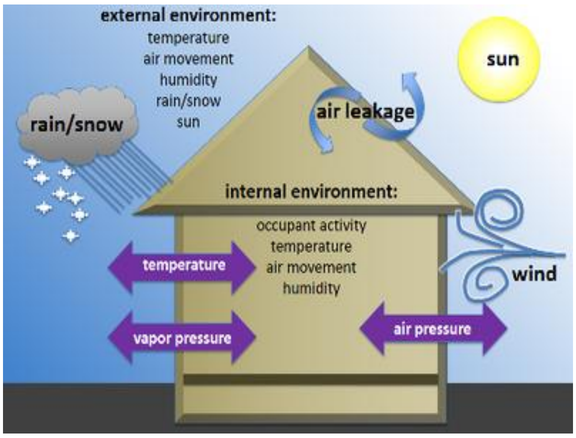
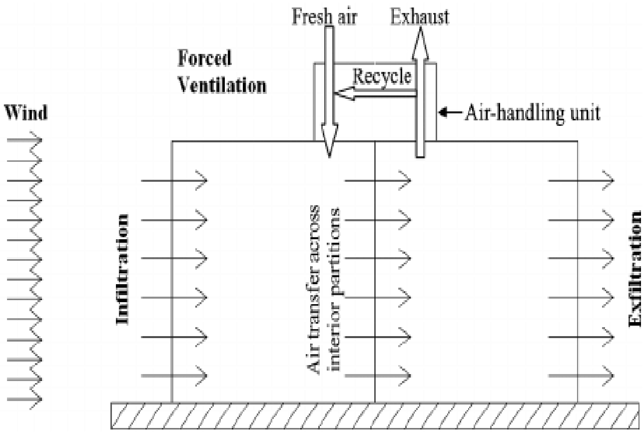
UNIT-IV

UNIT-IV: Infiltration and ventilation, Natural ventilation in commercial buildings, passive cooling, modelling air flow and ventilation, Concepts of daylight factors and day lighting, daylight assessment, artificial lighting, New light sources. Cooling buildings, passive cooling, mechanical cooling. Water conservation- taps, toilets and urinals, novel systems, collection and utilization of rain water.

INFILTRATION:

It refers to the unintentional and uncontrolled entry of outdoor air into the indoor environment. It can occur through gaps, cracks, openings, or leaks in the building envelope





Infiltration can lead to several issues:

1. ***Energy Loss:*** Uncontrolled air infiltration can cause heated or cooled indoor air to escape, leading to increased energy consumption and higher utility bills.
2. ***Temperature Variations:*** Infiltration can create drafts and temperature variations within the building, making it less comfortable for occupants.
3. ***Indoor Air Quality:*** Outdoor pollutants, allergens, and contaminants may enter the building through infiltration, potentially affecting indoor air quality.

To prevent infiltration, consider the following measures:

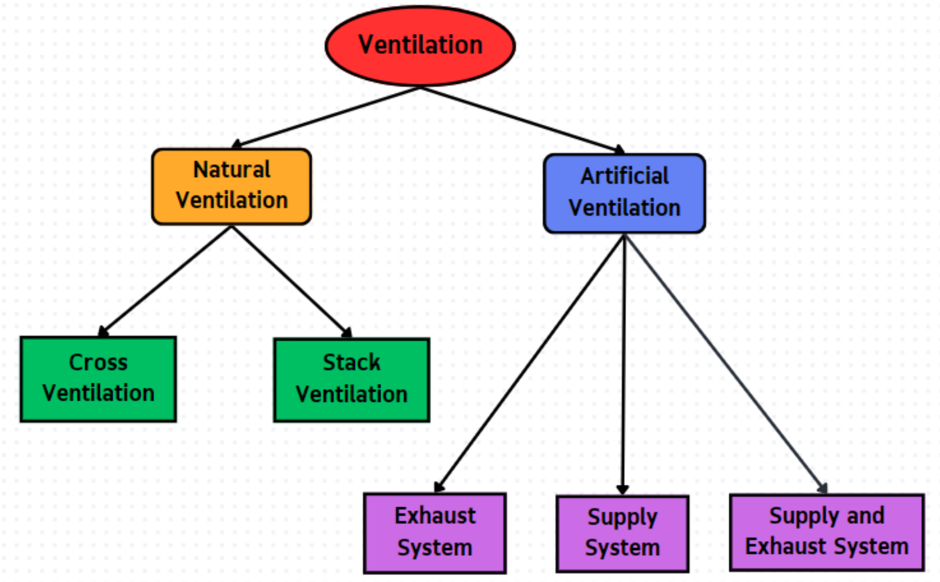
1. ***Weatherization:*** Seal gaps and cracks in building envelope using weatherstripping, caulk, or sealant. Focus on areas around windows, doors, pipes, electrical outlets, and wall seams.
2. ***Insulation:*** Properly insulate walls, ceilings, and floors to reduce heat transfer and the potential for air leakage.
3. ***Air Barriers:*** Install air barriers, such as sheathing, membranes, or house wraps, to restrict the movement of outdoor air through the building envelope.
4. ***Doors and Windows:*** Ensure that doors and windows are properly sealed and weatherstripped to minimize air leakage.
5. ***Proper Ventilation:*** Implement controlled ventilation systems, such as mechanical ventilation or natural ventilation, to provide fresh air in a controlled manner. This reduces the reliance on uncontrolled infiltration for indoor air exchange.

6. ***Regular Maintenance:*** Conduct routine inspections and maintenance to identify and address new gaps or cracks that may develop over time.
7. ***Building Design:*** Incorporate good building design practices that minimize the potential for infiltration, such as designing with airtightness in mind from the beginning.
8. ***Energy Recovery Ventilation System:*** This systems exchange heat or coolness between incoming and outgoing air streams, reducing the energy impact of infiltration.

VENTILATION & COOLING:

a) VENTILATION

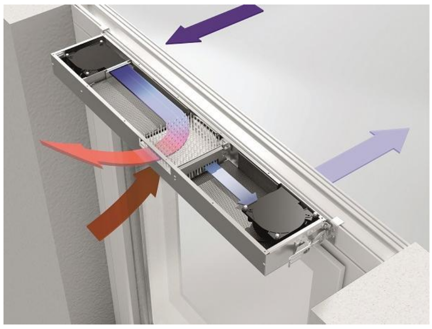
It is the process of supplying fresh air into a closed space or the removal of foul air from inside of a closed space.



a) Natural Ventilation of Commercial Building:

- Natural ventilation is making a strong comeback in commercial buildings. Driven by factors such as
  - High energy costs
  - Unhealthy indoor environments, and
  - The need to protect the ecosystem
- Buoyancy and air flow are the two principle drivers to naturally ventilate a building.
- Buoyancy refers to the principle that less-dense hot air will rise inside a building as cooler air is introduced.
- This relies on the temperature difference between indoor and outdoor air and employs stack ventilation, where rising warm air exits the structure to create a vacuum effect that pulls in cooler exterior air from below.
- As wind enter a natural ventilator, this air flow combined with the buoyancy effect, creates a circulation inside the building that leads to a cooler and more comfortable environment.
- There are two basic methods to provide natural ventilation in a building:
  a) Actuated window systems and

b) Integrated ventilators.

- ☐ Actuated systems involve windows or panels that can be automatically opened or closed using electronic actuators.
  - They can open or close based on room conditions like temperature, making it more comfortable.
  - Useful for windows that are hard to reach.
  - Can save energy by reducing the need for air conditioning or heating.
- ☐ An integrated ventilator brings fresh air into a space and can also remove stale air. Some even capture the heat from outgoing air to warm up the incoming cold air.
  - They provide fresh air consistently.
  - Can save energy by reusing the heat from the outgoing air.
  - Help in controlling moisture, reducing mold or dampness problems.

