GATE 2027
MINING ENGINEERING (MN)

MINING GEOLOGY & MINE DEVELOPMENT

SAR TUTORIAL ACADEMY HYDERABAD

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DAY - 1

MINERALS – FUNDAMENTALS & IDENTIFICATION

Today's Topics:
- ✓ Mineral definition
- ✓ Physical properties
- ✓ Crystal form
- ✓ Hardness
- ✓ Cleavage
- ✓ Fracture
- ✓ Streak
- ✓ Lustre
- ✓ Specific gravity
- ✓ Mineral identification

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1. What is a Mineral?

- A mineral is a naturally occurring, inorganic, homogeneous solid with a definite chemical composition and an orderly internal arrangement of atoms (crystalline structure).
- Minerals are the building blocks of rocks.

2. Characteristics of Minerals

- ✓ Naturally occurring
- ✓ Inorganic
- ✓ Solid
- ✓ Definite chemical composition
- ✓ Crystalline structure
- ✓ Homogeneous
- ✓ Formed by geological processes

3. Crystal Form (Habit)

- Minerals have a characteristic geometric shape due to internal arrangement of atoms.
- Common crystal systems:



Cubic | Tetragonal | Hexagonal



Orthorhombic | Monoclinic | Triclinic

4. Physical Properties

Property	Description
Crystal form	External shape due to internal atomic arrangement
Hardness	Resistance to scratching
Cleavage	Breaks along definite planes
Fracture	Irregular break (no definite planes)
Streak	Colour of powdered mineral
Lustre	Appearance in reflected light
Specific gravity	Ratio of mineral density to density of water (4°C)
Colour	External colour (not always reliable)
Transparency	Transparent, translucent, opaque
Tenacity	Brittle, malleable, sectile, flexible, etc.

5. Hardness (Mohs Scale)

- Relative resistance to scratching.

Mineral	Hardness	Common object
Talc	1	Fingernail (2.5)
Gypsum	2	
Calcite	3	Copper coin (3)
Fluorite	4	
Apatite	5	Knife (5.5)
Orthoclase	6	
Quartz	7	Steel file (6.5)
Topaz	8	
Corundum	9	
Diamond	10	

Higher the number, harder the mineral.

6. Cleavage vs Fracture

Cleavage
- Breaks along definite planes of weakness
- Produces smooth, flat surfaces
- Characteristic for many minerals



Cleavage in Calcite (3 directions at 90°)

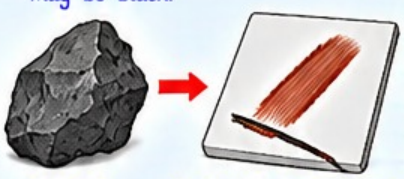
Fracture
- Irregular break
- No definite planes
- Produces uneven surfaces



Conchoidal fracture in Quartz

7. Streak

- Colour of the powdered mineral (rub on unglazed porcelain plate).
- More reliable than external colour.
- Example: Hematite has reddish-brown streak even if the external colour may be black.



Hematite → Reddish-brown streak

8. Lustre

- Appearance in reflected light.



Metallic (Galena) | Non-metallic (Quartz) | Pearly (Talc) | Resinous (Sulphur) | Vitreous (Quartz) | Earthy (Limonite)

9. Specific Gravity (G)

- ✓ Ratio of density of a mineral
- ✓ to the density of water at 4°C.

$$G = \frac{\rho_{mineral}}{\rho_{water\ (4°C)}}$$

$\rho_{water} = 1\ g/cm^3$

- Typical values:
  - Most common minerals: 2.5 – 3.5
  - Heavy minerals (e.g., Galena): 7.4
  - Gold: 15.6

10. Mineral Identification (Steps)

1. Observe colour and lustre
2. Determine hardness (scratch test)
3. Check cleavage or fracture
4. Find streak (porcelain plate)
5. Estimate specific gravity
6. Note crystal form and habit
7. Use other properties (magnetism, reaction with HCl, etc.)
8. Compare with mineral charts/handbooks

"Observe Test Compare Identify"

11. Example Minerals and Key Properties

Mineral	Formula	Hardness	Cleavage	Streak	SG	Lustre
Quartz	SiO_2	7	None	White	2.65	Vitreous
Calcite	$CaCO_3$	3	3 directions	White	2.71	Vitreous
Gypsum	$CaSO_4 \cdot 2H_2O$	2	1 direction	White	2.32	Vitreous
Halite	NaCl	2	3 directions	White	2.16	Vitreous
Fluorite	CaF_2	4	4 directiens	White	3.18	Vitreous
Galena	PbS	2.5	3 directiens	Lead grey	7.4	Metallic
Hematite	Fe_2O_3	5–6	None	Reddish-brown	5.2	Metallic
Magnetite	Fe_3O_4	5.5	None	Black	5.2	Metallic

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DAY - 2

MINING GEOLOGY & MINE DEVELOPMENT

ROCKS – ORIGIN & CLASSIFICATION

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Rocks are the building blocks of the Earth's crust.
Understanding rocks is essential for mineral exploration, mine planning and design.

1. What is a Rock?

- A rock is a naturally occurring aggregate of one or more minerals (or mineraloids) forming a coherent solid mass.
- Rocks may be homogeneous or heterogeneous and are formed by geological processes.
- Engineering behaviour of rocks affects mining, tunnelling and slope stability.

2. Rock Cycle



3. Classification of Rocks

Rocks

Igneous Rocks (Primary)	Sedimentary Rocks (Secondary)	Metamorphic Rocks (Tertiary)
Formed by cooling and solidification of magma/lava	Formed by deposition, compaction and cementation of sediments	Formed by transformation of existing rocks due to heat, pressure and chemically active fluids

4. Igneous Rocks

- Formed by cooling and solidification of molten magma (below surface) or lava (at surface).
- Crystalline, hard and massive.
- Two types: Intrusive (plutonic) and Extrusive (volcanic).
- Common examples: Granite, Diorite, Gabbro, Basalt.


Granite (Intrusive)


Basalt (Extrusive)

5. Sedimentary Rocks

- Formed by weathering, erosion, transportation, deposition, compaction and cementation of sediments.
- Usually bedded and stratified.
- May contain fossils.
- Types: Clastic, Chemical and Organic (Biochemical).
- Common examples: Sandstone, Shale, Limestone, Conglomerate.


Sandstone (Clastic)


Limestone (Chemical)

6. Metamorphic Rocks

- Formed by transformation of pre-existing igneous or sedimentary rocks due to heat, pressure and chemically active fluids.
- Recrystallized and more compact.
- Types: Contact metamorphism and Regional metamorphism.
- Common examples: Slate, Phyllite, Schist, Gneiss, Marble, Quartzite.


Marble (from limestone)


Gneiss (from granite)

7. Textures of Rocks

Texture	Description	Example
Phaneritic	Coarse-grained, visible crystals	Granite
Aphanitic	Fine-grained, not visible	Basalt
Porphyritic	Mixed large + small crystals	Andesite
Glassy	No crystalline structure	Obsidian
Vesicular	With gas cavities	Pumice
Pegmatitic	Very large crystals	Pegmatite
Clastic	Made of fragments	Sandstone
Crystalline	Interlocking crystals	Marble

8. Structures in Rocks

Structure	Description	Example
Bedding	Layering (sedimentary)	Sandstone
Foliation	Planar arrangement of minerals	Slate, Schist
Joints	Fractures with no displacement	All rocks
Faults	Fractures with displacement	All rocks
Folds	Bending of layers	Sedimentary, Metamorphic
Cleavage	Preferred breakage planes	Mica, Slate
Flow structure	Due to movement of magma	Igneous rocks

9. Engineering Significance

- ✓ Rock strength and hardness affect drilling, blasting and excavation.
- ✓ Joints, faults and bedding control groundwater movement and stability.
- ✓ Sedimentary rocks may be weaker and anisotropic.
- ✓ Metamorphic rocks are generally stronger and more competent.
- ✓ Rock texture and structure influence slope stability, pillar design and underground openings.
- ✓ Knowledge of rock type helps in selection of mining method and design of support systems.

10. Quick Comparison

Feature	Igneous	Sedimentary	Metamorphic
Origin	Cooling of magma/lava	Deposition & cementation	Heat & pressure
Texture	Crystalline	Bedded/stratified	Recrystallized
Fossils	Absent	Common	Rare
Hardness	Generally high	Generally lower	Generally high
Examples	Granite, Basalt	Sandstone, Limestone	Marble, Gneiss

"Different Rocks Different Stories Same Earth"

11. Key Takeaways

- ✓ Rocks are classified as igneous, sedimentary and metamorphic.
- ✓ Each rock type has distinct origin, texture and structure.
- ✓ Rock cycle shows interconversion between rock types.
- ✓ Engineering properties of rocks are crucial for safe and economical mining.
- ✓ Identify rocks in field using texture, structure and mineral composition.

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DAY - 3

MINING GEOLOGY & MINE DEVELOPMENT

IGNEOUS & SEDIMENTARY ROCKS

Rocks tell the story of Earth's processes — from molten magma to layered sediments.

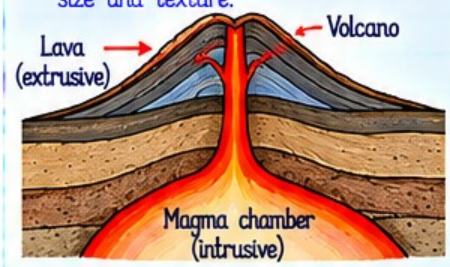
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1. Magma and Igneous Rocks

- Magma is a hot, molten mixture of silicate melt, crystals and gases present beneath the Earth's surface.
- On cooling and solidification, magma forms igneous rocks.
- Rate of cooling controls the crystal size and texture.



2. Types of Igneous Rocks

Intrusive (Plutonic)

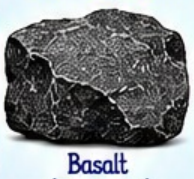
- Cool slowly beneath the Earth's surface.
- Coarse-grained (large crystals).
- Examples: Granite, Diorite, Gabbro.



Granite (Intrusive)

Extrusive (Volcanic)

- Cool quickly at or near the surface.
- Fine-grained or glassy texture.
- Examples: Basalt, Andesite, Rhyolite.



