GUJARAT TECHNOLOGICAL UNIVERSITY

BE-3 SEMESTER – OLD PAPER – S22 TO W25 – QUESTION BANK ANSWER

Subject Name & Code:

FLUID FLOW OPERATIONS (3130502)

(Disclaimer: The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check)

Unit 6: Transportation and Metering of Fluids

Q1 – Distinguish between pipe and tube. (4 marks)
Ans:

Feature	Pipe	Tube
Cross-section	Always circular	Circular, square, rectangular, oval
Dimension designation	Nominal Pipe Size (NPS) + Schedule number (wall thickness)	Actual outside diameter (OD) and wall thickness (BWG – Birmingham Wire Gauge)
Manufacturing	Rigid, heavy wall, less precise	More precise, lighter wall, often seamless or welded
Threading	Usually threaded ends for fittings	May be threaded, but often uses compression or flare fittings
Typical use	Fluid transport (water, gas, oil)	Heat exchangers, instrumentation, structural
Material	Steel, iron, PVC, copper	Copper, brass, stainless steel, plastic
Stress rating	Based on Schedule number	Based on wall thickness and material

Real-world application:

- Pipes – municipal water supply, natural gas lines.
- Tubes – condenser tubes in power plants, hydraulic lines.

Q2 – Explain working of Gate valve and Globe valve. (7 marks)
Ans:
Gate Valve
Construction:

- Body with inlet and outlet ports.
- Flat or wedge-shaped **gate** (disc) that slides vertically.
- **Stem** connected to handwheel – rotates to raise/lower the gate.
- Seats on both sides where gate seals.

Working:

- **Fully open:** Gate completely withdrawn from flow path → full bore, minimal pressure drop.
- **Fully closed:** Gate pressed against seats → flow stops.
- **Not suitable for throttling** – partial opening causes vibration and seat erosion.

Applications: On/off service in water pipelines, oil refineries.

Globe Valve

Construction:

- Body with a baffle separating inlet and outlet.
- **Disc** (plug) attached to a stem.
- **Seat** in the baffle.
- Handwheel rotates stem to move disc toward or away from seat.

Working:

- Fluid changes direction inside the body (enters, passes around baffle, exits).
- **Linear motion** of disc regulates flow – good for throttling.
- Higher pressure drop than gate valve.

Applications: Throttling service, cooling water lines, steam systems.

Feature	Gate Valve	Globe Valve
Flow control	On/off only	Excellent throttling
Pressure drop	Very low (full bore)	Moderate to high
Seat leakage	Low when fully closed	Very low
Direction	Bidirectional	Usually unidirectional (arrow on body)
Cost	Lower for same size	Higher

[DG PROMPT]
Title: Gate valve and Globe valve cross-sections
Description: Draw two side-by-side diagrams. Left: Gate valve – vertical stem with wedge gate raised, flow straight through. Right: Globe valve – stem vertical, disc seated against horizontal baffle, flow enters from left, passes under disc, exits right. Label: stem, handwheel, seat, disc/gate, body.
Real-world application:

- Gate valve – main isolation in pipelines.
- Globe valve – bypass lines, feedwater control.

Q3 – Explain construction and working of Venturimeter / Orifice meter / Rotameter. (7 marks)
Ans:
All three are flow meters. Below each explained separately.
Venturimeter
Construction:

- **Converging section** (inlet cone) – reduces area, increases velocity.
- **Throat** – minimum area, maximum velocity, minimum pressure.
- **Diverging section** (outlet cone) – gradually recovers pressure.
- **Pressure taps** at inlet and throat.

Working (Bernoulli + continuity):

- Pressure difference $\Delta P = P1 - P2$ is measured.

- Volumetric flow rate:
  $Q = C_d * (A2) / \sqrt{(1 - (A2/A1)^2)} * \sqrt{(2\Delta P/\rho)}$
- $C_d \approx 0.98$ (low loss).

Applications: Clean liquids, gases; high accuracy, permanent pressure loss moderate.

Orifice meter

Construction:

- Thin plate with a sharp-edged hole (orifice) inserted between flanges.
- Pressure taps: one upstream, one downstream (vena contracta).