Advantages of Natural Ventilation:

» Energy and Cost Savings
» Environmental Benefits
» Improved Indoor Air Quality
» Thermal Comfort
» Aesthetic and Architectural Benefits
» Low Maintenance
» Sustainability and Adaptability

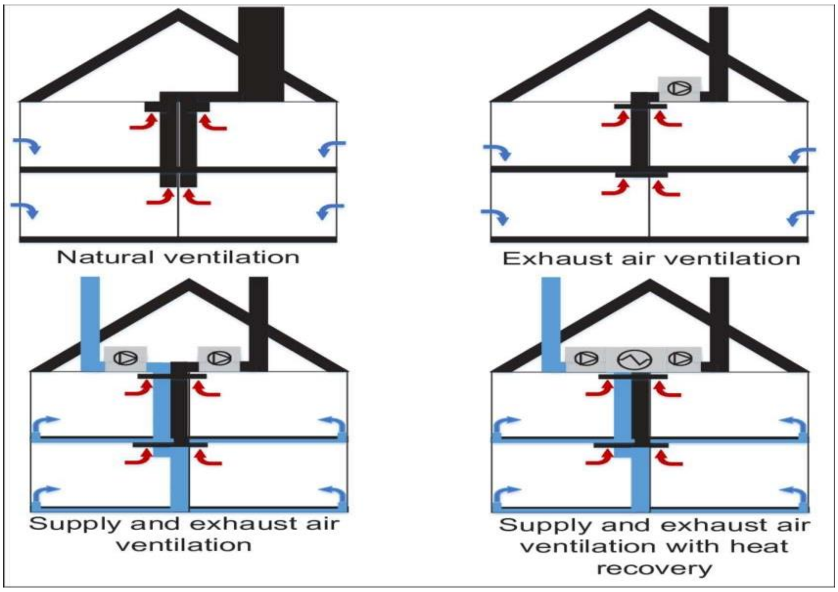
b) Artificial Ventilation:

- ☐ Mechanical ventilation is the one in which some mechanical arrangements are made to increase the rate of air flow.
- ☐ Air movement is produced with the right system of fans, vents, and duct. It is most suitable for large buildings, assembly halls, factories, theatres, etc.

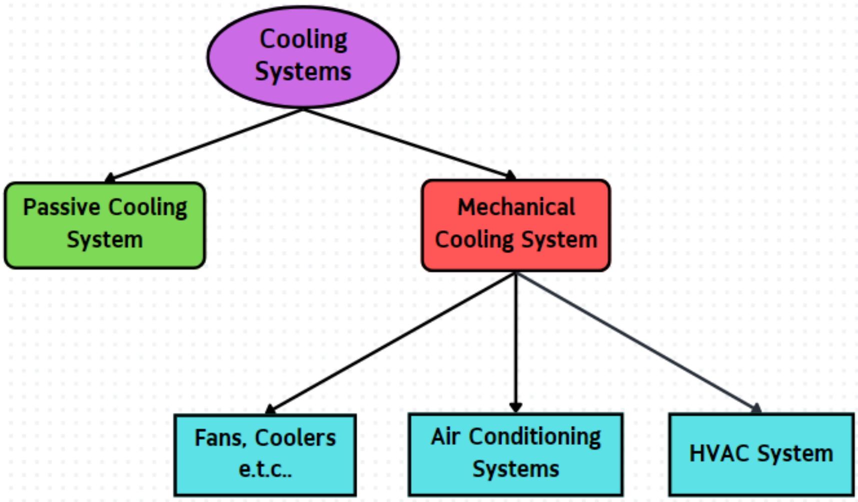
a) **Exhaust System:** This system is based on the creation of a vacuum in the room by exhausting the vitiated inside air by means of propeller type fans.

b) **Supply System:** In this system, fresh air is forced into the room and vitiated air is forced to leave through ventilators.

c) **Exhaust – Supply System:** This is an extension of supply system in which exhaust fans are used for the exit of the vitiated air from the room along with forced fresh air.



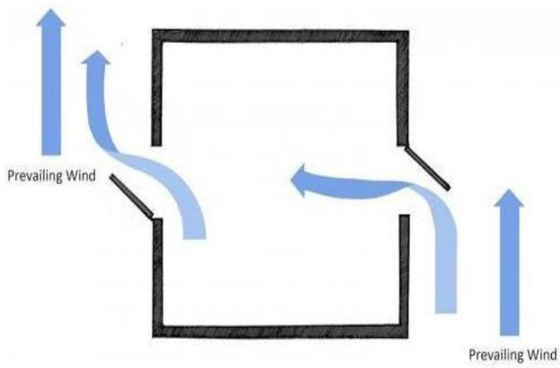
b) COOLING OF BUILDINGS:



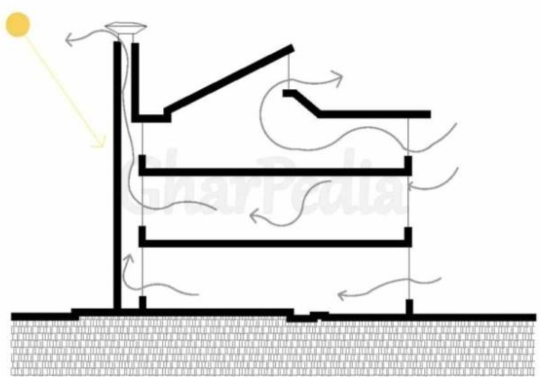
METHODS OF PASSIVE COOLING SYSTEMS:

a) Natural Ventilation:

- **Cross Ventilation:** Utilizing windows, doors, or vents placed on opposite sides of a room or building to allow cooler outdoor air to pass through, displacing warmer indoor air.
- **Stack or Chimney Effect:** Warm air within a building rises and exits through higher openings or vents, drawing in cooler air from lower openings.

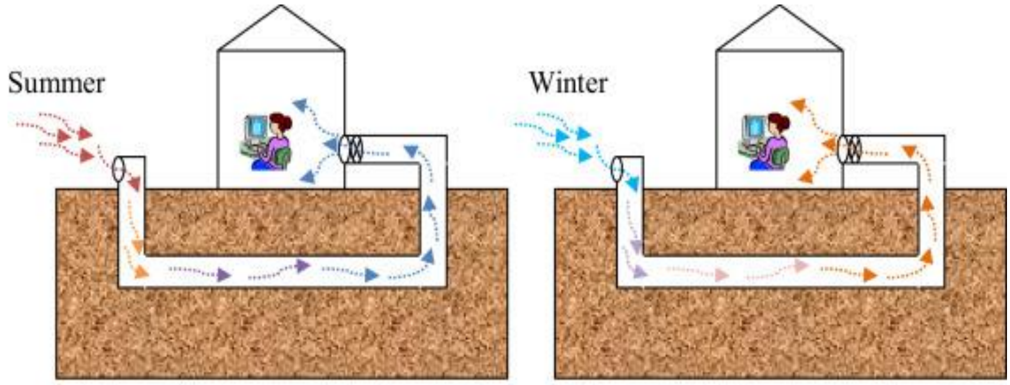


Cross Ventilation


Stack Ventilation

b) Earth Air Tunnels:

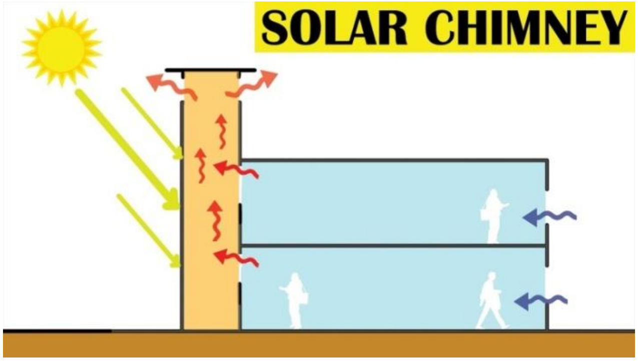
- At a depth of about 4 m below ground, the temperature inside the earth remains nearly constant round the year and is nearly equal to the annual average temperature of the place
- A tunnel in the form of a pipe or otherwise embedded at a depth of about 4 m below the ground will acquire the same temperature as the surrounding earth at its surface.
- Therefore, the ambient air ventilated through this tunnel will get cooled in summer and warmed in winter and this air can be used for cooling in summer and heating in winter



a) Cooling mode b) Heating mode

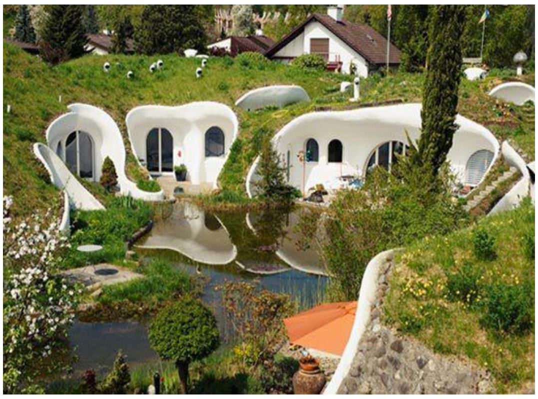
c) Thermal Chimney:

- As sun heats the chimney's surface, the air inside warms up and rises. It creates a suction effect at the base, drawing cooler air from building's interior or from shaded outdoor areas.
- As the warm air exits through the top vent, it helps in pulling and circulating fresh, cooler air throughout the building, thereby enhancing natural ventilation.