Basalt (Extrusive)

3. Common Igneous Rocks

Rock	Type	Texture	Colour	Common Minerals
Granite	Intrusive	Coarse	Light	Quartz, Feldspar, Mica
Diorite	Intrusive	Coarse	Dark	Plagioclase, Amphibole
Gabbro	Intrusive	Coarse	Dark	Pyroxene, Plagioclase
Basalt	Extrusive	Fine	Dark	Pyroxene, Plagioclase
Andesite	Extrusive	Fine	Grey	Plagioclase, Amphibole
Rhyolite	Extrusive	Fine	Light	Quartz, Feldspar
Obsidian	Extrusive	Glassy	Black	Silica (glass)
Pumice	Extrusive	Vesicular	Light	Silica (glass)

4. Sedimentation Process

- Weathering breaks down rocks into smaller particles (sediments).
- Sediments are transported by water, wind, glacier or gravity.
- They are deposited in low-energy environments like rivers, lakes, seas and deserts.
- Processes: Weathering → Erosion → Transportation → Deposition (Sedimentation)



5. Lithification

- Conversion of loose sediments into solid sedimentary rocks.
- Processes:
  - ✓ Compaction (reduction in voids)
  - ✓ Cementation (precipitation of minerals like silica, calcite, iron)
  - ✓ Results in hard, layered rocks with bedding.



6. Types of Sedimentary Rocks

Clastic (Detrital)

- Formed from fragments of pre-existing rocks.
- Classified based on particle size.
- Examples: Conglomerate, Sandstone, Siltstone, Shale.



Conglomerate (rounded clasts)



Sandstone (sand-size)

Non-Clastic (Chemical/ Organic)

- Formed by chemical precipitation or from biological remains.
- Examples: Limestone, Dolostone, Chert, Coal, Rock Salt, Gypsum.



Limestone (chemical)



Coal (organic)

7. Classification of Sedimentary Rocks

Type	Grain Size / Composition	Example
Conglomerate	> 2 mm (rounded)	Conglomerate
Breccia	> 2 mm (angular)	Breccia
Sandstone	0.062 – 2 mm	Sandstone
Siltstone	0.004 – 0.062 mm	Siltstone
Shale	< 0.004 mm	Shale
Limestone	Calcite ($CaCO_3$)	Limestone
Dolostone	Dolomite ($CaMg(CO_3)_2$)	Dolostone
Chert	Silica (SiO_2)	Chert
Coal	Organic matter	Coal
Rock salt	Halite (NaCl)	Rock salt
Gypsum	$CaSO_4 \cdot 2H_2O$	Gypsum

8. Textures in Rocks

Texture	Description	Example
Phaneritic	Coarse-grained, visible crystals	Granite
Aphanitic	Fine-grained	Basalt
Porphyritic	Large crystals in fine groundmass	Andesite
Glassy	No crystals, glassy	Obsidian
Vesicular	Gas cavities	Pumice
Amygdaloidal	Vesicles filled with minerals	Amygdaloidal basalt
Layered (Bedded)	Parallel layers	Sandstone, Shale

9. Mining Relevance

- ✓ Igneous intrusions are associated with many metallic ore deposits (e.g., Cu, Ni, Cr, Sn, W, Mo).
- ✓ Volcanic and hydrothermal processes concentrate valuable minerals.
- ✓ Sedimentary rocks host important deposits: Coal, Bauxite, Iron ore, Limestone, Phosphates, Evaporites (salt, gypsum).
- ✓ Rock type and texture affect drilling, blasting, excavation and slope stability in mines.
- ✓ Sedimentary structures (bedding, joints, fractures) control groundwater flow and mine stability.
- ✓ Knowledge of rock type helps in selecting mining method and support design.

"Different rocks, different resources, understanding them makes a better miner."

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DAY - 4

MINING GEOLOGY & MINE DEVELOPMENT

METAMORPHIC ROCKS & ROCK TRANSFORMATION

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"Same rock ... New Conditions ... New Identity"
Metamorphism transforms existing rocks into new rocks!

1. What is Metamorphism?

- Metamorphism is the process by which pre-existing igneous, sedimentary or earlier metamorphic rocks are transformed into new rocks due to changes in temperature, pressure and chemically active fluids without melting.
- Results in mineralogical, textural and structural changes.

"Metamorphism = Recrystallization in Solid State"

2. Agents of Metamorphism

1. Heat (Temperature)

- Increases mineral reactions and recrystallization.
- Source: Magma intrusion, geothermal gradient.

2. Pressure (Stress)

- Confining pressure – equal from all sides.
- Directed pressure (differential stress) – causes alignment of minerals (foliation).

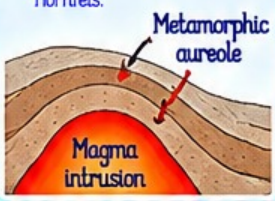
3. Chemically Active Fluids

- Hot solutions (H_2O, CO_2, etc.) help in chemical reactions and mineral changes.
- Enhances metamorphism at lower temperatures.

3. Types of Metamorphism

Contact Metamorphism

- Caused by high temperature near igneous intrusions (magma).
- Low pressure, high temperature.
- Usually non-foliated rocks.
- Forms a metamorphic aureole around intrusion.
- Examples: Marble, Quartzite, Hornfels.



Regional Metamorphism

- Occurs over large areas due to high temperature and high pressure.
- Associated with mountain building (orogeny).
- Usually produces foliated rocks.
- Common in deep crustal levels.
- Examples: Slate, Schist, Gneiss.



4. Grades of Metamorphism

With increase in temperature and pressure, the grade of metamorphism increases.

Low Grade → High Grade



Increase in temperature & pressure → Improved crystallinity → Coarser grains → Development of foliation

5. Textures of Metamorphic Rocks

Foliated Textures (due to directed pressure)

- Slaty (very fine) – Slate
- Phyllitic (silky sheen) – Phyllite
- Schistose (visible micas) – Schist
- Gneissic (alternate bands) – Gneiss

Non-Foliated Textures (due to uniform pressure)

- Granoblastic (equigranular) – Marble, Quartzite
- Hornfelsic (fine-grained) – Hornfels



Schist (foliated texture)



Marble (non-foliated texture)

6. Common Metamorphic Rocks

Rock	Parent Rock	Main Minerals	Texture
Slate	Shale	Fine micas (sericite)	Slaty (foliated)
Phyllite	Shale	Micas (sericite, chlorite)	Phyllitic (foliated)
Schist	Shale	Micas, quartz, feldspar	Schistose (foliated)
Gneiss	Granite/Shale	Quartz, feldspar, mica	Gneissic (foliated)
Marble	Limestone	Calcite/Dolomite	Granoblastic (non-foliated)
Quartzite	Sandstone	Quartz	Granoblastic (non-foliated)
Hornfels	Shale	Fine quartz, feldspar	Hornfelsic (non-foliated)

7. Rock Cycle Relationship



8. Engineering Significance

- ✓ Metamorphic rocks are generally harder, stronger and more competent.
- ✓ Important for selection of mining method and support design.
- ✓ Foliated rocks (slate, schist) may have weakness along foliation planes → influence slope stability and underground openings.
- ✓ Marble and quartzite are important industrial minerals.
- ✓ Metamorphic terrains often host economic mineral deposits (e.g., gold, graphite, talc, asbestos).
- ✓ Recognition of metamorphic grade and texture helps in exploration, mine planning and tunnelling.

9. Key Takeaways

- ✓ Metamorphism transforms existing rocks without melting.
- ✓ Agents: heat, pressure and chemically active fluids.
- ✓ Two main types: contact and regional metamorphism.
- ✓ Grade increases from slate → phyllite → schist → gneiss.
- ✓ Textures may be foliated or non-foliated.
- ✓ Metamorphic rocks are important for mining, tunnelling and often host valuable mineral deposits.

"Different conditions create stronger rocks."

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DAY - 5

MINING GEOLOGY & MINE DEVELOPMENT

ORE GENESIS

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"Ore deposits are nature's treasure — formed by geological processes over millions of years."

1. What is an Ore Deposit?

- An ore deposit is a natural concentration of valuable minerals (metals or non-metals) in the earth's crust.
- Formed by geological processes over long periods of time.
- Must be of sufficient grade, tonnage and continuity to be economically exploitable.
- A mineral deposit may or may not be an ore deposit.

"All ores are mineral deposits, but not all mineral deposits are ores."

2. Types of Mineral Deposits

Mineral Deposits

Metallic (Metal ores)
- Ferrous (Fe, Mn, Cr)
- Non-ferrous (Cu, Pb, Zn, Al, Sn, Ni, etc.)
- Precious (Au, Ag, PGE)

Non-Metallic (Industrial minerals)
- Fuels (Coal, Lignite)
- Chemical minerals (Limestone, Gypsum, Salt)
- Building materials (Sandstone, Granite, Clay)
- Refractories (Quartz, Fireclay)

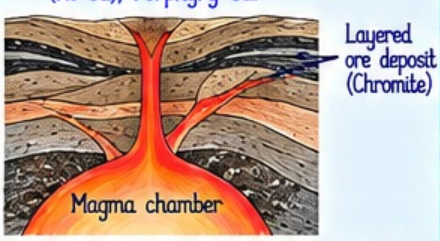
3. Major Ore-Forming Processes

1. Magmatic processes
2. Hydrothermal processes
3. Sedimentary processes
4. Residual and supergene processes
5. Placer processes
6. Metamorphic processes

These processes concentrate minerals by physical, chemical and biological mechanisms.

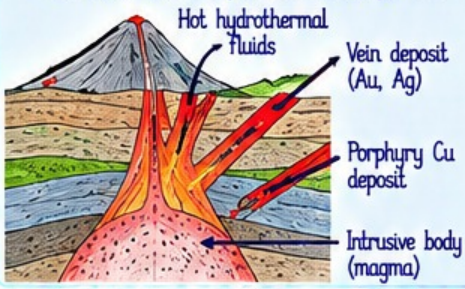
4. Magmatic Ore Deposits

- Formed by crystallization and differentiation of magma.
- Concentrations occur due to magmatic segregation, immiscible fluids or late-stage magmatic solutions.
- Common ores: Fe, Cr, Ni, Cu, Ti, V, PGE, Sn, W, Mo.
- Examples: Chromite (Kempirsai), Magnetite (Kiruna), Sulphide deposits (Ni-Cu), Porphyry Cu.