Working:

- Flow contracts downstream of orifice forming **vena contracta**.
- Pressure drop measured across the plate.
- Flow rate formula similar to venturi but with smaller discharge coefficient $C_d \approx 0.62$.
- Higher permanent pressure loss than venturi.

Applications: Simpler, cheaper, but higher energy loss; used in water, gas, steam.

Rotameter (Variable area meter)

Construction:

- Tapered vertical tube (glass or metal).
- Float (rotor) inside – heavier than fluid.
- Fluid enters bottom, exits top.

Working:

- Flow lifts the float until upward force (pressure drop × area) balances float weight.
- Float position indicates flow rate on scale.
- No external power – direct reading.
- Works for wide range of flow rates.

Applications: Laboratory, chemical dosing, low-flow gas/liquid measurement.

[DG PROMPT]

Title: Venturimeter, Orifice meter, Rotameter

Description: Draw three separate sketches. 1) Venturimeter: converging tube, narrow throat, diverging tube, pressure taps P1 and P2. 2) Orifice meter: flat plate with hole, flanges, pressure taps upstream and at vena contracta. 3) Rotameter: vertical tapered tube, float inside, fluid arrow up, scale on outside.

Real-world application:

- Venturi – water treatment plant flow measurement.
- Orifice – natural gas metering.
- Rotameter – medical oxygen flowmeter.

Q4 – Define NPSH, priming, cavitation. (4 marks)

Ans:

NPSH (Net Positive Suction Head):

- Total head at pump suction minus vapour pressure head.
- $NPSH_{available} = (P_{suction} / \rho g) + (V_s^2/2g) – (P_{vapour} / \rho g)$
- Must be > $NPSH_{required}$ (pump-specific) to avoid cavitation.

Priming:

- Process of filling pump casing and suction line with liquid before startup.
- Necessary for centrifugal pumps (cannot pump gas/air mixture).
- Methods: manual filling, foot valve, self-priming pump design.

Cavitation:

- Formation and collapse of vapour bubbles when local pressure falls below vapour pressure.

- Collapse occurs at higher pressure region → shock waves, pitting, noise, vibration, efficiency loss.
- Prevention: ensure NPSH available > NPSH required, reduce suction lift, increase suction pipe diameter.

Real-world application:

- Pump selection – avoid cavitation in cooling water pumps.
- Priming – required after maintenance.

Q5 – Explain construction and working of centrifugal pump / reciprocating pump. (7 marks)

Ans:

Both pumps are covered below.

Centrifugal Pump

Construction:

- **Impeller** – rotating vaned disk (open, semi-open, or closed).
- **Casing** – volute (spiral) or diffuser type.
- **Shaft** with mechanical seal or stuffing box.
- **Suction nozzle** (eye of impeller) and **discharge nozzle**.

Working:

- Liquid enters impeller eye.
- Impeller rotation imparts centrifugal force → liquid thrown outward.
- Velocity converted to pressure in volute casing.
- Continuous flow as long as impeller rotates.
- Requires **priming** before start.

Advantages: Smooth, pulsation-free, high flow, simple, low maintenance.
Limitations: Not self-priming, efficiency drops at low flow, cavitation risk.
Applications: Water supply, chemical transfer, HVAC.

Reciprocating Pump (Positive Displacement)

Construction:

- **Cylinder** with piston or plunger.
- **Suction valve** and **discharge valve** (non-return).
- **Crank-connecting rod** mechanism.

Working:

- **Suction stroke:** piston moves back → pressure drops → suction valve opens, liquid enters.
- **Discharge stroke:** piston moves forward → pressure rises → discharge valve opens, liquid expelled.
- Flow is pulsating.

Advantages: Self-priming, high pressure (up to 1000 bar), constant flow regardless of pressure.
Limitations: Pulsating flow, requires dampener, lower flow rate, more maintenance.
Applications: Metering pumps, oil well injection, high-pressure cleaning.