d) Earth Berming:

- Earth berming involves building a structure partially or fully underground or mounding earth against its exterior walls.
- This takes advantage of the earth's consistent subterranean temperatures to passively regulate the building's internal temperature.
- In essence, the earth serves as insulation: it keeps the building cool during hot weather and warmer during cold periods, significantly reducing the need for additional heating or cooling and promoting energy efficiency.



e) Evaporative Cooling:

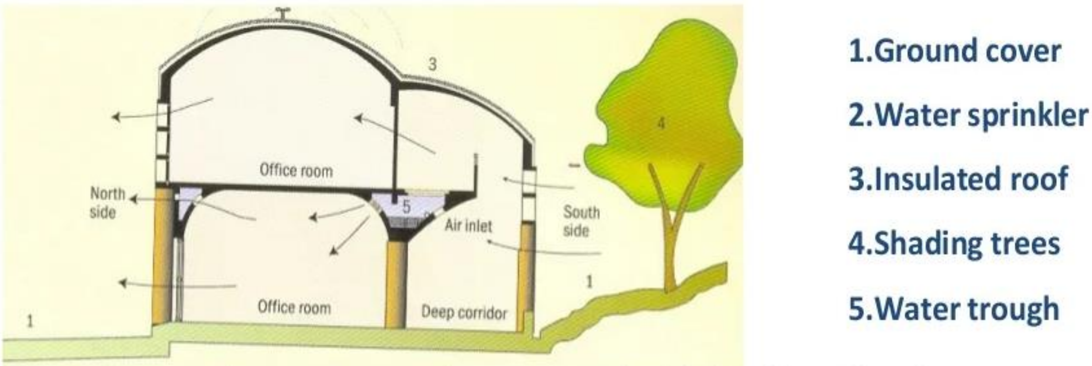
» Evaporative cooling lowers indoor air temperature by evaporating water.

» It is effective in hot and dry climate where the atmospheric humidity is low.

» In evaporative cooling, the sensible heat of air is used to evaporate water, thereby cooling the air, which, in turn, cools the living space of the building.

» Increase in contact between water and air increases the rate of evaporation.

» The presence of a water body such as a pond, lake, and sea near the building or a fountain in a courtyard can provide a cooling effect.



A Typical Section Showing Passive Solar Features Of **Walmi Building, Bhopal**

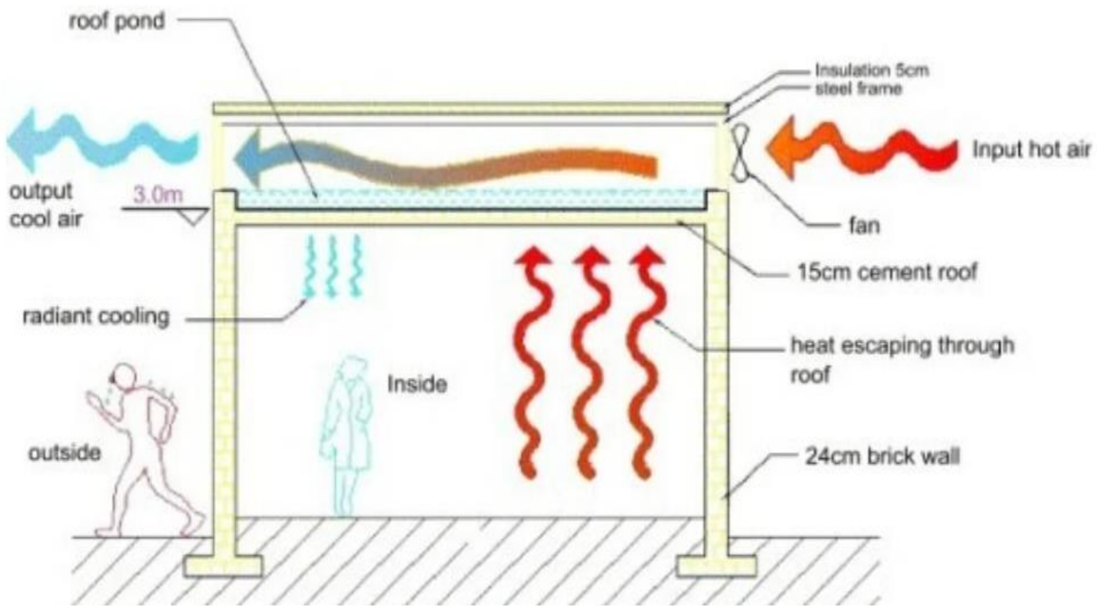
f) Roof Pond System:

» A water body on the roof may provide cooling where during summers it is covered with insulation with a surface finish of low absorptivity.

» During the day time, this minimizes the solar radiation impact on the roof, as the water in the pond holds the heat gain and further increases the time lag.

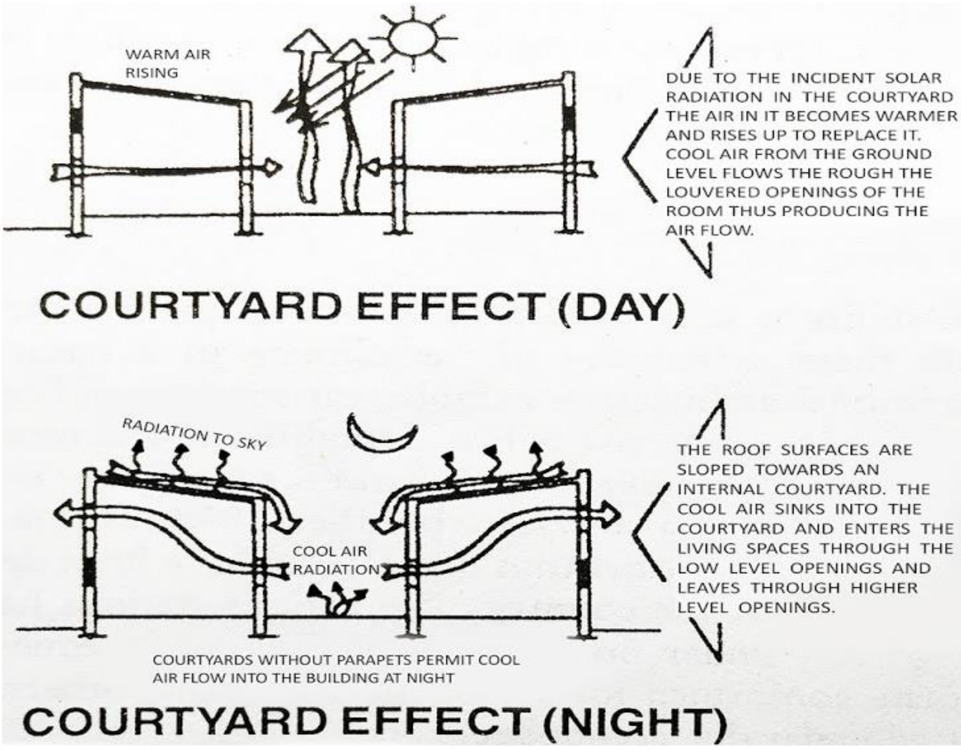
» During the night, insulation is removed and the heat stored in the day time is exchanged with the night sky. In winter, the operation of the movable insulation is reversed to allow heat gain in daytime and reduce heat loss during the night.

» All such provisions shall however be without prejudice to the need of compliance to the requirement of structure safety.



g) Courtyard Effect:

- Due to incident solar radiation in a courtyard, the air gets warmer and rises
- Cool air from the ground level flows through the louvered openings of rooms surrounding a courtyard, thus producing air flow
- At night, the warm roof surface get cooled by **convection and radiation**



Advantages of Passive Cooling Systems:

1. ***Energy Efficiency:*** One of the most significant benefits of passive cooling is that it doesn't require electrical energy, leading to lower energy bills and reduced environmental impact.
2. ***Low Maintenance:*** Since there are fewer moving parts and mechanical systems involved, there's less that can break down, resulting in lower maintenance requirements.

3. ***Sustainability:*** Passive systems usually have a smaller carbon footprint than active systems, making them more environmentally friendly.
4. ***Low Operational Cost:*** Without the need for continuous electricity, the running costs are minimal or get reduced.
5. ***Increased Lifespan:*** Passive systems, due to their simplicity and lack of complex machinery, tend to have longer lifespans than their mechanical counterparts.
6. ***Improved Indoor Air Quality:*** By promoting natural ventilation, passive cooling can enhance indoor air quality by reducing the concentration of indoor pollutants.