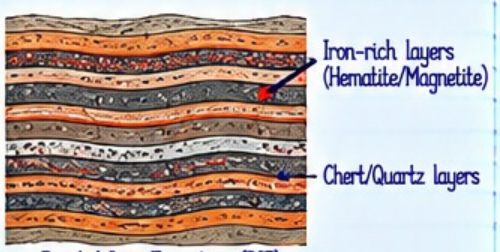
5. Hydrothermal Ore Deposits

- Formed by hot aqueous solutions (hydrothermal fluids) derived from magma or metamorphic sources.
- Minerals are deposited from solution by change in temperature, pressure, pH, redox conditions or chemical reaction.
- Common ores: Cu, Pb, Zn, Au, Ag, Sn, W, Mo, Hg.
- Examples: Vein deposits (Au, Ag), Porphyry Cu, Skarn (Fe, Cu, W), Epithermal (Au, Ag), VMS.



6. Sedimentary Ore Deposits

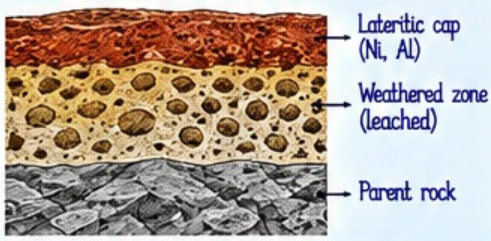
- Formed by mechanical or chemical concentration during sedimentation.
- Include chemical precipitation, mechanical accumulation and organic activity.
- Common ores: Fe, Mn, Al (bauxite), U, P, evaporites.
- Examples: Banded Iron Formation (BIF), Manganese nodules, Phosphate deposits, Evaporites (Halite, Gypsum), U deposits.



Banded Iron Formation (BIF)

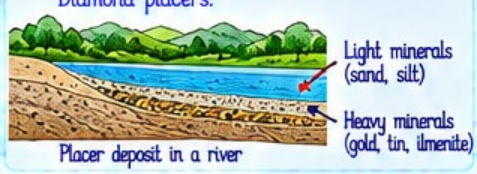
7. Residual (Weathering) Ore Deposits

- Formed by intense weathering and leaching of primary rocks.
- Insoluble and resistant minerals are left behind, while soluble components are removed.
- Common ores: Bauxite (Al), Laterite (Ni), Iron ore (residual), Tin (residual).



8. Placer Deposits

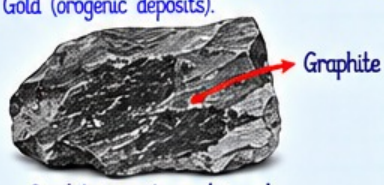
- Formed by mechanical concentration of heavy minerals by water, wind, or ice.
- Resistant and high specific gravity minerals are concentrated in alluvial, beach, river or glacial deposits.
- Common ores: Gold, Platinum, Tin, Diamond, Ilmenite, Monazite.
- Examples: Alluvial gold, Beach placer (ilmenite, rutile), Cassiterite (tin), Diamond placers.



Placer deposit in a river

9. Metamorphic Ore Deposits

- Formed during regional or contact metamorphism by remobilization and reconcentration of minerals.
- Common ores: Graphite, Talc, Asbestos, Magnetite, Mn, Au (in greenstone belts).
- Examples: Graphite (metamorphosed carbon rocks), Iron ore (metamorphic banded iron), Gold (orogenic deposits).



Graphite in metamorphic rock

10. Ore-Forming Environments

Environment	Examples
Magmatic (Igneous)	Layered intrusions, Porphyry systems
Hydrothermal	Veins, Skarn, Epithermal, VMS
Sedimentary	BIF, Phosphorites, Evaporites
Residual (Weathering)	Bauxite, Laterite
Placer (Surface)	Alluvial, Beach, Glacial placers
Metamorphic	Graphite, Gold (orogenic)

11. Key Takeaways

- ✓ Ore deposits form by various geological processes.
- ✓ Magmatic, hydrothermal, sedimentary, residual, placer and metamorphic processes are important.
- ✓ Each deposit type has characteristic minerals, textures and geological settings.
- ✓ Understanding ore genesis helps in exploration, resource estimation and mine planning.
- ✓ Geological environment controls the type, size and grade of ore deposits.
- ✓ Useful for GATE and also for real-world mining applications.

12. Remember for GATE

- ✓ Process → Minerals → Examples
- ✓ Key geological features
- ✓ Diagrams and cross-sections
- ✓ Terminology: vein, skarn, porphyry, BIF, laterite, placer, orogenic
- ✓ Compare and contrast deposit types
- ✓ Link with exploration and mining

"Different processes...
Different deposits...
Same Earth... Infinite Opportunities!"

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DAY - 6

MINING GEOLOGY & MINE DEVELOPMENT

STRUCTURAL GEOLOGY – FUNDAMENTALS

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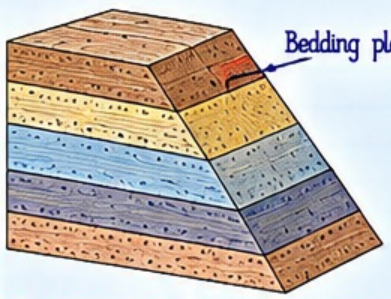
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"Structures in rocks control the location, shape and continuity of mineral deposits."

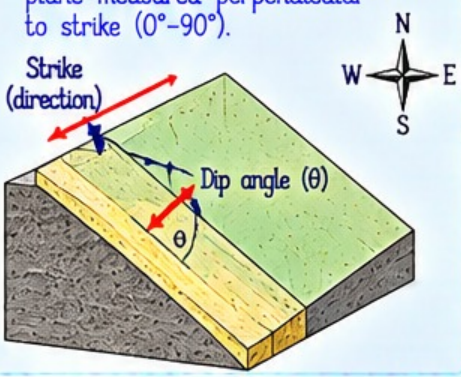
1. Bedding

- Bedding is the layered arrangement of sedimentary rocks.
- Each layer is called a bed.
- Bedding plane separates two successive layers.
- Given by strike and dip.



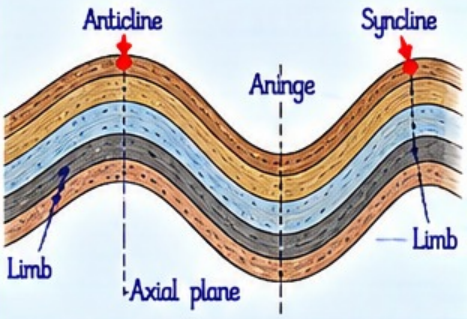
2. Strike and Dip

- **Strike:** Direction of horizontal line on an inclined plane (measured clockwise from North, 0°–360°).
- **Dip:** Maximum inclination of the plane measured perpendicular to strike (0°–90°).



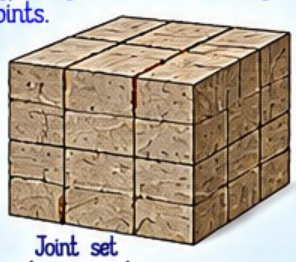
3. Folds

- Folds are bends in rock layers due to compressive forces.
- **Elements:** Hinge, limb, axial plane, plunge.
- **Types:** Anticline (upward fold), Syncline (downward fold), Monocline.



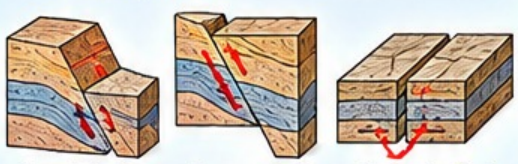
4. Joints

- Joints are fractures in rocks with no displacement.
- Form due to tension, unloading or cooling.
- Types: Systematic and non-systematic joints.



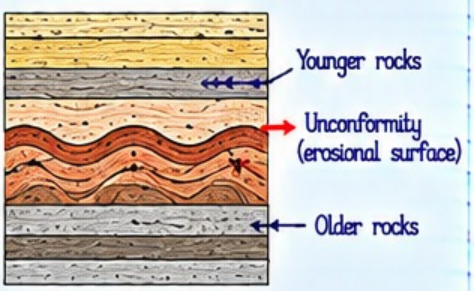
5. Faults

- Faults are fractures along which there is displacement of blocks.
- Caused by tensile, compressive or shear forces.
- Types: Normal fault, Reverse fault, Strike-slip fault.



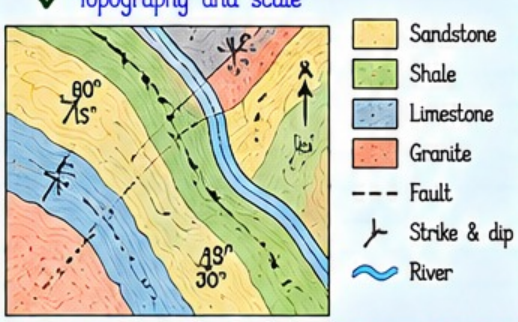
6. Unconformities

- Unconformity is a surface representing a time gap in geological record.
- Types: Angular unconformity, Disconformity, Nonconformity.



7. Geological Maps

- Show the distribution of rock types, structures and geological features on the surface.
- Important elements:
  - ✓ Rock outcrops and boundaries
  - ✓ Strike and dip symbols
  - ✓ Faults, folds and joints
  - ✓ Topography and scale



8. Structural Interpretation

- Helps in understanding subsurface geology and continuity of mineral deposits.
- Uses cross-sections, contour maps and borehole data.
- Important for:
  - ✓ Locating ore bodies
  - ✓ Planning mine development
  - ✓ Assessing ground stability
  - ✓ Predicting continuity of seams and structures

"Structures control mineralization, groundwater movement and mine stability."

9. Key Takeaways

- ✓ Bedding defines primary layering.
- ✓ Strike and dip describe orientation of planes.
- ✓ Folds form due to compression.
- ✓ Joints are fractures without displacement.
- ✓ Faults have displacement.
- ✓ Unconformities indicate a time gap.
- ✓ Geological maps help in surface interpretation.
- ✓ Structural knowledge is essential for mineral exploration, mine planning and slope stability.

"Read the rocks...
They reveal the history,
the structure and the opportunities."

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MINING ENGINEERING (MN)

DAY - 7

MINING GEOLOGY & MINE DEVELOPMENT

STRUCTURAL GEOLOGY – GATE PROBLEMS

SAR TUTORIAL ACADEMY HYDERABAD

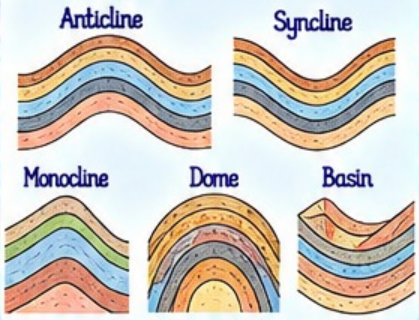
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"From field structures to GATE questions – Apply concepts, solve problems, explore mining applications."

