Ports and Harbours:

Serve as interface between water and land transportation infrastructure

Harbour:

A ‘harbour’ or ‘haven’ is a protected water area where ships may shelter from weather

Harbours can be ‘natural’ or ‘man-made’.

A ‘man-made harbour’ will have sea-walls or breakwaters and may require dredging

A ‘natural harbour’ is surrounded on most sides by land

‘Tidal harbour’ is a type of harbour that can only be entered or exited at certain tidal levels

Examples of natural harbours:

- Durban harbour, South Africa
- Visakhapatnam Inner harbour, India

Examples of man-made harbours:

- Rotterdam, The Netherlands
- Tuticorin, India
- The Visakhapatnam Outer Harbour

Port:

‘Port’ is a facility for receiving and/or for transferring cargo.

The best ports have deep waters and protection from winds and waves.

Ports consist of quays, wharfs, jetties, piers and slipways.

Ports which handle international cargo also have “customs” facility

The pre-requisite for a Port is a harbour with water of sufficient depth to receive ships.

Ports often have cargo-handling equipment such as cranes and forklifts for use in loading and unloading of cargo from ships.

Access to inter-modal transportation such as trains or trucks are critical to ports so that passengers and cargo can also move further inland beyond the port-area. Besides they have storage facilities such as open-stacking area, transit-sheds, ware-houses etc.

Port types:

- **Sea Port:**
  Is a port having facilities to handle ocean-going vessels. It is further classified as ‘cruise-ports’ and ‘cargo-ports’
• **River port:**
  Is a port handling river traffic, such as barges and other shallow-draft vessels

• **Fishing Port:**
  Is a type of port facility particularly suitable for landing and distributing fish

• **Port of call:**
  It is an intermediate port for a ship on its sailing itinerary. At these ports, a cargo ship may take supplies of fuel as well as loading and unloading of cargo. But for a cruise ship, it is the premier stop where cruise ships take on passengers to enjoy their vacation.

  **Development of Ports:**

• **Indian Scenario:**
  - Coast line: 7600 km
  - Major Ports: 12
  - East coast
  - West coast
  - Notified Minor Intermediate Ports: 187
  - Total cargo throughput: 530 million tonne (2008-09): Vizag port 62 mt
  - Share of major ports: 80%
  - Traffic projections 2011-12: 1 billion tonne
  - Minor ports are expected to contribute significantly

• **Global Scenario:** (year 2006)
  - Rotterdam port (The Netherlands): 378 mt
  - Singapore Port: 448 mt
  - Shanghai port (China): 537 mt

**Port Infrastructure:**

- Breakwaters
- Harbour basin
- Channels
- Turning circle
- Berthing structures
- Land structures
- Buildings (offices, work shops canteens, rest shelters, railway cabins, electrical sub stations, fire stations etc.)
- Stacking areas
  1. Containers
  2. Bulk cargo
- Railway yards
- Road net work
  1. Roads
  2. Bridges
  3. culverts
- Sand bypassing system for maintenance dredging
- Handling equipment
  1. Cranes
  2. Floating craft
  3. Motor vehicles
  4. Sub-station equipment
  5. Fire vehicles
  6. Fire-fighting equipment including fire monitors
  7. Dust suppression equipment
8. Reclaimers and stackers for bulk cargo
9. Conveyors and connecting equipment

Breakwaters:

- **What is a Breakwater/Function of a breakwater:**
  A protective barrier constructed to enclose harbours, and to keep the harbour waters undisturbed by the effect of heavy and strong seas are called breakwaters. Such a construction makes it possible to use the area thus enclosed as a safe anchorage for ships and to facilitate loading/unloading of cargo in comparatively calm waters.

- **Types of break waters:**
  - **Rubble mound breakwaters:**
    The structure is relatively porous, and absorbs therefore a greater part of wave energy. The structure is flexible, not sensitive for uneven settlement. It remains functional even when heavily damaged.

  Especially in deep waters, rubble mound breakwaters require vast quantities of material.

  - **Monolithic breakwaters (vertical wall breakwaters):**
    A massive structure, and may consist of concrete caissons, cellular sheet piling, stacked block walls etc. Wave energy is not absorbed but reflected.

    The structure is sensitive to uneven settlement, damage leads often to complete destruction and loss of function.

  - **Composite breakwaters:**
    Consist of both rubble mound and a monolithic structure in one cross-section.