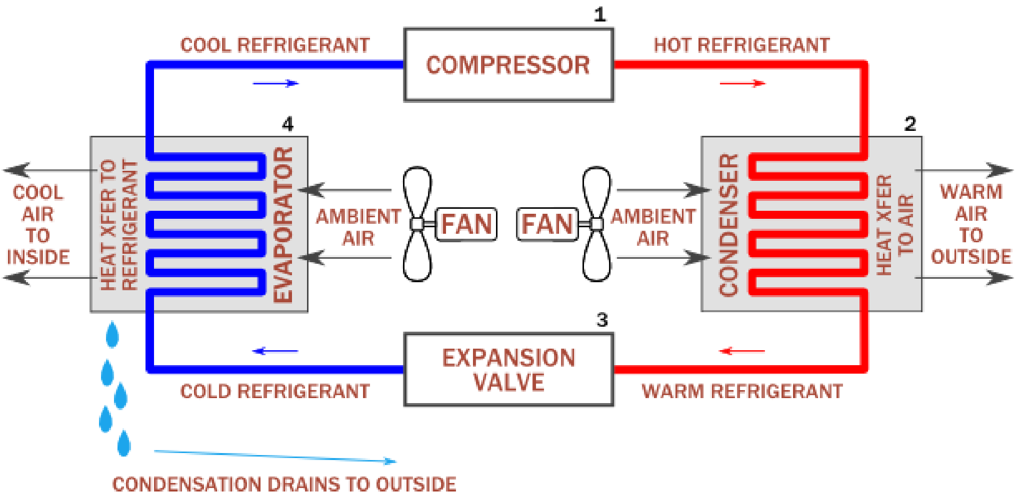
Disadvantages of Passive Cooling Systems:

1. ***Limited Control:*** Passive systems react to the environment rather than being controlled to meet specific desired conditions. This can lead to less precision in maintaining desired indoor temperatures.
2. ***Dependence on Climate:*** The effectiveness of passive cooling strategies can be highly dependent on the local climate. Some methods might be effective in dry climates but less so in humid ones, and vice versa.
3. ***Space Requirements:*** Some passive cooling strategies, like large overhangs or courtyard designs, can require more space or specific architectural designs.
4. ***Initial Costs:*** While operational costs are lower, the initial investment for integrating passive cooling features into a building's design can be higher.
5. ***Not Always Sufficient:*** In extremely hot or humid conditions, passive cooling alone might not provide sufficient cooling, and supplemental active cooling systems might be necessary.
6. ***Potential for Overcooling:*** In transitional seasons or during cool nights, passive cooling techniques (like high thermal mass) may lead to overcooling, making indoor spaces too cold.

METHODS OF ACTIVE OR MECHANICAL COOLING:

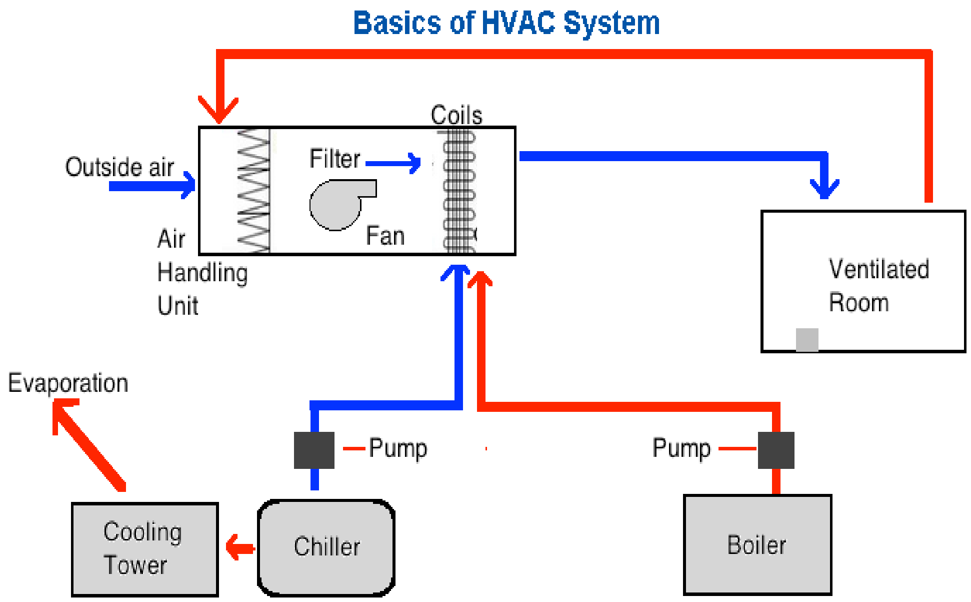
A mechanical cooling system typically refers to systems that use a mechanical process to transfer heat from one location (where it's not wanted) to another (where it's less problematic). The common methods for Mechanical Cooling explained below.

a) Air Conditioning System:



1) ***Refrigerant*:** The air conditioner uses a special fluid called a refrigerant (CFC or HFC), which has the property of easily absorbing and releasing heat.
2) ***Evaporation***: Inside the building, the refrigerant is evaporated in a coil, called the evaporator coil. Refrigerant absorbs heat from the indoor air & gets evaporated in the coil, making the air cooler. A fan blows this cooler air into the room.
3) ***Compression***: The now-gaseous refrigerant, carrying the absorbed heat, is pumped by a compressor. This compression process increases the refrigerant's temperature and pressure.
4) ***Condensation***: The hot, high-pressure refrigerant then flows through another coil outside the building, called the condenser coil. Here, the refrigerant releases the heat it absorbed earlier, and it condenses back into a liquid form. A fan helps blow outside air over the condenser coil to assist in cooling the refrigerant.
5) ***Expansion***: Before refrigerant returns to the evaporator coil, it passes through an expansion valve. This valve reduces pressure of the refrigerant, causing it to cool down.
6) ***Repeat***: The cool refrigerant then flows back into the evaporator coil, and the cycle repeats.

b) HVAC System (Heat Ventilation and Air Conditioning System):



An HVAC system is used to make a room cool, hot, dry, clean, etc. Remember that there are different types of HVAC systems are available and they work with different principles.

AHU (Air Handling Unit)

» Initially room air and outside air enters into the AHU, it gets filtered by the filter then it goes through cooling coil where its temperature got decreased so the room will be cooled.

» But when the cooling coil is not charged and the heating coil is charged condition then the temperature of the Air will be increased so the room will be hot.

» Basically, the cooling coil helps to control the temperature whereas the heating coil helps to maintain or control the humidity.

» After the heating coil a fan that is used to circulate the air. It helps to pull air from the outside to the room inside and circulate the air. The air inside the room again comes to the input of the AHU. Thus the air circulates.

Chiller:

» The main function of the chiller is to produce the cold or Chill water that flows through the cooling coil of the AHU or Air Handling Unit.

» This chilled water continuously flowed through the cooling coil so when the air passes through the cooling coil it got chilled.

» Water-cooled chiller that requires a cooling tower and condenser pump for cooling. Condensor pump helps to circulate the water between the chiller and cooling tower. Cooling tower reduced the temperature at the normal environmental temperature.

» The primary pump helps to transmit water from the chiller to AHU and the secondary pump helps to transmit water from AHU to the chiller.

Heat Pump

» Heat Pump produces the hot water that circulates through the heating coil of the AHU. So when the airflow passes through the heating coil it got hot so that can maintain the humidity or increase the room temperature.

» The primary pump helps to transmit the hot water from the heat pump to AHU and the secondary pump helps to transmit the hot water from AHU to the heat pump.

Advantages of Active Cooling Systems:

1. ***Effective Temperature Control:*** Active cooling systems provide precise control over temperature, ensuring the desired comfort levels in buildings or the optimal operating temperature for devices.
2. ***Quick Response:*** Active cooling systems can rapidly adjust to varying loads and external conditions, offering immediate cooling when needed.
3. ***Scalability:*** These systems can be designed to cater to a wide range of cooling loads, from small electronic components to large buildings.
4. ***Air Quality Control:*** In buildings, active cooling systems, especially when integrated with HVAC systems, can help filter and purify the incoming air, reducing indoor air pollutants.
5. ***Consistency:*** They offer a consistent cooling output regardless of external weather conditions, which is especially important in regions with extreme temperatures.
6. ***Humidity Control:*** In addition to temperature control, many active cooling systems also control humidity, adding to the comfort of building occupants.

Disadvantages of Active Cooling Systems:

1. ***Energy Consumption:*** Active cooling systems can consume significant amounts of energy, leading to higher utility bills and environmental impacts.
2. ***Environmental Concerns:*** Many older active cooling systems use refrigerants that are harmful to the environment, contributing to ozone layer depletion and global warming. While newer systems have begun using more environmentally friendly refrigerants, there's still an environmental impact associated with their use and disposal.
3. ***Maintenance and Cost:*** These systems have various components that require regular maintenance to ensure efficiency and longevity. This leads to additional costs over time.