1. Types of Folds

- Anticline – convex upward (older rocks at core).
- Syncline – concave upward (younger rocks at core).
- Monocline – step-like fold.
- Dome – closed anticline.
- Basin – closed syncline.
- Plunge – horizontal component of fold axis.

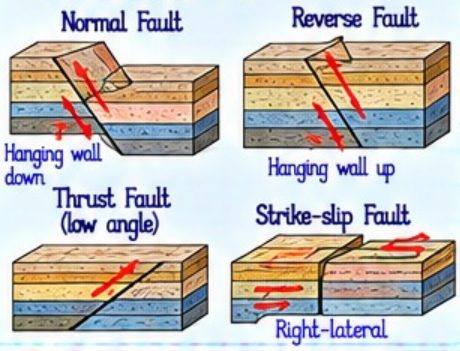


2. Fold Classification

Type	Feature	Sketch	Example
Anticline	Convex up, older at core		Aravalli
Syncline	Concave up, younger at core		Himalaya
Symmetrical fold	Equal limb dips		Ideal case
Asymmetrical fold	Unequal limb dips		Many orogenic belts
Overturned fold	Both limbs dip same direction		High compression
Recumbent fold	Axial plane nearly horizontal		Intense deformation
Isoclinal fold	Parallel limbs		Metamorphic terrains

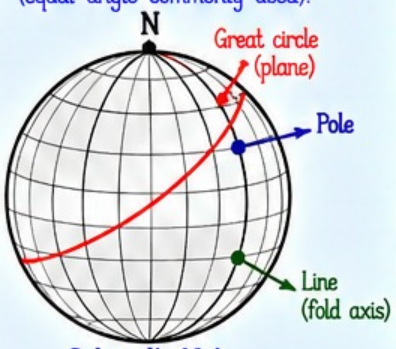
3. Fault Classification

- Normal fault – hanging wall moves down (tensional).
- Reverse fault – hanging wall moves up (compressional).
- Thrust fault – low angle reverse fault.
- Strike-slip fault – horizontal movement (right-lateral or left-lateral).
- Oblique-slip fault – both vertical and horizontal movement.



4. Stereographic Concepts

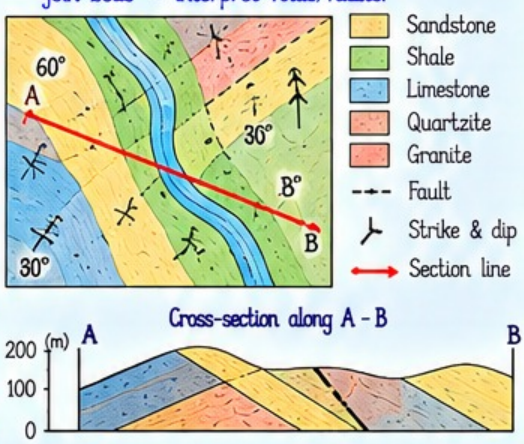
- Used to represent 3D structures on a 2D plane (equal area/angle).
- Plotting planes, lines (poles), fold axes, faults.
- Great circle, small circle, pole to plane.
- Used for kinematic analysis and slope stability in mining.
- Tools: Wulff net or Schmidt net (equal angle commonly used).



Schmidt Net (equal angle projection)

5. Geological Maps & Cross-sections

- Geological map shows outcrop patterns, structures and rock distribution.
- Use strike & dip symbols, contours, rock boundaries.
- Construct geological cross-sections to understand subsurface structure.
- Steps: mark section line → project dips → join beds → interpret folds/faults.



6. Structural Calculations

1. True dip (δ)

$\tan \delta = \tan \alpha \times \sin \theta$

α = apparent dip
θ = angle between strike and line of section

2. Thickness (true thickness, T)

$T = t \times \cos \delta$

t = apparent thickness

3. Vertical separation (V)

$V = h \times \tan \delta$

h = horizontal distance

4. Unconformity time gap

Estimated from truncation of beds, missing formations and correlation.

5. Fold axis trend & plunge

Determined using stereographic projection or intersection of axial plane and bedding planes.

7. GATE Level Practice Question

Q.1 A bed has an apparent dip of 40° in a section making 30° with the strike. The true dip of the bed is:

(A) 30° (B) 40° (C) 60° (D) 70°

Solution:

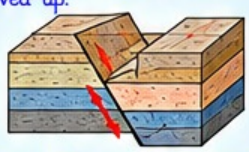
$\tan \delta = \tan 40° \times \sin 30°$

$= 0.839 \times 0.5 = 0.4195$

$\delta = \tan^{-1}(0.4195) \approx 22.8° (\approx 23°)$

Answer: (A) 30°

Q.2 Identify the type of fault shown in the block diagram. The hanging wall has moved up.



(A) Normal fault (B) Reverse fault
(C) Strike-slip fault (D) Oblique-slip fault

Answer: (B) Reverse fault

8. Mining Applications

- ✓ Folds and faults control location, continuity and thickness of ore deposits.
- ✓ Structural traps for hydrothermal ores.
- ✓ Faults act as conduits for mineralizing fluids.
- ✓ Fractures and joints influence blasting, excavation and slope stability.
- ✓ Structural mapping is essential for tunnel, shaft and stope design.
- ✓ Stereographic analysis helps in assessing roof stability in underground mines.
- ✓ Understanding structures reduces exploration risk and improves resource estimation.

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MINING ENGINEERING (MN)

DAY - 8

MINING GEOLOGY & MINE DEVELOPMENT

METHODS OF ACCESS TO DEPOSITS

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"Access creates opportunity → the first step towards mining."

1. Why Access is Needed?

- To reach the mineral deposit.
- For exploration, development and production.
- For transportation of men, materials, ore and equipment.
- For ventilation, pumping and services (electric power, communication).
- For emergency exit.

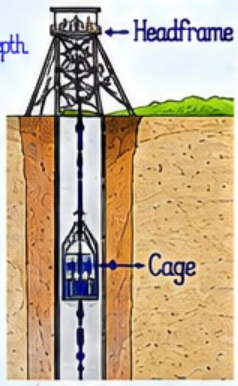
"A good access system ensures safe, economic and efficient mining operations."

2. Types of Access to Deposits

1. Shaft (vertical access)
2. Incline (inclined access upward)
3. Adit (horizontal access from surface)
4. Decline (inclined access downward)
5. Tunnel (long horizontal access)

3. Shaft

- Vertical opening from surface to depth.
- Used for deep deposits.
- Can be used for hoisting, man and material transport, ventilation and service lines.
- Usually circular or rectangular.

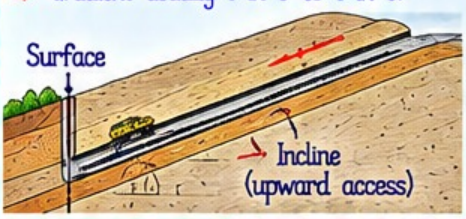


Advantages
- ✔ Suitable for deep mines
- ✔ Large capacity
- ✔ Separate compartments for men, material, services

Limitations
- ✘ High initial cost
- ✘ More construction time
- ✘ Complex design and maintenance

4. Incline

- Inclined opening from surface to deposit (upward direction).
- Generally used for shallow to moderate depsths.
- Transport by rail, conveyor or vehicles.
- Gradient usually 1 in 6 to 1 in 8.

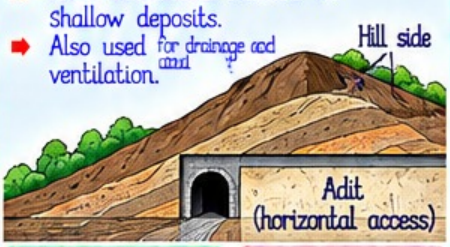


Advantages
- ✔ Lower cost than shaft
- ✔ Easier construction
- ✔ Suitable for shallow deposits

Limitations
- ✘ Not suitable for great depth
- ✘ Lower capacity
- ✘ Affected by surface terrain

5. Adit

- Horizontal opening from hill side to reach the deposit.
- Used when the deposit outcrops on a hillside.
- Most economical method for shallow deposits.
- Also used for drainage and ventilation.

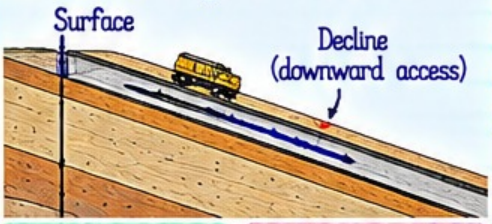


Advantages
- ✔ Low cost
- ✔ Simple construction
- ✔ Provides natural drainage
- ✔ Useful for exploration

Limitations
- ✘ Possible only when deposit outcrops
- ✘ Limited to shallow depth
- ✘ Not suitable for deep deposits

6. Decline

- Inclined opening from surface to deposit (downward direction).
- Used for moderate to deep deposits.
- Transport by rail, conveyor or trucks.
- Gradient usually 1 in 7 to 1 in 10.

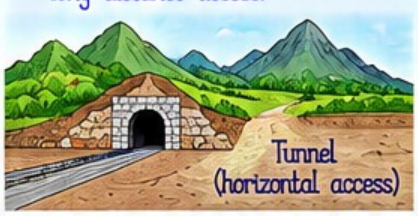


Advantages
- ✔ Can be used for both men and materials
- ✔ Lower cost than shaft
- ✔ Flexible and faster construction

Limitations
- ✘ Not suitable for very deep mines
- ✘ Longer travel distance
- ✘ Ventilation may be more difficult

7. Tunnel

- Long horizontal opening, usually driven through a hill or mountain.
- Used to access deposits, connect shafts or adits.
- Also used for transportation, ventilation and drainage.
- Common in hilly terrain and for long distance access.



Advantages
- ✔ Suitable for long distance
- ✔ Useful in hilly areas
- ✔ Can be used for multiple purposes (transport, ventilation, drainage)

Limitations
- ✘ High excavation cost
- ✘ Requires suitable geology
- ✘ Time consuming

8. Selection of Access Method

Factor	Considerations
Depth of deposit	Shallow → adit/incline Deep → decline/shaft
Topography	Hilly terrain → adit/tunnel Plain area → shaft/decline
Geological conditions	Stable rocks → any method Weak rocks → inclined access may be preferred
Cost and time	Adit/incline → lower cost Shaft → high cost but required for deep mines
Purpose	Haulage, ventilation, drainage, man access, emergency exit
Life of mine	Long life → shaft or decline Short life → adit or incline
Environmental impact	Minimum surface disturbance is preferred

"Right access at the right place makes mining safe, economical and sustainable."