  - **Floating breakwaters:**
    Can be either rigid or flexible. This type is cheap, quickly fabricated and well suited for temporary protection.

    Wave dampening characteristics are rather poor.

  - **Hydraulic and pneumatic breakwaters:**
    These dampen the wave action by discharging air or fluid from a submerged porous pipe line.

    This system is very energy intensive and is feasible for temporary protection.

- **Choice of type of breakwater:**
  - Availability of materials for construction of breakwater
  - Bearing capacity of the soil supporting the breakwater and its grain size distribution (very important in the case of vertical wall type breakwater to examine the possibility of liquefaction of the soil under constant wave attack)
  - Availability of construction equipment
  - Optimum cost

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**Design considerations:**
- Mean high water spring tide
- Storm surge (the rise above normal water level on the open coast due to the action of wind stress on the water surface)
- Wave-set up (superelevation of water surface over normal surge elevation due to onshore mass transport of water by wave action alone)
- Design wave height and predominant wave direction
- Overtopping/non-overtopping section

**Harbour basin:**

- **Depth depends on the draught of the maximum size of vessel to be handled**
- **Area and size to depend upon:**
  - The berthing facilities required inside the harbour including future expansion
  - Vessel stopping distance (7 Times the length of vessel)
  - Turning circle

**Harbour entrance:**

- **Width:**
  This is the minimum required clear distance between the breakwaters for the ship to enter or leave the harbour basin safely, without hitting the breakwater. This gap should also take care of the effects of cross current that tries to drift the ship, besides the extra with required for bank suction.

- **Depth:**
  Equal to the depth of the approach channel

**Approach channel:**

- **Depth:**
  Shall include:
  - Draught
  - Wave response
  - Squat
  - Trim
  - Sedimentation allowance
  - Sounding errors
  - Dredging tolerance
  - Keel clearance

- **Width:**
  A ship going through the water does not move along a completely straight line. The ship has 6 degrees of freedom (Roll, pitch, heave, yaw, sway and surge). Consequently a ship in its movement needs more space than its own width. This is called the “sweep-path”. For this sweep-path we can take 1.8 B if there is no cross-current to be taken into consideration. If there is cross current the ship must steer a compensating course, causing the ship to move through water more or less “crab-wise”, thus widening the sweep path to a maximum of approximately 3.3 B. Besides provision is also to be made for” bank suction”

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Length:
Approach channels must be straight. A length of 10 times the L.O.A. of the design vessel can be considered as an acceptable measure.

Turning circle or swinging area:
- **Diameter:**
  Normally to be 2 times the L.O.A. of the maximum size vessel calling on the port

- **Dredged depth:**
  This shall be equal to the depth at entrance minus (wave response + squat)

Berthing structures:
Berthing structures inside a harbour are structures constructed for mooring of vessels to enable handle cargo or passengers or a combination of both. These are also called ‘docking platforms’ and include wharfs, quay walls and piers.

- **Wharf/quay wall:** A dock or a quay is a dock which parallels the shore. A bulk-head or quay wall, while similar to a wharf, is backed up by ground.

- **Pier/jetty:** A pier or a jetty is a dock which projects into water. As contrasted to a wharf which can be used for docking on one side only, a pier may be used on both sides.

Factors governing the selection of the type of the berthing structure:
- Type of cargo to be handled
- Permanent or temporary installation
- Size of ships using the platform
- Soil conditions
- Ship response
- Economical type of construction

Design considerations in respect of berthing structures:
- Elevation of the berth as determined by the high water spring tide
- Loading conditions:
  - Vertical live loads due to:
    - Cargo storage
    - Moving loads of cranes, trucks, rail road wagons and other handling equipment
  - Horizontal loads:
    - Impact of ships striking the berth (berthing impact)
    - Wind force acting on the exposed ship (bollard pull)
    - Horizontal wind and sway forces from traveling cranes etc.
    - Earth pressure due to back fill
    - Earth quake loads
    - Current and wave forces

Different configurations (shapes/types) of Berthing Structures:
- Monoliths sunk into the ground to required depth (masonry/concrete)
  - Quay walls
- Free standing caissons placed on dredged ground over filter (outer harbours)
  - pre-cast and towed and sunk and at the required location

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- Concrete cribs at intervals placed on dredged ground over filter and connected with beams and slabs (piers for both side berthing)
  - pre-cast and towed and sunk and at the required location