4. ***Complexity:*** Active cooling systems, especially in large buildings, can be complex, requiring specialized knowledge for installation, operation, and troubleshooting.
5. ***Noise:*** Mechanical components, like fans and compressors, can produce noise, which might be disruptive in certain environments.
6. ***Dependence on Power:*** Since they rely on electricity, active cooling systems can be rendered non-operational during power outages unless backed up by generators.

MODELLING AIR FLOW AND VENTILATION:

☐ Modeling airflow and ventilation is a crucial aspect in various domains, such as building design, environmental engineering, and aerodynamics.

☐ Proper airflow ensures the following

- » Comfort of building occupants
- » Prevents the spread of contaminants
- » Maintains the structural integrity of buildings and other structures.

☐ There are basically two types of ventilation i.e,

a) Natural Ventilation and
b) Mechanical Ventilation.

Methods for Modeling Air Flow:

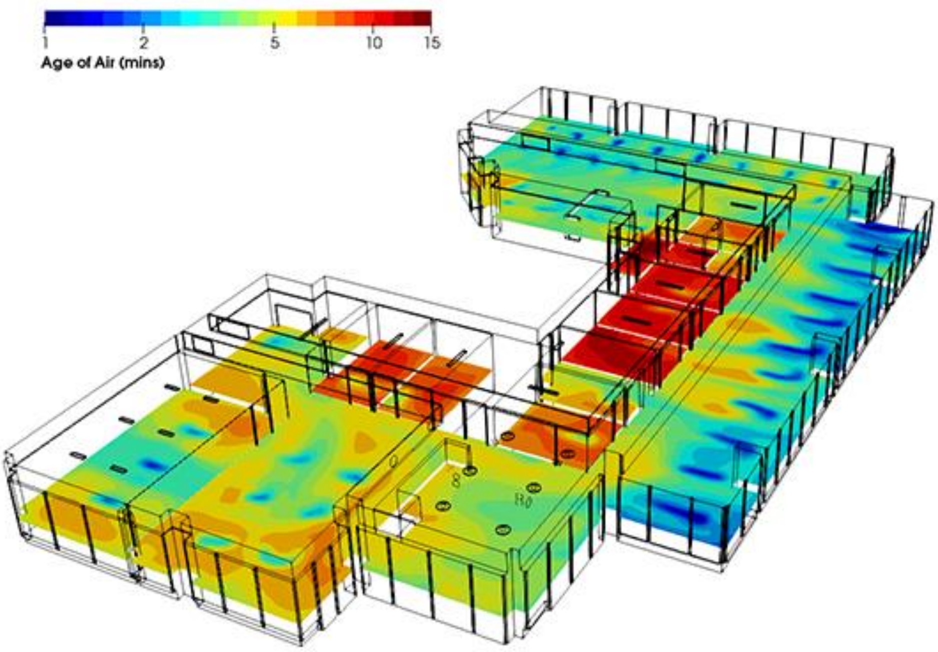
a. ***Computational Fluid Dynamics (CFD):*** A numerical method used to solve the equations governing fluid flow (which includes air). CFD can predict air patterns, pressure, and temperature distribution in a given space. Software like ANSYS Fluent and Autodesk CFD are commonly used for such simulations.
b. ***Multi-Zone Models:*** These are simpler than CFD and divide buildings or rooms into zones. They calculate airflow between these zones based on pressure differentials. CONTAM is well-known software for multi-zone modeling.
c. ***Monodraught Windcatcher System:*** This system uses the wind's direction and speed to ventilate buildings naturally. It's a passive system without mechanical components.

☐ **Measurements and Testing:** Airflow Meters, Tracer Gas Methods, Smoke Tests

☐ **Importance of Good Ventilation:** Indoor Air Quality, Thermal Comfort, Energy Efficiency

☐ **Factors to Consider:**

- » ***Building Envelope:*** This includes walls, roofs, windows, and doors. How leaky or tight a building is can dramatically affect airflow.
- » ***Internal Loads:*** Equipment, lighting, and occupants can generate heat, affecting the internal airflow due to convection.
- » ***Weather Conditions:*** External factors like wind speed, direction, and outdoor temperature can influence the airflow and ventilation rate.



In the above simulation, the age of air in an office space is tracked over time, from one minute (blue) to 15 minutes or more (red), to show where better ventilation is needed.

Analysis of indoor air patterns is emerging as a critical tool for making indoor spaces healthier, during the pandemic and beyond. We use a range of tools, including advanced computational fluid dynamics (CFD) modeling, to assess how air behaves in your space and whether ventilation and comfort are adequate.

LIGHTENING:

Illuminance:

- **Definition**: Illuminance is the amount of light incident on a surface per unit area.
- **Unit**: It is measured in **lux (lx)** in the International System of Units (SI). One lux is equal to one lumen per square meter (lm/m^2). In the imperial system, foot-candles (fc) is used, where 1 foot-candle is equal to one lumen per square foot.
- **Equation**: $E = \frac{\Phi}{A}$
  - Where:
    - E = Illuminance (lux or foot-candles)
    - Φ = Luminous flux (lumens, lm)
    - A = Area of the surface (m^2 or ft^2)

"Illumination" refers to the provision or presence of light in a space, allowing vision and the perception of the environment. In technical terms, it refers to the amount of light (luminous flux) received on a surface per unit area. The unit of measurement for illumination is the "lux" in the metric system.

Importance:

Illumination is a critical factor in various fields:

1. **Architecture & Interior Design**: Ensuring appropriate illumination levels in rooms, halls, and other spaces is crucial for functionality and aesthetics.
2. **Photography**: Proper illumination is essential for capturing images, determining the quality, clarity, and mood of the photo.
3. **Safety**: Adequate illumination is essential in places like roadways, workplaces, and public spaces to ensure safety and prevent accidents.
4. **Visual Comfort**: Proper illumination levels can reduce eye strain and improve overall well-being.

Daylight Factor (DF)

The **Daylight Factor (DF)** is a commonly used metric in building design to quantify the amount of daylight received in an indoor space. It's defined as the ratio of the illuminance at a point inside to the unobstructed horizontal illuminance outside under overcast sky conditions. The reason for using overcast conditions is that they offer a relatively consistent level of illumination and represent the worst-case scenario.

Certainly! Daylighting refers to the practice of placing windows, skylights, other openings, and reflective surfaces to allow sunlight to provide effective internal lighting. The amount of daylight available to an indoor space depends on various factors like the size and orientation of the openings, the reflectivity of surrounding surfaces, and the outdoor light conditions.

Mathematically, the Daylight Factor (DF) is given as:

$$DF(\%) = \left(\frac{E_{in}}{E_{out}}\right) \times 100$$

Where:

- DF = Daylight Factor (expressed as a percentage)
- E_{in} = Illuminance at a point inside (lux)
- E_{out} = Unobstructed horizontal illuminance outside (lux) under overcast conditions.

Components of Daylight Factor:

The Daylight Factor can be broken down into three main components:

Sky Component (SC): This is the direct light that comes from the sky and enters the room through the window without being obstructed or reflected.

$$SC = \left(\frac{E_{sky}}{E_{out}}\right) \times 100$$

Where E_{sky} is the illuminance due to direct sky light.

Externally Reflected Component (ERC): This is the light that is reflected off external objects (like buildings, ground surfaces, etc.) before entering the room.

$$ERC = \left(\frac{E_{external\_reflected}}{E_{out}}\right) \times 100$$

Where $E_{external\_reflected}$ is the illuminance due to light reflected externally.

Internally Reflected Component (IRC): This is the light that enters the room, reflects off internal surfaces (like walls, floors, ceilings, etc.) and contributes to the overall illuminance.

$$IRC = \left(\frac{E_{internal\_reflected}}{E_{out}}\right) \times 100$$

Where $E_{internal\_reflected}$ is the illuminance due to light reflected internally.