[DG PROMPT]

Title: Centrifugal pump and Reciprocating pump
Description: Left sketch: centrifugal – impeller inside volute casing, arrows showing liquid entering eye and exiting tangentially. Right sketch: reciprocating – cylinder with piston, suction valve (inlet), discharge valve (outlet), crank and connecting rod, arrows for suction and discharge strokes.

Comparison table:

Feature	Centrifugal	Reciprocating
Flow	High, continuous	Low to medium, pulsating
Pressure	Low to medium	Very high
Priming	Required	Self-priming
Efficiency	60-85%	80-95%
Maintenance	Low	High (valves, packing)
Viscous fluids	Poor	Good

Q7 – Explain target meter. (4 marks)
Ans:
Definition: A target meter (drag force meter) measures flow rate by sensing the **drag force** on a target (disc or rod) placed perpendicular to flow.
Construction:

- Target (circular disc or streamlined body) centrally mounted inside the pipe.
- Force sensor (strain gauge, load cell, or pneumatic transducer) connected to the target support.
- Transmitter to convert force to flow rate.

Working:

- Flow exerts drag force $F_D = C_D * (½ \rho V^2) * A_{target}$.
- For a given geometry, $F_D \propto \rho V^2 \propto \rho (Q/A)^2$.
- Therefore $Q \propto \sqrt{F_D / \rho}$.

Advantages:

- No pressure taps (no clogging).
- Suitable for dirty, slurry, or corrosive fluids.
- Low permanent pressure loss compared to orifice.

Limitations: Accuracy depends on calibration; target wear affects reading.
Applications: Pulp and paper, wastewater, food slurries.

Q8 – Explain insertion meter concept. (3 marks)
Ans:
Definition: An insertion meter is a flow meter where the sensing element (e.g., turbine rotor, electromagnetic probe, pitot tube) is inserted into the pipe through a small opening, rather than being installed inline.
Concept:

- Measures **point velocity** at a specific radial location.
- Average velocity is inferred using known velocity profile (e.g., log law for turbulent flow).
- Can be installed without cutting the pipe (hot tapping).

Types: Insertion turbine, insertion electromagnetic, insertion ultrasonic, pitot tube.
Advantages: Low installation cost, minimal pressure drop, can be used in large pipes ($\geq$ 150 mm).
Limitations: Less accurate than full-bore meters (needs profile correction), sensitive to

upstream disturbances.
Applications: Large water mains, HVAC ducts, stack gas flow.

Q9 – Explain stuffing boxes / prevention of leakage around moving parts. (4 marks)
Ans:
Definition: A stuffing box (or gland packing) is a sealing device that prevents fluid leakage along a rotating or reciprocating shaft where it passes through a casing (e.g., pump, valve).
Construction:

- **Gland** (compression ring) – presses packing into the box.
- **Packing rings** – braided fibres (PTFE, graphite, aramid) or soft material.
- **Lantern ring** (optional) for lubrication or cooling fluid injection.
- **Gland follower** – applies pressure via studs and nuts.

Working:

- Packing is compressed axially → expands radially against shaft and housing.
- Slight leakage (controlled) lubricates the packing.
- For higher pressure or toxic fluids, **mechanical seals** or **bellows seals** are used.

Prevention methods (other than stuffing boxes):

- **Mechanical seals** – two flat faces (rotating and stationary) spring-loaded.
- **Lip seals** – elastomer ring with flexible lip.
- **Labyrinth seals** – non-contact, uses tortuous path.
- **Magnetic drives** – no shaft penetration.

Real-world application:

- Centrifugal pump shaft sealing.
- Valve stems.

Q10 – Discuss fans, blowers, compressors – differences. (4 marks)
Ans:
All are **gas moving devices** – difference lies in pressure rise and compression ratio.

Parameter	Fan	Blower	Compressor
Pressure rise	Low: up to 0.1 bar (10 kPa)	Medium: 0.1 to 1 bar	High: > 1 bar
Compression ratio	< 1.1	1.1 to 1.2	> 1.2
Type of flow	Axial or centrifugal	Centrifugal or positive displacement	Reciprocating, rotary, centrifugal
Cooling requirement	Not required	Not required	Required (intercooling)
Isothermal efficiency	Low	Moderate	High
Typical application	Ventilation, cooling towers	Pneumatic conveying, combustion air	Gas turbines, refrigeration, air cylinders

Selection criterion: Required discharge pressure and flow rate.