- Piled platforms
  - Pre-cast
  - Bored cast-in-situ
- Relieving platforms on piles (vertical/raker)
- Piled platforms with rock bund behind to retain back fill
- Diaphragm wall type of constructions
  - Retaining diaphragms
  - Anchor diaphragms

- Types of Fenders:
  - Fender pile systems: Employ piles driven into the sea bed. Berthing energy is absorbed mainly by bending of the piles.
    - Wooden fenders for small jetties
    - Bamboo fenders (in the early years)
    - Tyre fenders (for small crafts)
    - Rubber fenders: (most usual)
      - Hollow cylindrical (tubular): Convenient and economical
      - Solid square
      - Arch (V type)
      - "M" type
      - Pneumatic: Pressurized air-tight devices
      - Air block
      - Axially loaded (end loaded)
      - Large cylindrical fenders (Jumbo)
  - Gravity type fenders:
    These fenders are designed to transform the kinetic energy of the moving ship into potential energy by raising a weight.
    E.g. a large concrete block suspended below the quay deck by two pairs of cables

- Torque fendering systems:

- Fender selection:
  - Energy absorption requirements
  - Reaction force shall be kept as low as possible
  - Reaction/Deflection ratio to be as low as possible
  - Ship hull pressure should be within limits so that no permanent damage is caused to the ship (generally not to exceed 40 t/sq.m)
  - Tidal range: Fender must be suitable for the smallest and largest ships in loaded or ballast conditions during low water and high water
  - Low capital costs
  - Low maintenance costs
  - Fenders which have Energy-Reaction curves linear, are considered better as they offer more or less proportionate reactions with varying sizes of vessels
    - Hollow cylindrical fenders for smaller size vessels
    - Large fixed cylindrical fenders (Jumbo fenders)/ Pneumatic fenders for large vessels

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Waves

● Generation

Water covers 71% of the earth, and thus a large part of the Sun’s radiant energy not reflected back into space is absorbed by the water of the oceans, which in turn, warms the air above the oceans and forms air currents caused by difference in air temperature. These air currents blow across the water, returning some energy to the water by generating “wind waves”. These waves then travel across the oceans until they reach the land where their remaining energy is expended on the shore

Wind waves at a site dependent on

○ Fetch:
The distance the wind blows over in the generating area

○ Wind speed
○ Duration
○ Water depth

● Range
Waves up to 30m height can occur in deep water

● Characteristics:
○ Predominant wave direction
○ Wave Height (H)
○ Wave Length (L)
○ Wave Celerity (velocity) (C)
○ Wave Period (T):
Example: 5 to 9 seconds for Visakhapatnam

○ Relationships
• C=L/T
• Co (deep water)=gT/2 =1.56 m/s
Lo (deep water) =gT/2 =1.56T² m

Eg; refr notes(21/6/11)

● Propagation
○ Decay: Reduction in wave length and height with decrease in water depth (shoaling)
○ Decay distance: the distance wave travels after leaving the generating area
○ Deep water wave: When d/L is greater than 1/2
○ Transitional water wave: When d/L is between 1/2 and 1/25
○ Shallow water wave: When d/L is less than 1/25

Where ‘d’ is the water depth and ‘L’ is the wave length

○ “Seas”: Winds of local storm blowing towards the shore result in waves reaching the shore in the same forming which they are generated. The waves are steep and wave length between 10 to 20 times the wave height
○ “Swell”: Wave generated by distant storm travel through hundreds of miles of calm wind areas before reaching the shore. Waves decay—short and steep waves are transformed into relatively long and low waves which reach the shore. Have wave lengths from 30 to more than 500 times the wave height(thes wil have long wave lengths)
**Reflection:** That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier or other reflecting surface.

**Refraction:** The process by which the direction of a wave moving in shallow water at an angle to the contours is changed: the part of the wave advancing in shallow water moves more slowly than that part still advancing in deep water, causing the wave crest to bend.

**Diffraction:** When a part of a train of waves is interrupted by a barrier, such as an edge of a breakwater, the effect of diffraction is manifested by propagation of waves into sheltered the region within the barrier’s geometric shadow.

- **Wave observation**
  - **Ship observation**
  - **Wave recorders**

- **Wave prediction:**
  Wave prediction is called “hind-casting” when based on past meteorological conditions and “forecasting” when based on predicted conditions. Same procedure is used for hind-casting and forecasting, the only difference is the source of meteorological data.

- **Wave hind casting**
  The use of synoptic wind charts to calculate characteristics of waves that probably occurred some past time.