9. Vertical vs Horizontal Access

	Vertical Access (Shaft)	Horizontal Access (Adit/Tunnel)
Direction	Vertical	Horizontal
Depth suitability	Deep deposits	Shallow deposits
Cost	High	Low
Construction time	More	Less
Capacity	High	Moderate
Transport	Hoisting	Rail/Conveyor/Truck
Ventilation	Separate system required	Natural ventilation possible
Best suited for	Deep, large mines	Hilly terrain, shallow deposits

Key Takeaways

- ✔ Selection depends on depth, topography, geology, cost and purpose.
- ✔ Each method has its own advantages and limitations.
- ✔ Combination of methods is often used in large mines.
- ✔ Proper access ensures safe, efficient and economical mining.

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DAY - 9

MINING GEOLOGY & MINE DEVELOPMENT

UNDERGROUND DRIVAGES

"Drivages connect the mine — they make mining possible."

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1. What are Underground Drivages?

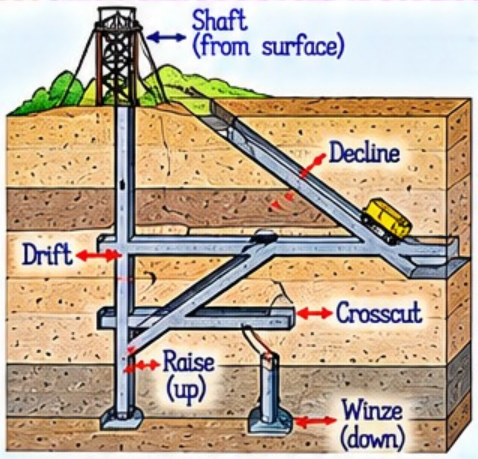
- Underground drivages are openings made in the earth to explore, develop and extract mineral deposits.
- They provide access, transportation, ventilation, drainage and services inside the mine.
- Types: drifts, crosscuts, raises, winzes, tunnels, declines, shafts etc.

"Drivages are the backbone of underground mining."

2. Types of Drivages

Drivage	Direction / Purpose	Typical Use
Drift	Horizontal opening along strike	Main haulage, ventilation
Crosscut	Horizontal opening across strike	To intersect ore body
Raise	Vertical upward opening	Ventilation, man and material
Winze	Vertical downward opening	Exploration, ventilation, drainage
Tunnel	Long horizontal opening (from surface)	Access to mines, transportation
Decline	Inclined opening downward	Access, haulage by rail/track
Shaft	Vertical opening (from surface)	Main access, hoisting men and materials

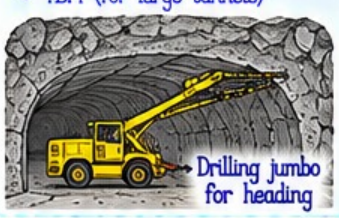
3. Typical Layout of Underground Drivages



Schematic view of underground drivages

4. Heading Methods

- Common heading methods:
  - Hand drilling and blasting
  - Machine drilling (jumbo, roadheader)
  - Cut and fill method
  - Raise boring (for raises)
  - TBM (for large tunnels)

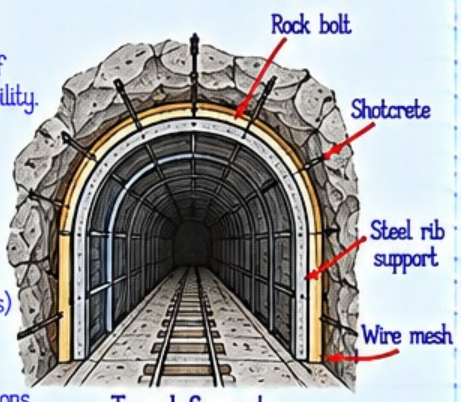


Factors affecting method selection:

- ✔ Rock type and strength
- ✔ Size of opening
- ✔ Required advance rate
- ✔ Cost and availability of equipment
- ✔ Geological conditions

5. Support in Drivages

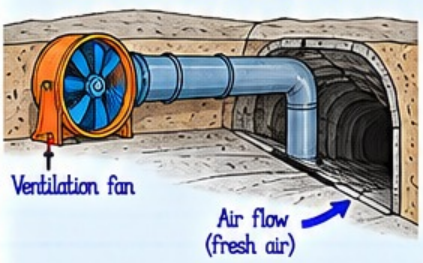
- Support is provided to prevent roof and side falls and to maintain stability.
- Types of support:
  - Timber supports (props, sets)
  - Steel supports (arches, ribs)
  - Rock bolts
  - Shotcrete
  - Wire mesh and strapping
  - Concrete/steel liners (for tunnels)
- Support selection depends on:
  - Rock mass quality (RMR/Q)
  - Size of opening and stress conditions



Tunnel Support

6. Ventilation in Drivages

- Ventilation supplies fresh air, removes foul air, dust and harmful gases.
- **Methods:**
  - Natural ventilation
  - Mechanical ventilation (fans, blows)
- **Common systems:**
  - Exhaust system
  - Forcing system
  - Combination system
- **Important for:**
  - Dilution of harmful gases (CH_4, CO, etc.)
  - Removal of dust
  - Safe and healthy working environment



7. Development Cycle

Drilling → Charging → Blasting → Mucking → Support (if required) → Ventilation → Marking & Survey

Typical cycle for drivage advance

8. Drivage Calculations

1. **Advance rate**

$$R = \frac{L}{t}$$

R = advance rate (m/day)
L = total advance (m)
t = time (days)

2. **Volume of excavation**

$$V = A \times L$$

A = cross-sectional area (m^2)
L = length of drivage (m)

3. **Number of rounds**

$$N = \frac{L}{a}$$

a = advance per round (m)

4. **Powder factor**

$$PF = \frac{W}{V}$$

W = explosive used (kg)
V = volume excavated (m^3)

9. Key Takeaways

- ✔ Drivages provide access, exploration and services in underground mines.
- ✔ Each type of drivage has a specific purpose and orientation.
- ✔ Heading method depends on rock conditions, size and production requirement.
- ✔ Proper support and ventilation are essential for safety and stability.
- ✔ Development cycle includes drilling, charging, blasting, mucking, support and ventilation.
- ✔ Drivage calculations help in planning and monitoring progress.

"Good planning of drivages ensures safe, productive and economical mining."

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DAY - 10

MINING GEOLOGY & MINE DEVELOPMENT

DRILLING METHODS & MACHINES

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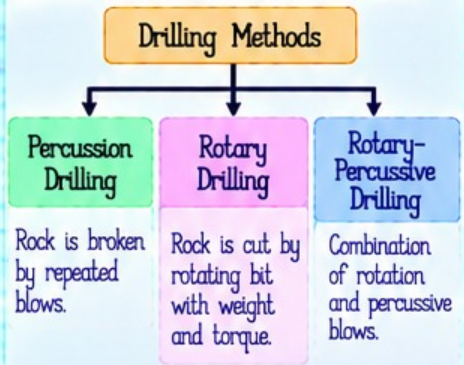
"Drilling opens the earth and gives access to its hidden wealth."

1. Importance of Drilling

- Used for exploration, development, production and blasting.
- Provides access to subsurface minerals and rocks.
- Also used for water wells, drainage, ventilation and ground investigation in mines.
- Helps in sampling, in-situ testing and installation of instruments.

"Drilling is the key to exploration, extraction and engineering in mining."

2. Types of Drilling Methods



3. Percussion Drilling (Cable Tool)

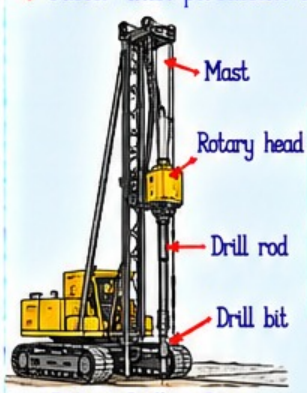
- Rock is broken by repeated lifting and dropping of a heavy drill bit (chisel).
- Used mainly in soft to medium hard rocks.
- Equipment: Derrick, rope, drill bit, sand pump.
- Simple and economical but slow.



Cable Tool Drilling

4. Rotary Drilling

- Rock is cut by a rotating drill bit under weight on bit (WOB).
- Uses drilling mud/air/water to remove cuttings.
- Widely used in exploration, production and large diameter holes.
- Faster than percussion drilling.



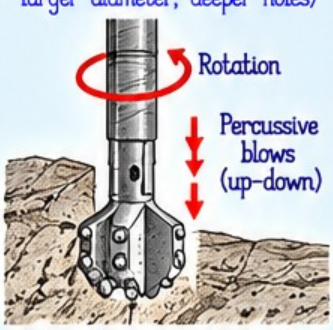
Rotary Drilling Rig

Applications

- ✓ Exploration drilling
- ✓ Production drilling
- ✓ Water wells
- ✓ Geotechnical drilling

5. Rotary-Percussive Drilling

- Combines rotation with percussive blows.
- More effective in hard and fractured rocks.
- Two main types:
  - **Top-hammer drilling** (for smaller diameter, shallow to medium depth)
  - **Down-the-hole** (DTH) drilling (for larger diameter, deeper holes)



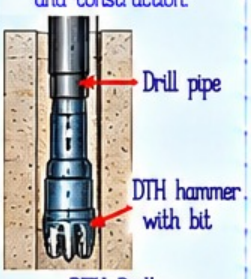
Rotary-Percussive Mechanism

6. Top-Hammer vs DTH Drilling

Top-Hammer (TH)	Down-the-Hole (DTH)
Percussive hammer is at the top (surface).	Hammer is at the bottom (down the hole).
Used for small to medium diameter (50–115 mm).	Used for larger diameter (100–300 mm).
Suitable for shallow to medium depth.	Suitable for deeper holes.
Common in quarries, small mines.	Higher penetration rate.
	Widely used in mines and construction.

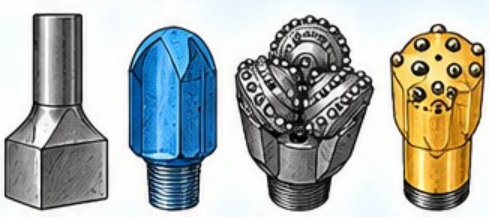


Top-Hammer Drill



DTH Drilling

7. Drill Bits



Chisel bit (percusion) | Drag bit (rotary) | Tricone bit (rotary) | Button bit (DTH)

Selection depends on:

- ✓ Rock type and hardness
- ✓ Hole diameter and depth
- ✓ Drilling method
- ✓ Cost and availability
- ✓ Purpose (exploration / production / blasting / water well)

8. Drilling Parameters

1	Weight on Bit (WOB)	→ Force applied on bit (kN).
2	Rotary Speed (RPM)	→ Speed of rotation (rev/min).
3	Penetration Rate (ROP)	→ Depth drilled per unit time (m/hr).
4	Air/Water Flush	→ Removes cuttings, cools bit, stabilizes borehole.
5	Bit Life	→ Total depth drilled before bit replacement.