The total Daylight Factor is thus the sum of these components:

$$DF = SC + ERC + IRC$$

Importance of Day lighting:

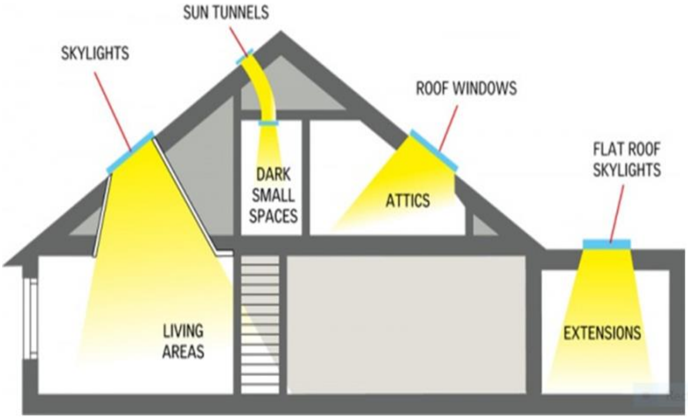
1. ***Energy Savings:*** Proper day lighting design can reduce the need for artificial lighting during the daytime, which can result in significant energy savings.
2. ***Well-being:*** Access to natural light has shown to improve productivity, well-being & health.
3. ***Sustainability:*** Reducing dependence on artificial lighting reduces energy consumption & CO_2 emissions.

DAY LIGHTING AND CONTROLS

DAYLIGHTING STRATEGIES (or) PASSIVE SOLAR LIGHTING:

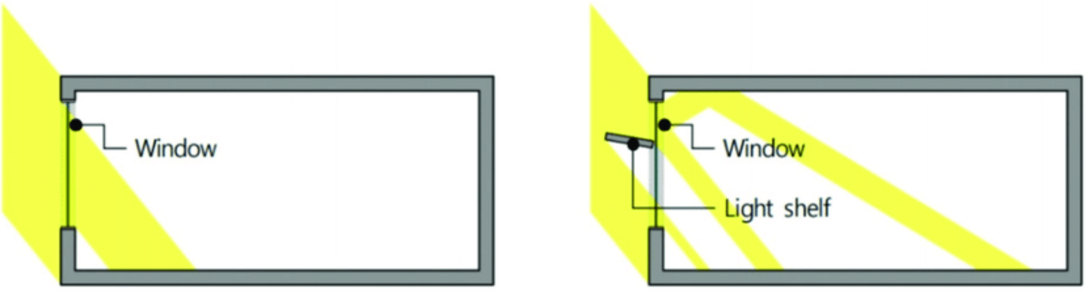
a) Skylights:

- Skylights are the windows which are provided on the roof which admits light into the space, these are often used for daylighting.
- Skylights admit more light per unit area and distribute it more evenly over a space.
- White translucent acrylic is a 'Lambertian Diffuser' meaning transmitted light is perfectly diffused and distributed evenly over affected areas.
- Optimum number of skylights (usually quantified as "effective aperture") varies according to climate, latitude, and the characteristics of the skylight, but is usually 4-8% of floor area.



b) Light shelves:

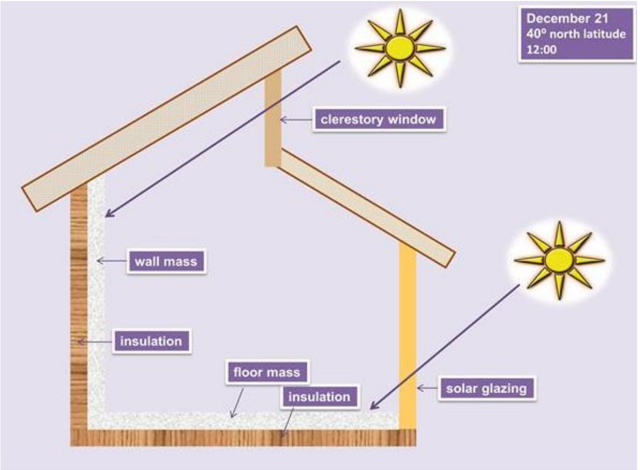
- Light shelves can also be used.
- They are placed so that the sunlight drawn in by the windows is reflected and lights a room from top to bottom.
- These shelves can bring natural light deeper into a room



(a) (b)

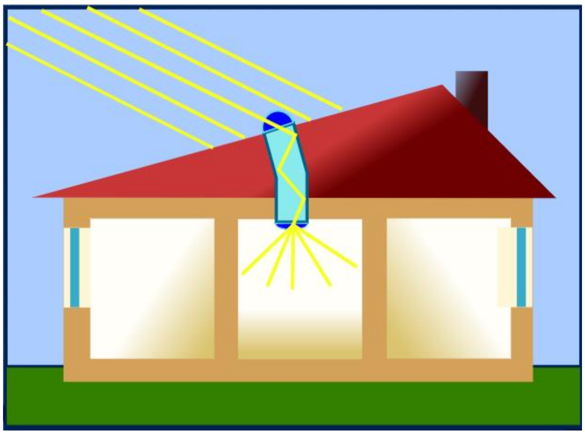
c) Clerestory windows:

- A row of windows located at top of a wall, near the roof. Skylights, when combined with sensors and other lighting elements, can ensure that lighting inside a building stays even.
- Window glass can be double- and triple-paned, efficiency of windows can be increased by
  - » Chemical compounds between panes
  - » Coatings and glazings of windows
- Some window coatings can carry an electric current that can moderate how much light or heat is let in based on weather conditions.



d) Tubular Daylight Devices or Light Tubes:

- These devices capture sunlight from the roof and channel it down through reflective tubes, illuminating interior spaces, including those far from exterior walls.
- These devices enable natural light to be piped into the building indoors from rooftops through sophisticated mirror tubes.



e) Light Wells and Courtyards:

- Recessed outdoor spaces or courtyards can funnel light into adjacent rooms, aiding in lighting interior spaces that might be otherwise deprived of direct sunlight.
- A courtyard is an unenclosed space. Courtyards possess an "outdoor" or exterior character and are not covered by roofs.

Advantages of Passive Solar Lighting:

1. ***Energy Savings:*** Utilizing sunlight can significantly reduce the need for artificial lighting during daylight hours, which lead to substantial energy savings and reduced electricity bills.
2. ***Environmental Benefits:*** Reducing the demand for artificial lighting helps decrease energy consumption, which in turn reduces the emission of greenhouse gases if the source of energy is fossil fuels.
3. ***Improved Daylight Quality***: Natural light often provides better visual clarity and color rendition than many artificial lights. This can make spaces feel more vibrant and natural.
4. ***Health Benefits:*** Exposure to natural light during the day can help regulate the human body's circadian rhythm, leading to better sleep patterns. Natural light has also been associated with increased productivity and reduced eye strain.
5. ***Aesthetically Pleasing:*** Spaces illuminated with natural light often feel more open, spacious, and welcoming.
6. ***Reduced Heat Emission:*** Unlike many artificial lights, sunlight does not produce additional heat, which can be beneficial in reducing cooling demands during certain times of the year.

Disadvantages of Passive Solar Lighting:

1. ***Overheating:*** If not properly managed or designed, passive solar lighting can lead to unwanted heat gain, making spaces uncomfortably warm and increasing the need for air conditioning in the building spaces.
2. ***Glare:*** Sunlight can cause glare, which can be discomforting and reduce the visibility of screens and other surfaces.

3. ***Inconsistent Lighting:*** The amount and intensity of sunlight vary throughout the day and across seasons. This can make it challenging to maintain consistent lighting levels, especially during cloudy days or during winter in higher latitudes.
4. ***Privacy Concerns:*** Large windows or other design elements aimed at maximizing sunlight may sometimes compromise privacy.
5. ***Initial Design and Construction Costs:*** Incorporating passive solar lighting might involve additional costs in design, larger windows, skylights, and other architectural features.
6. ***Maintenance:*** Features like skylights may sometimes be prone to leaks or require periodic cleaning to maintain their effectiveness.

DAYLIGHTING CONTROLS:

It is commonly referred to as "daylight harvesting controls", these are the systems or devices that adjust the level of artificial lighting in response to the amount of natural daylight available. It optimizes lighting levels while minimizing energy consumption. They are…

1. ***Photosensors (Photocells):*** These are light-sensitive devices that measure the amount of available natural light and send signals to the lighting control system to adjust artificial lighting levels. There are two main types:
   » **Ceiling-mounted photosensors:** These measure the light that strikes the floor or work surfaces. They are commonly used in spaces where daylight comes from windows.

   » **Atrium or skylight-mounted photosensors:** These measure the light coming directly from the sky, ideal for top-lighted spaces.

2. Continuous or Stepped Dimming:

» **Continuous Dimming:** This control continuously adjusts the light output in response to changes in daylight levels. It offers a smooth transition & is more pleasing to occupants.

» **Stepped Dimming:** Light levels change in distinct steps, such as reducing to 75%, 50%, or 25% brightness. While less subtle than continuous dimming, it's often more affordable.