  **Synoptic chart:** chart showing the distribution of meteorological conditions over a given area at a given time.

- **Wave forecasting**
  The theoretical determination of future wave characteristics, usually from observed or predicted meteorological phenomena.

- **Nowcasting:** The forecasting within next six hours or on daily basis is often referred to as nowcasting.

- **Wave breaking:**
  Waves break when the ratio of water depth to wave height reaches certain limit.

- **Reflected waves (standing wave/clapotis)**
  If a wave form merely moves up and down at a fixed position, it is called a “complete standing wave” or a “clapotis”

- **Design wave height:**
  - Hs (Significant Wave Height)
  - H10
  - H5
  - H1 (H1 is the highest wave)

- **Permissible waves inside harbor**
  - Bearing on size of vessel
  - Ship motions

*Heaving, surging, swaying, rolling, pitching, yawing*

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- **Damage to fenders**
- **Damage to berthing structures**

**Tides**

- **Phenomenon of tides:**
  Tides are created by the gravitational force of Moon, and to a lesser extent the Sun. These forces of attraction, and that the fact Sun, Moon and the earth are always in motion relative to each other, cause waters of the ocean set in motion

There are normally two tides per day, but some locations have only one per day.

Semi diurnal, diurnal and mixed tides (Seetharaman)

Tides constantly change the level at which water attack the beach.

**Tide terms:**

- **Height of tide**
- **Spring tide**
  That occurs at or near the time of new or full moon and which rises highest and falls lowest

- **Neap tide**
  That occurs when the Sun and Moon are working against each other (near the time of quadrature of Moon with the Sun) Neap tidal range usually 10 to 30 percent less than mean tidal range.

- **Tidal range:**
  Changes predominantly with geographic location; 1.8 m at Visakhapatnam, and about 11 m in Bhavanagar

- **High water, low water, lowest low water, highest high water**
- **Mean sea level:**
  Average height of sea water surface, for all stages of tides over 19 year period, is usually determined from hourly height readings.

- **Chart datum:**
  The plane or level to which soundings (or elevations) or tide heights are referenced (usually low water datum). To provide safety for navigation, some level lower than mean sea level is generally selected for hydrographic charts, such mean low water.

- **Tide tables:** by Survey of India with tide predictions
- **Effects of tide:**
  Tidal currents, tidal bore, density currents

**Currents**

**Types of Currents:**

1. **Tidal currents:**
   - Flood/Ebb
   - Coastal (offshore in deeper water and parallel to shore line)

These are significant at entrance to harbours

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2. Wind driven currents (surface currents):
3. Wave induced currents:
   Long shore (littoral): in the breaker zone, parallel to the shore line
   Coastal
4. Density currents:
   Temperature
   Salinity

Current measurements:
- Moored current meters
- Hydrographic survey
- Hydrodynamic model to be considered as computer generated forecast for guidance

Navigation/Navigability:

Navigation:

Navigation is the act of conducting ships or,
Finding the position and determining the course.

Types of Navigation:
- Ocean navigation
- Coastal navigation
- Port/River navigation

Navigability:

Conditions for safe passage of ships
The availability of facilities favourable for safe navigation

Requirements for Navigability:

1. Dredging.
2. Aids to Navigation (Navigational aids)

Risks in Navigation:

- Colliding with other vessels
- Grounding (due to sand bars, ship wrecks, rocky out crops)

Aids to Navigation (ATONS):

Purpose: To guide the mariner and his ship during the full path of its movement by installing proper signals, especially,
- To locate ports.
- To avoid dangerous zones like hidden rocky outcrops and sand bars,
- To follow proper harbor approaches

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Aids in these respects have to be provided particularly at night times or when long range visibility becomes poor due to fog or cloudy weather conditions

**Aids to Navigation:**

Fixed signals:
- Light houses
- Floating signals:
  - Buoys
  - Day beacons
  - Fog signals (bells)
  - Lights and sight ships

**Inland navigation:**

**Introduction: (Historical development)**

In the past, rivers, estuaries and coastal waters in most countries were the principal means of conveyance. The ships that plied upon these water-ways were comparatively small and did not require much depth for navigation; their dimensions were more or less adapted to the natural conditions of the waterways.

Also, the dimensions of ocean going vessels and cargo volumes moving through ocean going vessels were limited during these times.