Higher WOB, optimum RPM and efficient flushing give better penetration rate and economical drilling.

9. Key Takeaways

- ✓ Drilling is essential for exploration, development, production and support activities.
- ✓ Percussion, rotary and rotary-percussive are the main methods.
- ✓ Top-hammer for shallow/smaller holes; DTH for deep/larger holes.
- ✓ Proper drill bit selection and drilling parameters improve efficiency.
- ✓ Machine selection depends on rock type, hole size, depth, purpose and cost.
- ✓ Drilling technology is continuously improving with automation and better bits.

"Right method, right machine, right parameters – successful drilling."

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DAY - 11

MINING GEOLOGY & MINE DEVELOPMENT

EXPLOSIVES & INITIATION SYSTEMS

"Controlled energy breaks rock and creates opportunities."

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1. Role of Explosives in Mining

- Used to break and fragment rocks for mineral extraction.
- Essential in surface and underground mining.
- Helps in excavation of openings, development and production blasting.
- Economical and suitable for hard and competent rocks.

"Explosives convert solid rock into useful fragments."

2. Properties of Explosives

- High energy release
- High detonation velocity (VOD)
- High density
- Stability during storage
- Controlled sensitivity
- Good water resistance
- Fume characteristics
- Suitability for application
- Safe handling

An ideal explosive should be powerful, safe, stable and economical.

3. Explosive Strength

- Indicates the ability to do work (break rock).
- Measured relative to a standard (TNT = 1).
- Depends on heat of detonation, density and VOD.

Relative Strength (Approx.)

Explosive	Relative Strength
TNT	1.0
ANFO	0.8
Dynamite	1.0 – 1.2
Emulsion	0.9 – 1.1
Slurry	0.8 – 1.0

4. Sensitivity of Explosives

- Ease with which an explosive can be initiated.
- Expressed in terms of impact, friction and electrical sensitivity.
- Higher sensitivity → easier to initiate, but less safe.
- Lower sensitivity → safer in handling and transportation.

Type of Sensitivity	Test Method
Impact	BAM fall hammer test
Friction	BAM friction tester
Electrical	Minimum current required for initiation

5. Density of Explosives

- Mass per unit volume (g/cc).
- Higher density → higher energy per unit volume.
- Typical range: 0.8 – 1.6 g/cc.
- Affects detonation velocity and blasting performance.

Bulk explosives generally have lower density than cartridge explosives.

6. Types of Explosives

Cartridge Explosives

- Packed in cylindrical cartridges.
- Examples: Dynamite, slurry, emulsion cartridges.
- Used in small to medium size operations.



DYNAMITE CARTRIDGES

Bulk Explosives

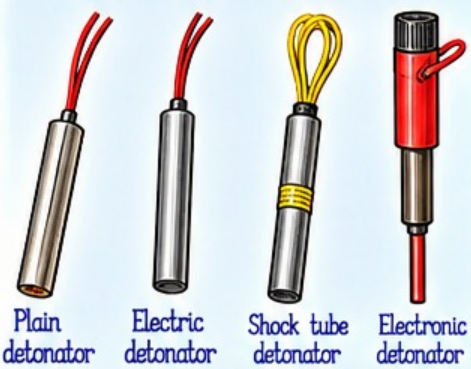
- No individual cartridges.
- Examples: ANFO (Ammonium Nitrate Fuel Oil), heavy ANFO, slurry, emulsion.
- Used in large scale surface and underground mining.



ANFO (bulk explosive)

7. Detonators

- Device used to initiate the explosive.
- Produces a shock wave or high temperature to start detonation.
- Types:
  - Plain (Non-electric) detonators
  - Electric detonators
  - Shock tube (Non-electric delay)
  - Electronic detonators

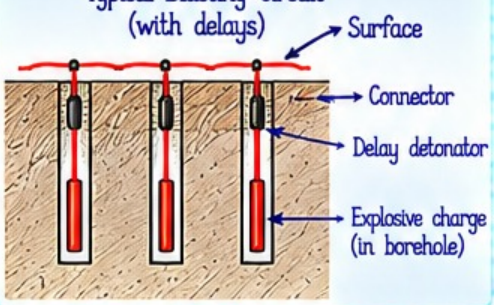


Plain detonator | Electric detonator | Shock tube detonator | Electronic detonator

8. Initiation Systems

- Arrangement of detonators and connecting devices to initiate a number of explosive charges in a desired sequence.
- Used to achieve proper timing, fragmentation and control.
- Common systems:
  - Single shot system
  - Delay system (time delays)
  - Non-electric system (shock tube)
  - Electronic initiation system

Typical Blasting Circuit (with delays)



9. Safety in Handling Explosives

- Follow statutory regulations (Explosives Act and rules).
- Proper storage in magazines.
- Careful transportation and handling.
- Avoid impact, friction and heat.
- Use approved initiation systems.
- Maintain safe blasting procedures and exclusion zones.
- Training and supervision of personnel.

Safety First

- ✔ Handle with care
- ✔ Store in approved magazines
- ✔ Follow regulations
- ✔ Use proper blasting procedures
- ✔ Protect people, equipment and environment

"Explosives are useful when controlled, dangerous when careless."

GATE 2027
MINING ENGINEERING (MN)

DAY - 12

MINING GEOLOGY & MINE DEVELOPMENT

BLASTING TOOLS & BLAST DESIGN

"Right design, safe blasting, better fragmentation."

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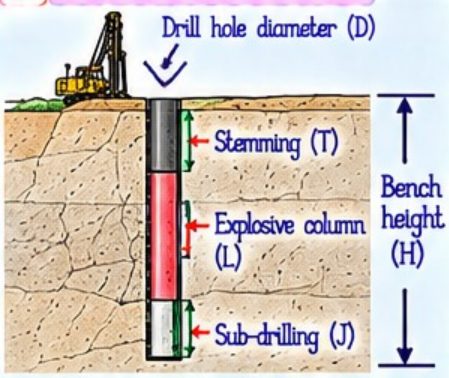
Mining Knowledge Today A Better Tomorrow

1. Role of Blasting in Mining

- Breaks rock for excavation, loading and transport.
- Used in opencast and underground mines.
- Improves productivity and reduces cost.
- Proper design gives desired fragmentation with minimum environmental impact.

"Blasting converts rock mass into movable fragments."

2. Drill-hole Parameters

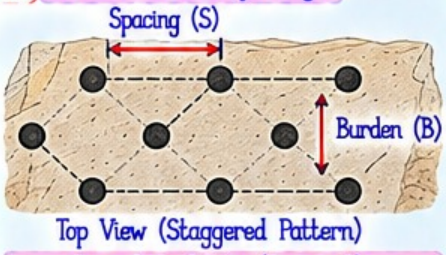


Basic elements of a vertical blast hole

3. Important Terms

Parameter	Description
Bench height (H)	Height of the bench to be blasted.
Burden (B)	Shortest distance from hole to free face.
Spacing (S)	Distance between adjacent holes in a row.
Stemming (T)	Inert material (sand, drill cuttings) to confine explosive gases.
Sub-drilling (J)	Extra depth below bench floor for proper breakage.
Hole diameter (D)	Diameter of drill hole.
Charge length (L)	Length of explosive column.
Charge concentration	Amount of explosive per unit volume (kg/m^3).

4. Burden and Spacing

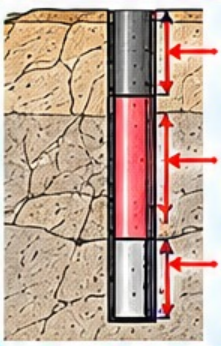


Top View (Staggered Pattern)

Typical Guidelines (Opencast)

B = 20 – 35 D
S = 1.0 – 1.5 B

5. Stemming and Sub-drilling



Stemming (T)
T = 20 – 30 D

Explosive column (L)
L = H + J – T

Sub-drilling (J)
J = 0.2 – 0.3 H

6. Charge Concentration

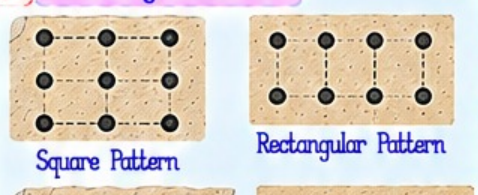
- Amount of explosive per unit volume of rock.
- Affects fragmentation and throw.
- Typical range: 0.2 – 1.0 kg/m^3 (depending on rock type and hole diameter).

Formula:

$$\text{Charge concentration } (q) = \frac{W}{B \times S \times H}$$

W = weight of explosive per hole (kg)
B, S, H = burden, spacing and bench height (m)

7. Blasting Patterns

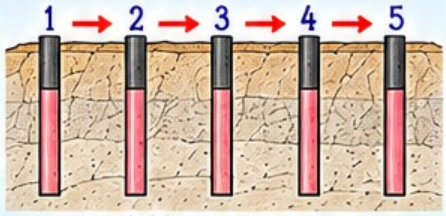


Square Pattern | Rectangular Pattern

Staggered Pattern | V-Pattern (for trenching)

8. Delay Sequence

- Delays are used to control the sequence of blasting.
- Helps in better fragmentation, lower ground vibration and controlled throw.
- Types:
  - Millisecond delays
  - Non-electric delay detonators (NED)
  - Electronic detonators



Typical delay sequence in a row

9. Fragmentation

- Objective is to get desired fragment size suitable for loading and transport.
- Depends on rock properties, explosive energy and blast design parameters.
- Measured by fragmentation analysis (size distribution).
- Better controlled blasting → higher percentage of desired size.

Factors Affecting Fragmentation

- ✔ Burden and spacing
- ✔ Charge concentration
- ✔ Rock mass characteristics
- ✔ Delay sequence
- ✔ Stemming length
- ✔ Explosive type and energy
- ✔ Drilling accuracy

10. Blasting Tools & Equipment

- Drills (DTH, rotary, top-hammer)
- Compressor and flushing equipment
- Explosives and accessories
- Measuring and marking tools
- Safety and monitoring instruments (seismographs, fly rock protection)



Drill rig | Explosive | Detonator | Electronic blasting system

11. Key Takeaways

- ✔ Proper drill-hole design is essential for efficient and safe blasting.
- ✔ Maintain correct burden, spacing, stemming and sub-drilling.
- ✔ Use suitable charge concentration and delay sequence.
- ✔ Choose proper blasting pattern based on site conditions.
- ✔ Good blasting gives better fragmentation, higher productivity and lower environmental impact.