3. Scheduling Systems: These controls use time schedules to adjust lighting. For example, if a building is typically unoccupied after 6 PM, the system might automatically dim or turn off the lights. When integrated with daylighting controls, these systems can account for natural light availability during occupied hours.

4. Occupancy or Motion Sensors: While not strictly a daylighting control, when combined with photosensors, occupancy sensors can ensure lights are dimmed or turned off when spaces are unoccupied, saving even more energy.

5. Shading Devices:

» **External Shading**: Structures like overhangs, louvers, pergolas, and brise-soleil can block direct sunlight, particularly when the sun is at a high angle.

» **Internal Blinds or Shades**: These are adjustable window coverings inside the building that can be manually or automatically controlled to filter sunlight.

6. Automated Window Shades: Integrated with daylighting controls, automated shades can adjust to maximize daylight intake without introducing glare or unwanted heat gain. By controlling the amount of daylight entering the space, they work in tandem with lighting systems to maintain desired light levels.

DAYLIGHT ASSESSMENT:

Performing a daylight assessment involves several steps to evaluate and optimize natural light in a building or space. Steps involved are given below:

1) ***Define Objectives:*** Determine the purpose of your daylight assessment.
   - Are you aiming to maximize natural light?
   - Reduce energy costs?
   - Meet specific lighting standards?
2) ***Gather Information:***
   - Collect floor plans, building orientation, and window locations.
   - Note the geographical location and climate data, as sun angles vary by location.
   - Document interior finishes and reflectance values.
3) ***Daylight Metrics:***
   - *Calculate Daylight Factor (DF):* This measures the ratio of natural to artificial light and is crucial for assessing overall daylight availability.
   - *Calculate Spatial Daylight Autonomy (sDA):* It quantifies the % of floor area that receives sufficient daylight for a specified period (e.g., 300 lux for 50% of occupied hrs).
   - *Calculate Annual Sunlight Exposure (ASE):* This metric indicates potential glare and should be minimized.
4) ***Simulation Software:*** Use of the daylight simulation software like Radiance, DIVA, or Honeybee to model daylighting in the space. These tools can help with complex calculations and visualizations.
5) ***Consider Shading and Glazing:*** Evaluate shading devices, blinds, or curtains to control glare and optimize light distribution. Choose appropriate glazing materials based on their light-transmitting properties.
6) ***Design Solutions:***
   - Modify window sizes and positions to increase or decrease natural light as needed.
   - Use light shelves, reflective surfaces, or diffusing materials to distribute light evenly.
   - Implementation of the automated lighting controls that adjust artificial lighting based on available natural light.
7) ***Assessment:***
   - Use simulation results to assess the effectiveness of design changes.
   - Verify if your design meets daylighting standards or building codes (e.g., LEED, WELL Building Standard).
8) ***Iterate:*** If necessary, refine your design based on the assessment results to achieve the desired daylighting goals.
9) ***Documentation:*** Document your findings, calculations, and design choices for reference and future modifications.

ARTIFICIAL LIGHTENING & NEW LIGHT SOURCES:

Requirements of Artificial Lightening:

1. ***Energy Efficiency:*** Lighting systems should use energy-efficient technologies such as LED bulbs to reduce electricity consumption and minimize the building's carbon footprint.
2. ***Daylight Integration:*** Incorporate daylight harvesting systems to maximize natural light and reduce the need for artificial lighting during the day.
3. ***Lighting Controls:*** Implement advanced lighting controls, such as motion sensors, dimmers, and timers, to adjust lighting levels based on occupancy and natural light availability.
4. ***Light Quality:*** Ensure that artificial lighting provides appropriate illumination levels, color rendering, and color temperature to support occupant comfort and productivity.
5. ***Light Pollution Mitigation:*** Design lighting to minimize light spill and glare, preventing light pollution and enhancing the building's ecological sustainability.
6. ***Zoning and Task Lighting:*** Segment spaces into different lighting zones and use task lighting to provide optimal illumination where needed, reducing over-lighting and energy waste.
7. ***Maintenance and Longevity:*** Choose lighting fixtures and systems that are durable, have long lifespans, and are easy to maintain, reducing waste and replacement costs.
8. ***Sustainable Materials:*** Use eco-friendly materials in lighting fixtures and ensure their recyclability or safe disposal at the end of their life cycle.
9. ***Adherence to Standards:*** Comply with local building codes and green building certifications (e.g., LEED, BREEAM) to meet environmental performance and energy efficiency criteria.
10. ***User Education:*** Educate building occupants on the importance of energy-efficient lighting practices and encourage responsible use to minimize energy consumption.

Brief History of Artificial Lighting:

1. Fire: The earliest source of light, including torches, oil lamps, and candles.

2. Gas lighting: In the 1800s, gas lighting became popular. It was brighter than candles but had its limitations. Light is produced by burning a gaseous fuel, such as hydrogen, methane, carbon monoxide, propane, butane, acetylene, ethylene, or natural gas.

3. Incandescent Bulbs:

- ☐ ***Working:*** These work by passing electric current through a thin tungsten filament, which glows and produces light when heated.
- ☐ ***Applications:*** Residential lighting, decorative lighting.
- ☐ ***Advantages:*** Warm light quality, Inexpensive, Dimmable.
- ☐ ***Disadvantages:*** Inefficient (most of the energy is wasted as heat), Short lifespan.

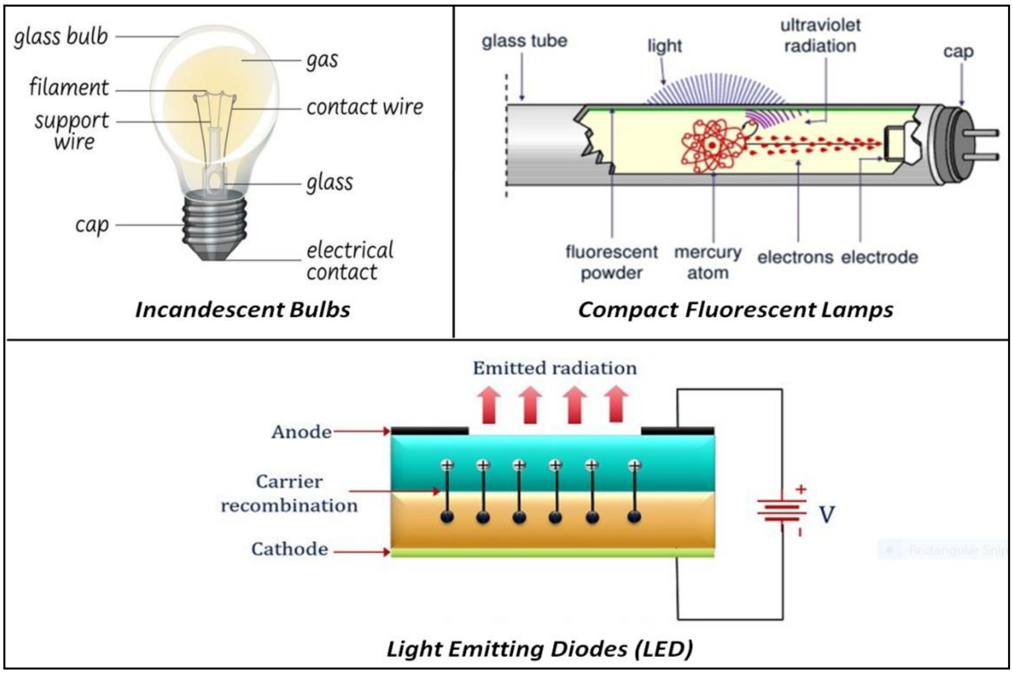
4. Compact Fluorescent Lamps (CFL):

- ☐ ***Working:*** Electricity stimulates a mix of gases, produces ultraviolet light. This ultraviolet light illuminates the phosphorescent coating inside the bulb to produce visible light.
- ☐ ***Applications:*** Residential and commercial interiors.
- ☐ ***Advantages:***
    - Energy-efficient compared to incandescents.
    - Longer lifespan than incandescents.

- ☐ ***Disadvantages:***
  - Contains mercury, a hazardous substance.
  - Can be sensitive to cold temperatures.

5. Light Emitting Diodes (LED):

- ☐ ***Working:*** Electrons move through a semiconductor material, releasing energy in the form of photons (light).
- ☐ ***Applications:*** Residential lighting, commercial spaces, indicators, traffic lights e.t.c...
- ☐ ***Advantages:***
  - Highly energy-efficient & Long lifespan.
  - Dimmable and available in various color temperatures.
- ☐ ***Disadvantages:***
  - Higher initial cost.
  - Heat dissipation can be an issue in poorly designed units.