As time passed, due to international competition, ocean vessels increased in tonnage, and consequently, the inland vessels, which had to transport these products to hinterland destinations also needed enlargement in size... But as the enlargement of inland vessels is still limited by the natural properties of the rivers and waterways, a gap developed between the ever enlarging ocean vessels and the boats which plied upon the inland waterways.

Then, with the improvements in the sea port trade, there were simultaneous developments in the road and rail transport modes, resulting in integrated transport systems, enabling quick dispatch of cargo to the destinations.

The changed scenario resulted in lesser importance for the inland navigation systems, despite the fact that the inland navigation had several advantages.

Other impediments include:
- Construction of dams and other hydraulic works
- Priority of use for irrigation

**Uses:**
- Inland shipping
- Pleasure cruising
- Towpath walking
- Recreational uses
Types of cargo moved:

- Coal (thermal coal for thermal plants and coaking coal for steel plants and imported from US and Ausis)
- Petroleum
- Containers
- Farm products
- Aggregates used for construction
- Metal ores, fertilizers and manufactured products

Advantages:

- Economical
- Reliable and efficient
- Fuel efficient (Savings in fuel consumption)
- Environmentally advantageous (Reduced greenhouse gas emissions)
- Reduced traffic congestion
- Fewer accidents
- Less noise and disruption in cities and towns

Vessels:

“Tow boats” push barges lashed together to from a “tow”. A tow may consist of 4 or 6 barges on smaller water ways, up to even 40 barges in mighty rivers.

Inland Water Transport in India:

Inland Water Transport Authority of India (IWT):

India has extensive network of rivers, lakes and canals, which, if developed for shipping and navigation, can provide an efficient network of inland transportation.

An optimal mix of road, rail and inland water transport will provide an efficient infrastructure with mobility, flexibility and cost effectiveness.

India has navigable waterways aggregating to about 14500 km., of which 5200 km. of major rivers, 485 km. of canals are suitable for operation of mechanized crafts.

Most of the waterways suffer from navigational hazards like shallow waters, narrow width of channels during dry weather, siltation, bank erosion, absence of infrastructural facilities like terminals, and inadequacy of navigational aids.

There are 6 National Waterways:

1. NW1: Ganga-Bhagirathi-Hoogly river system
2. NW2: The Brahmaputra
3. NW3: West Coast Canal (Kottpuram-Kollam)
4. NW4: Kakinada-Puduchery Canal
5. NW5: East Coast Canal integrated with Brahmani and Mahanadi delta system
6. NW6: Lakhipur to Bhanga of river Barak (Proposed)
Development activities:
- Fairway development (a way that which a vessel can move in terms of depth and width)
- Terminals (for handling containers and other cargo)
- Navigational aids (channel marks for day navigation)

Navigational hazards in Inland Waterways:
- Shallow waters (shoaling (formation of sand bars)/sandbars)
- Ship-wrecks
- Siltation (due to dredged of either sand silt etc.,)
- Narrow width of channels
- Bank erosion

Maintenance of Waterways: (maintenance of ‘fairway’)

1. Administrative:
   - Putting place official waterway regulations (lane traffic)
   - Patrol service system
2. Technical:
   - Systematic Hydrographic and hydraulic survey (soundings (eco-sounders), current measurements, sediment data)
   - Slope protection works to maintain the width
   - Dredging to maintain the minimum depths
   - Installation and maintenance of navigational aids (buoys and beacons)
   - Navigation with radar must be considered in case of night navigation and when the visibility is poor

Construction of environmentally engineered banks:

Some general design criteria for canal lining are:

1. A lining system may not increase the hydraulic resistance of the canal
2. A lining must be water tight under all conditions of operation
3. A lining system must be able to withstand the light impact of ships
4. A lining must be easily repairable
5. Materials for lining must be obtainable locally

These general design considerations may lead to a basic design of a lining system which is suitable for unfavourable conditions. Modifications and cost savings can be effected if supported by favourable site investigations of local conditions, particularly ground water level, permeability, expected settlements and re-use of excavated material. In that case the design criteria should be reviewed.

In case of deep excavation where percolation is likely, water tightness of the lining may not be essential and a waterproof membrane and ballast material could be omitted.

Similarly, when the canal passes through impermeable ground, waterproof membrane and ballast material could be omitted.

Where the canal passes rocky ground, a simple RCC slab would suffice. In case of clayey soil, the clay itself will act as waterproofing membrane.

Where uneven settlement takes place, a closed lining system will crack and eventually fail.