"Science in design, precision in execution, success in mining."



Controlled blasting for better results

GATE 2027
MINING ENGINEERING (MN)

DAY - 13

MINING GEOLOGY & MINE DEVELOPMENT

BLAST DESIGN PRACTICES & CALCULATIONS

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"Right design + proper calculation = better fragmentation, higher productivity."

1. Why Blast Design is Important?

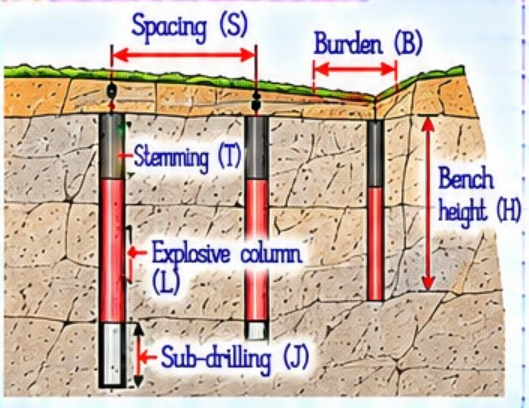
- Ensures proper fragmentation of rock.
- Reduces ground vibration and fly rock.
- Improves productivity and lowers cost per tonne.
- Optimizes the use of explosives.
- Ensures safety and environmental compliance.

"A well-designed blast breaks only the rock, not the bank."

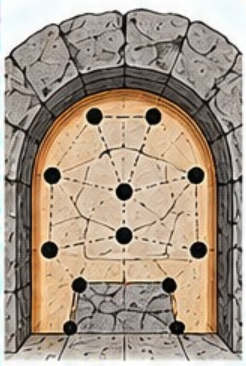
2. Types of Blasting

1. Bench blasting (surface mines)
2. Underground blasting (tunnels, drives)
3. Cut blasting (initial breakage)
4. Production blasting (main blasting)
5. Controlled blasting (low vibration)
6. Special blasting (sloping ground, hard rock, sensitive areas)

3. Bench Blasting Design



4. Underground Blasting

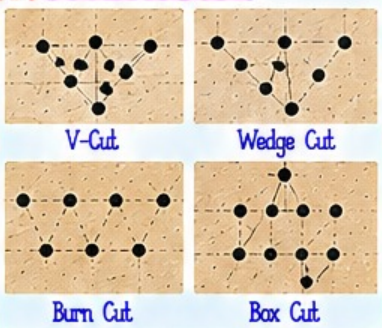


Typical Underground Face

- Used in development and stoping.
- Common in tunnels, drifts, raises and winzes.
- Cut hole + stoping holes + lifter holes.
- Smaller burden and spacing compared to surface.
- Proper delay sequence is important to control vibration and overbreak.

"Proper blast design ensures smooth development and stable openings."

5. Cut Patterns



- ✓ Cut pattern creates free face for subsequent holes.
- ✓ Used mainly in hard and competent rocks.
- ✓ Common patterns: V-cut, Wedge cut, Burn cut, Box cut.

6. Important Design Parameters

Parameter	Symbol	Typical Range / Relation
Bench height	H	5 – 15 m
Burden	B	0.8 – 1.2 H
Spacing	S	1.0 – 1.5 B
Stemming	T	0.7 – 1.0 B
Sub-drilling	J	0.2 – 0.3 H
Hole diameter	D	64 – 311 mm
Charge length	L	L = H + J – T
Charge concentration	q	kg/m (depends on rock type)
Powder factor	PF	kg/m³ (typical: 0.2 – 0.8)

General relations:

S = 1.0 – 1.5 B T = 0.7 – 1.0 B J = 0.2 – 0.3 H

7. Charge Calculations

1. Charge per hole

$$Q = q \times L$$

q = charge concentration (kg/m)
L = charge length (m)

2. Total explosive required

$$Q_{total} = n \times Q$$

n = number of holes

3. Powder factor (PF)

$$PF = \frac{W}{V}$$

W = total explosive (kg)
V = volume of rock (m^3)

Typical PF:

- Soft rock : 0.2 – 0.4 kg/m^3
- Medium rock : 0.4 – 0.6 kg/m^3
- Hard rock : 0.6 – 0.8 kg/m^3

8. Fragmentation & Blast Optimization

- Fragmentation depends on:
  - Burden and spacing
  - Charge concentration
  - Rock mass properties (jointing, hardness)
  - Explosive type and energy
  - Proper delay sequence
  - Stemming and sub-drilling

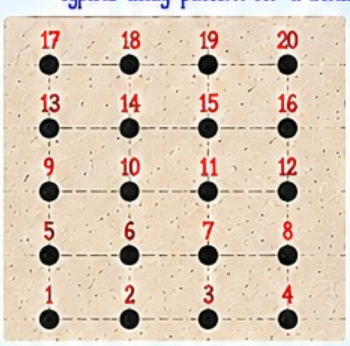
Tips for Better Fragmentation:

- ✓ Use correct burden/spacing ratio.
- ✓ Optimize charge concentration.
- ✓ Use suitable delay sequence.
- ✓ Ensure proper stemming.
- ✓ Consider rock mass characteristics.
- ✓ Avoid overcharging (prevents fly rock).

Optimized blast design
= Better fragmentation
+ Higher productivity
+ Lower cost

9. Delay Sequence (Example)

Typical delay pattern for a bench



- ✓ Use millisecond or non-electric delays.
- ✓ Sequence should ensure progressive breakage.
- ✓ Helps in better fragmentation and controls vibration.
- ✓ Common patterns: row by row or chevron pattern.

"Design smart, blast safe, mine better."

GATE 2027
MINING ENGINEERING (MN)

DAY - 14

MINING GEOLOGY & MINE DEVELOPMENT

GROUND VIBRATION & BLAST EFFECTS

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"Control the vibration, protect the environment, ensure safe mining."

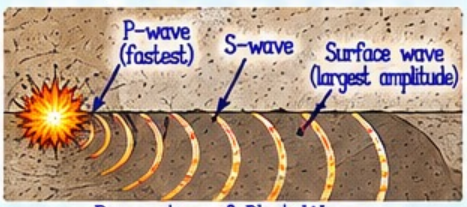
1. Introduction

- Blasting releases large amount of energy in a short time.
- Part of the energy is carried through the ground as seismic waves (ground vibration).
- Can affect nearby structures, people, equipment and underground openings.
- Proper prediction, monitoring and control are essential.

"Not only rock breaks, but ground also moves."

2. Blast-induced Vibration

- Caused by propagation of elastic waves generated during blasting.
- Main wave types:
  - **P-waves** (Primary / Compressional)
  - **S-waves** (Secondary / Shear)
  - **Surface waves** (Rayleigh and Love)
- Surface waves cause maximum damage.
- Amplitude decreases with distance and depends on charge weight, rock properties and site conditions.



Propagation of Blast Waves

3. Peak Particle Velocity (PPV)

- PPV = maximum particle velocity of ground during blasting (mm/s).
- Used to assess potential damage to structures.
- Measured using seismographs / vibration monitors.
- Damage potential increases with higher PPV.

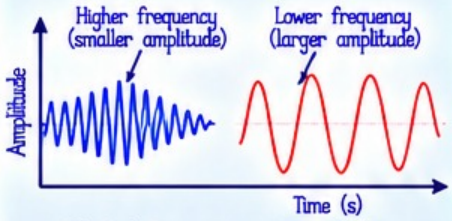
Typical PPV Damage Criteria (Approx.)

Structure / Object	PPV (mm/s)
Residential buildings	5 – 10
Industrial buildings	10 – 25
Reinforced concrete structures	25 – 50
Heritage / old structures	2 – 5
Underground openings / tunnels	25 – 50
Sensitive equipment	2 – 5

"Keep PPV within safe limits."

4. Frequency of Vibration

- Frequency (Hz) = number of vibrations per second.
- High frequency → lower damage potential (generally).
- Low frequency → higher damage potential.
- Blasting vibrations usually have frequency range: 5 – 200 Hz (mostly 10 – 100 Hz).



Effect of Frequency on Ground Motion

5. Scaled Distance

- Scaled distance (SD) is used to predict vibrations from blasting.
- It combines charge weight and distance.

$$SD = \frac{D}{\sqrt{W}}$$

D = distance from blast to point of interest (m)
W = maximum charge per delay (kg)

Empirical Prediction Equation

$$PPV = K\,(SD)^{-n}$$

K, n = site constants (depend on geology, rock mass, blasting conditions)

Larger scaled distance → lower PPV

6. Vibration Monitoring

- Measured using seismograph / vibration monitor.
- Records PPV, frequency and waveform.
- Monitors are placed at sensitive locations (villages, buildings, underground openings).
- Helps in:
  - Assessing compliance with standards
  - Validating prediction equations
  - Optimizing blasting design



7. Prediction and Control

Methods of Prediction

- Empirical equations ($PPV = K\,(SD)^{-n}$)
- Site-specific testing (trial blasts)
- Numerical modelling (in complex cases)

Methods of Control

- Reduce charge per delay
- Increase burden and spacing
- Use appropriate delay sequence
- Use decking (air/decked charges)
- Stemming with proper material and length
- Smooth blasting / controlled blasting
- Use of non-electric or electronic detonators (better control)

"Design to break rock, not to shake the world."

8. Blast Effects

- Besides vibration, blasting can cause:
  - Air overpressure (air blast)
  - Fly rock
  - Ground heave and cratering
  - Damage to nearby structures
  - Disturbance to people, animals and environment



Blast Effects on Surroundings

9. Key Takeaways

- ✔ Blast-induced vibration is a major environmental and safety concern.
- ✔ PPV is the key parameter for damage assessment.
- ✔ Scaled distance is used for prediction of PPV.
- ✔ Follow safe limits as per standards.
- ✔ Use proper blasting design and control measures to minimize vibration.
- ✔ Field monitoring is essential for validation and compliance.
- ✔ Optimized blasting ensures safe, economical and environmentally responsible mining.

"Measure – Predict – Control – Mine Sustainably."

GATE 2027
MINING ENGINEERING (MN)

DAY - 15

MINING GEOLOGY & MINE DEVELOPMENT

25 GATE NUMERICALS (PRACTICE SET)

"Practice Numericals – Build Confidence – Crack GATE."