Incandescent Bulbs

Compact Fluorescent Lamps

Light Emitting Diodes (LED)

6. OLED (Organic Light-Emitting Diode) Lighting:

- ☐ ***Description:*** OLEDs consist of organic materials that emit light when an electric current is applied. They produce diffused, uniform light and can be made in flexible, thin, and lightweight panels.
- ☐ ***Advantages:*** Thin and flexible form factor, excellent color rendering, and a natural-looking light source.
- ☐ ***Disadvanatges:*** Cost, Water sensitivity, Limited Brightness.
- ☐ ***Applications:*** Used in displays, lighting panels, and specialty lighting designs.

7. Tunable White Lights:

- ☐ ***Description:*** Tunable white lights are lighting systems that allow users to adjust the color temperature of a light source. This is achieved primarily through LED technology. By adjusting the relative outputs of 'warm' and 'cool' LEDs in a fixture, one can achieve a range of white color temperatures.

- ☐ ***Advantages:*** Customizability, Aesthetic, Energy Efficiency & Improved Visual Comfort
- ☐ ***Disadvantages:*** Complexity of Installation and Control, Cost, Durability and Reliability Concerns, Potential for misuse
- ☐ ***Applications:*** Healthcare, Offices, Educational Institutions, Residential

8. Smart Light Bulbs:

- ☐ ***Description:*** Smart light bulbs are lighting devices that can be controlled remotely, usually via smartphone apps, voice commands, or home automation systems. They often utilize LED technology and come with a variety of features such as color temperature tuning, color changing, dimming, and more.
- ☐ ***Advantages:*** Remote Control, Energy Efficiency, Customizable, Scheduling & Automation, Connection with other devices.
- ☐ ***Disadvantages:*** Cost, Compatibility Issues, Security Concerns, Setting & operating complexity, Reliability on Wi-Fi

WATER CONSERVATION:

Water conservation is the practice of using water efficiently to reduce unnecessary water usage. Water conservation in the context of taps, toilets, and urinals can be achieved through various methods and novel systems.

1. Taps (Faucets):

- » *Aerators:* These are devices that can be fixed at the mouth of taps to reduce the flow of water by mixing air with the water stream. This results in a bubbly stream that uses less water but is equally effective.
- » *Sensor-based taps:* These are automatic taps that release water only when a hand is detected underneath. It ensures that water isn’t wasted when not in use.
- » *Low-flow fixtures:* These taps are designed to release water at a reduced rate compared to regular taps. They maintain functionality while using less water. It is achieved by incorporating internal mechanisms, such as flow restrictors or aerators, which limit the water flow rate.
- » *Regular Maintenance:* Taps can become leaky over time. Regular maintenance and replacement of washers can prevent leaks and save water.

2. Toilets:

- » *Dual flush toilets:* These toilets offer two flush options – a half flush for liquid waste and a full flush for solid waste. This can save a significant amount of water over time.
- » *Low-flow toilets:* Traditional toilets can use up to 6 gallons per flush, whereas low-flow models use 1.6 gallons or less. It can be achieved by incorporating aerators & restrictors.
- » *Composting or Biofiltration toilets:* These are waterless systems that treat human waste through a biological process. They're especially useful in areas with water scarcity.

- *Regular Maintenance:* Like taps, toilets can also leak. Ensuring the flapper and fill valve are in good condition can prevent unnecessary water wastage.

3. Urinals:

- *Waterless urinals:* These urinals use no water. Instead, they utilize a trap filled with a liquid sealant that allows urine to pass through into the drain while preventing sewer gases from coming back up.
- *High-Efficiency Urinals:* Install high-efficiency urinals that use less water per flush compared to conventional models.
- *Sensor-based flush systems:* Urinals can be equipped with sensors that detect usage and flush accordingly, ensuring that they use water only when necessary.

4. Novel Systems for Water Conservation:

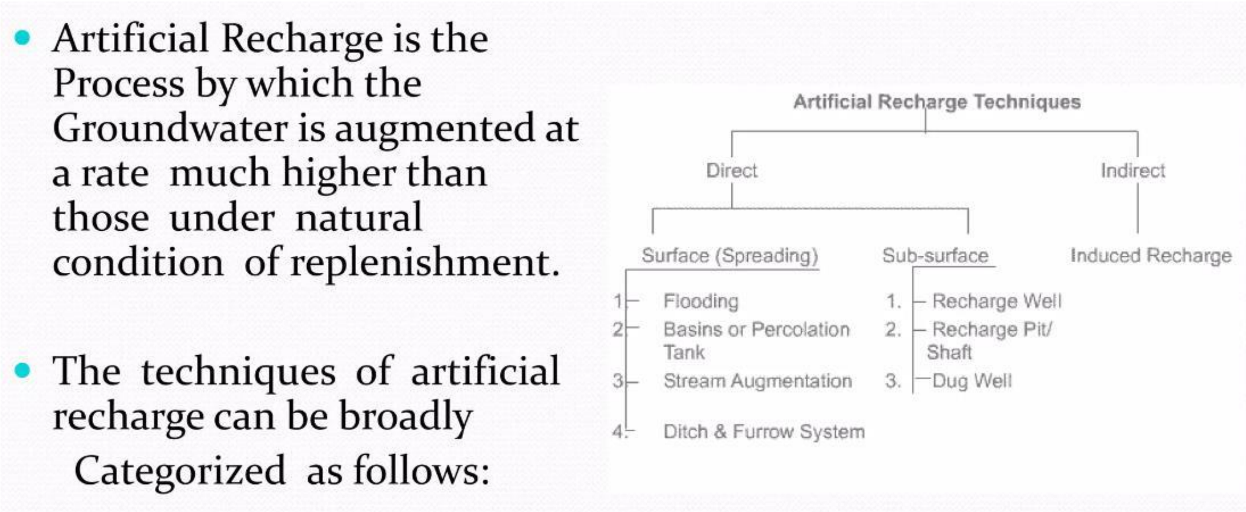
- *Greywater systems:* These systems capture and treat water from sinks, bathtubs, and washing machines for reuse in toilet flushing or garden irrigation.
- *Smart home water monitors:* These devices monitor your household's water usage in real-time, helping you identify and fix leaks and understand where you're using the most water.
- *Soil moisture sensors:* For those who have gardens, these sensors can help ensure that plants are only watered when necessary.
- *Rainwater harvesting:* It's a method by which rainwater is collected and stored, typically from rooftops, and can be used for various non-drinking purposes.
  - Two broad approaches to rainwater harvesting are
    1) Storing rainwater for direct use / Roof Top Rainwater Harvesting ***(Direct Method)***
    2) Recharging groundwater aquifers ***(Indirect Method)***

RAINWATER HARVESTING:

1) ROOF TOP RAINWATER HARVESTING: -------(*Refer UNIT-II*)------

2) RECHARGING GROUNDWATER AQUIFERS:

It involves techniques used to transfer surface water into the ground to restore groundwater levels. Artificial recharge is typically used in areas where there is a decline in the underground water levels due to excessive pumping of groundwater.



1. Surface Spreading Techniques:

- ☐ *Recharge Basins and Ponds:* These are shallow basins constructed to hold water, allowing it to percolate into the ground. They're often interconnected to manage the inflow and outflow of water efficiently.
- ☐ *Flood Spreading:* Here, floodwaters are spread over large areas, such as fields, enabling them to percolate down and recharge aquifers.
- ☐ *Check Dams and Nala (Stream) Plugs:* Structures are built across small streams to slow the flow of water, causing it to pond & allowing more time for it to seep into the ground.
- ☐ *Ditch and Furrow System:* Parallel ditches or furrows allow water to be spread over a large area. The water then percolates into the ground, recharging the underlying aquifers.

2. Sub-Surface:

- ☐ *Recharge Wells:* Directly transferring water from the surface into deep aquifers, bypassing less permeable layers that might be present near the surface.
- ☐ *Shaft Technique:* These are large diameter wells (1-3 m) which reach down to the water table. They're filled with coarse aggregates to prevent collapsing and are useful in areas with thick unsaturated zones.
- ☐ *Dug Well Recharge:* Existing or specially dug wells are used to guide surface water into the ground.

3. Induced Recharge: When a well or borewell is pumped near a source of surface water, it can induce the flow of surface water into the well, thereby recharging the aquifer. This method is especially useful when the quality of surface water is better than groundwater.

UTILIZATION OF RAINWATER:

- » ***Domestic:*** For household tasks like toilet flushing, laundry, or even drinking when properly treated.
- » ***Agricultural:*** To water plants, gardens, or fields.
- » ***Recharge:*** To refill underground water sources.
- » ***Industrial:*** In factories or businesses for certain processes.