Q11 – Explain jet ejector with diagram. (4 marks)
Ans:
Definition: A jet ejector (or eductor) uses a high-pressure motive fluid to entrain and pump a low-pressure suction fluid – no moving parts.
Construction:
- **Motive nozzle** (convergent-divergent) – accelerates high-pressure fluid to supersonic.
- **Suction chamber** – low pressure region.
- **Mixing throat** – where momentum exchange occurs.
- **Diffuser** – converts kinetic energy back to pressure.

Working:
- Motive fluid enters nozzle → high velocity jet.
- Jet creates low pressure in suction chamber → draws in suction fluid.
- Mixing occurs in throat; diffuser recovers pressure.

Applications:
- Vacuum pumps (steam ejectors).
- Pumping of corrosive or abrasive fluids.
- Chemical reactors – gas entrainment.

[DG PROMPT]
Title: Jet ejector
Description: Draw horizontal tube. Left side: motive nozzle converging to a throat then diverging. Suction chamber above or side with arrow labelled "Suction fluid". Motive fluid arrow entering left. Mixing throat downstream of nozzle. Diffuser diverging right. Exit arrow. Label: motive nozzle, suction chamber, mixing throat, diffuser.

Q12 – List check valves and draw labeled diagram. (4 marks)
Ans:
Check valves (non-return valves): Allow flow in one direction only.
Types:
1. **Swing check valve** – hinged disc swings open.
2. **Lift check valve** – disc lifts vertically.
3. **Ball check valve** – ball seats against a ring.
4. **Wafer check valve** – dual-plate, spring-loaded.
5. **Stop check valve** – can be manually closed.

Diagram description (Swing check):
Horizontal pipe. Body with a disc hinged at top. Flow from left pushes disc open (upward). Reverse flow pushes disc against seat (closed). Label: disc, hinge, seat, direction arrow.
[DG PROMPT]
Title: Swing check valve
Description: Cross-section of pipe. Left side inlet, right side outlet. Inside, a circular disc attached to a hinge at the top. Disc rests on a seat at the bottom when closed. Arrow from left to right above disc showing open position. Dashed arrow from right to left showing disc closed.
Applications: Pump discharge lines, to prevent backflow.

Q13 – Define Schedule number & BWG. (3 marks)
Ans:
Schedule number (Sch.)
- Standard for pipe wall thickness.

- Defined as: Sch = 1000 × (P_design / S_allowable) (approximate).
- Higher schedule = thicker wall = higher pressure rating.
- Common: Sch 40, Sch 80, Sch 160.
- For same NPS (nominal pipe size), ID changes with schedule.

BWG (Birmingham Wire Gauge)

- Standard for tube wall thickness (and wire diameter).
- Lower gauge number = thicker wall.
- Example: 10 BWG = 3.4 mm wall, 18 BWG = 1.2 mm wall.
- Used for heat exchanger tubes, instrument tubing.

Difference: Schedule for pipes (large diameters), BWG for tubes (smaller diameters, precise dimensions).

Q14 – Distinguish between notch and weir. (3 marks)
Ans:

Feature	Notch	Weir
Definition	An opening in the side of a tank or channel – fluid flows through it.	A raised barrier across a channel – fluid flows over it.
Shape	Rectangular, triangular (V-notch), trapezoidal.	Broad-crested, sharp-crested, rectangular.
Size	Small (laboratory, small channels).	Large (rivers, irrigation canals).
Flow measurement	Used to measure small flow rates.	Used for large flow rates in open channels.
Formula	Q ∝ H^n (n depends on shape).	Same as notch but with crest length.
Typical material	Metal plate, acrylic.	Concrete, masonry.

Real-world application:

- Notch – laboratory flow measurement.
- Weir – river flow gauging, wastewater treatment plant influent.

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