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Mining Knowledge Today A Better Tomorrow

1. Mineral / Rock Properties (Q1–Q3)

Q1. A rock sample has a density of 2.65 g/cc and porosity of 4%. Find the bulk density.

Bulk density, $\rho_b = \rho_s (1 - n)$
$\rho_s = 2.65$ g/cc, $n = 0.04$
$\rho_b = 2.65 (1 - 0.04) = 2.54$ g/cc

Q2. A mineral has specific gravity 3.2 and the mass of ore is 4800 kg. Find the volume.

$$\text{Volume, } V = \frac{\text{Mass}}{(SG \times 1000)} = \frac{4800}{3.2 \times 1000}$$
$$V = 1.5 \text{ m}^3$$

Q3. A rock has UCS of 120 MPa. Estimate its RMR class (qualitative).

2. Structural Geology (Q4–Q6)

Q4. A bed has a true dip of 30°. The strike is N60°E. Find the dip direction.

Dip direction = Strike + 90°
= N60°E + 90° = S30°E

Q5. Calculate the true thickness (T) of a bed of apparent thickness 5 m observed at an angle of 45° to the normal.

$$T = t_{app} \times \sin\theta$$
$$= 5 \times \sin 45° = 3.54 \text{ m}$$

Q6. Two joint sets are inclined at 60°/120° and 75°/210°. Find the acute angle between them (plan view).

3. Access to Deposits (Q7–Q9)

Q7. The vertical depth to a deposit is 300 m. A decline is driven at 1 in 7 gradient. Find the length of decline.

Length = Depth × Gradient
= 300 × 7 = 2100 m

Q8. Compare the suitability of shaft vs incline for a deep deposit (numerical based on cost data).

Q9. A shaft of 5 m diameter is sunk to a depth of 400 m. Calculate the volume of material excavated (neglecting bulking).

$$V = \frac{\pi}{4} \times D^2 \times H = \frac{3.1416}{4} \times 5^2 \times 400$$
$$= 7850 \text{ m}^3$$

4. Underground Drivages (Q10–Q11)

Q10. A drift of 4.0 m × 4.0 m cross-section is driven for 120 m. Calculate the volume of excavation.

$$V = A \times L = (4 \times 4) \times 120 = 1920 \text{ m}^3$$

Q11. A raise of 2.5 m diameter is driven to a height of 30 m. Find the volume excavated.

$$V = \frac{\pi}{4} \times D^2 \times H$$
$$= \frac{3.1416}{4} \times 2.5^2 \times 30 = 147.3 \text{ m}^3$$

5. Drilling (Q12–Q14)

Q12. A blast hole of 115 mm diameter and 3.0 m depth is drilled. Calculate the volume of rock per hole.

$$V = \frac{\pi}{4} \times D^2 \times L$$
$$= \frac{3.1416}{4} \times (0.115)^2 \times 3 = 0.0313 \text{ m}^3$$

Q13. A rotary drill penetrates 15 m in 45 min. Find the rate of penetration (m/hr).

$$\text{ROP} = \frac{15}{(45/60)} = 20 \text{ m/hr}$$

Q14. Calculate the number of holes required to break 1200 m³ of rock, given volume per hole = 0.03 m³, with 10% extra.

$$N = \frac{1200}{0.03 \times 1.10} = 44{,}000 \ (\approx 44 \text{ holes})$$

6. Explosives (Q15–Q17)

Q15. An explosive has VOD of 4500 m/s. Calculate the time taken for the detonation wave to travel 10 m.

$$t = \frac{\text{Distance}}{\text{VOD}} = \frac{10}{4500} = 0.0022 \text{ s } (2.2 \text{ ms})$$

Q16. A blast hole of 3 m length is charged with 2.5 kg of explosive. Find the linear charge concentration.

$$q_L = \frac{\text{Charge}}{\text{Length}} = \frac{2.5}{3} = 0.83 \text{ kg/m}$$

Q17. Compare cartridge explosives vs bulk explosives (numerical on cost per kg).

7. Blast Design (Q18–Q20)

Q18. For a bench of 10 m height, take burden = 2.5 m and spacing = 3.0 m. Calculate the number of holes for a bench 50 m long (staggered pattern).

$$N = \left(\frac{\text{Length}}{\text{Spacing}}\right) \times \text{rows}$$
$$= \left(\frac{50}{3}\right) \times 2 = 33 \ (\approx 34 \text{ holes})$$

Q19. Calculate stemming length if hole depth is 3.5 m and stemming ratio is 0.25.

$$T = 0.25 \times 3.5 = 0.875 \text{ m}$$

Q20. If charge per hole = 6 kg and 34 holes are used, find the total explosive required.

$$Q_{ottal} = 6 \times 34 = 204 \text{ kg}$$

8. Powder Factor (Q21–Q22)

Q21. A blast uses 250 kg of explosive and produces 1250 m³ of rock. Find the powder factor.

$$PF = \frac{W}{V} = \frac{250}{1250} = 0.20 \text{ kg/m}^3$$

Q22. If the powder factor is 0.35 kg/m³ and 3000 m³ of rock is to be blasted, find the explosive required.

$$W = PF \times V = 0.35 \times 3000 = 1050 \text{ kg}$$

Typical PF values (kg/m³)	
Soft rock	0.2 – 0.4
Medium rock	0.4 – 0.6
Hard rock	0.6 – 0.8

9. Ground Vibration (Q23–Q24)

Q23. The peak particle velocity at 50 m distance is 25 mm/s for a charge of 10 kg. Estimate PPV at 100 m using SD concept (n = 1.6).

$$\frac{PPV_1}{PPV_2} = \left(\frac{R_2}{R_1}\right)^n$$
$$PPV_2 = 25 \left(\frac{100}{50}\right)^{-1.6} = 8.25 \text{ mm/s}$$

Q24. Check whether a blast with PPV = 12 mm/s is within safe limit for a residential building (allowable = 15 mm/s).

Since 12 < 15 mm/s → Safe

10. Comprehensive Numerical (Q25)

Q25. A bench of 8 m height is to be blasted in a hard rock. Hole diameter = 115 mm, burden = 2.5 m, spacing = 3.0 m, stemming = 25% of hole depth, charge concentration = 0.8 kg/m, powder factor = 0.45 kg/m³. For a bench length of 60 m, design the blast and calculate: (i) number of holes (ii) charge per hole (iii) total explosive (iv) expected muck volume (v) PPV at 100 m (use SD formula with given site constant).

Use all concepts together:
- ✓ Drilling
- ✓ Blast design
- ✓ Charge calculation
- ✓ Powder factor
- ✓ Vibration prediction

"Numericals turn knowledge into real problem solving. Practice more, perform better."

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Study Practice Succeed

Questions Today → Concepts Stronger → GATE Success Tomorrow

GATE 2027
MINING ENGINEERING (MN)

DAY - 16

MINING GEOLOGY & MINE DEVELOPMENT

50 MCQ / MSQ / NAT (PRACTICE SET)

"Practice Today → Stronger Concepts → Higher Score in GATE."

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Mining Knowledge Today A Better Tomorrow

1. MCQ – Mineralogy

Which of the following is NOT a common gangue mineral in metallic ore deposits?

(A) Quartz (B) Calcite
(C) Feldspar (D) Galena

Gangue minerals are generally non-valuable. Galena (PbS) is an ore mineral.

2. MCQ – Rock Properties

The property of a rock that indicates its resistance to indentation or scratching is called:

(A) Toughness (B) Hardness
(C) Cleavage (D) Porosity

Hardness is resistance to scratching (identified using Mohs scale).

3. MCQ – Structural Geology

In a bedding plane, the true dip is 30° towards N60°E. What is the strike direction?

(A) N60°E (B) N30°W
(C) N30°E (D) N60°W

Strike is perpendicular to dip direction. Strike = N60°W (or S60°E).

4. MCQ – Methods of Access

Which of the following is generally NOT considered an advantage of a tunnel (adit) for accessing a deposit?

(A) Lower construction cost
(B) Useful in hilly terrain
(C) Provides natural drainage
(D) Limited to above water table

Tunnels (adits) are generally used above the water table due to natural drainage.

5. MCQ – Underground Drivages

A raise is a nearly vertical excavation driven:

(A) Downwards from a higher level
(B) Upwards from a lower level
(C) Horizontally between two shafts
(D) At a slight inclination for transportation

A raise is a vertical or near-vertical excavation driven upwards.

6. MCQ – Drilling

Which drilling method is best suited for large diameter holes in hard rock for production blasting in surface mines?

(A) Percussion drilling
(B) Rotary drilling
(C) Rotary-percussive (DTH) drilling
(D) Top-hammer drilling

DTH (rotary-percussive) is widely used for large diameter, deep holes in hard rock.

7. MCQ – Explosives

Which of the following explosives is classified as a slurry explosive?

(A) ANFO (B) Dynamite
(C) Emulsion (D) Gelignite

Slurry explosives are water-resistant bulk explosives, commonly emulsion based.

8. MCQ – Blast Design

In bench blasting, an increase in burden generally results in:

(A) Finer fragmentation
(B) Coarser fragmentation
(C) No change in fragmentation
(D) Decrease in throw

Larger burden → higher rock volume per hole → coarser fragmentation (if not optimized).

9. MCQ – Ground Vibration

Peak particle velocity (PPV) due to blasting is mainly measured in:

(A) m/s (B) mm/s
(C) cm/s (D) Hz

PPV is measured in mm/s. It is used to assess potential damage.

10. MSQ – Multiple Correct

Which of the following are used to control ground vibrations due to blasting?

(A) Use of delay detonators
(B) Proper burden and spacing
(C) Increase in charge per hole
(D) Smooth blasting / pre-splitting

(A), (B) and (D) help in controlling vibrations. (C) increases vibration.

11. MSQ – Multiple Correct

Identify the correct statements regarding powder factor (PF).

(A) It is expressed in kg/m³.
(B) Higher PF generally gives finer fragmentation.
(C) PF depends on rock properties and blast design.
(D) It is the ratio of total explosive to volume of rock.

Correct: (A), (C) and (D).
(B) is not always correct (very high PF may overbreak).

12. NAT – Numerical Answer Type

A blast uses 1200 kg of explosive to break 5000 m³ of rock. What is the powder factor (kg/m³)?
(Write answer up to two decimal places)

Answer: _____

PF = W/ V = 1200 / 5000 = 0.24 kg/m³

Question Distribution

Type	No. of Questions
MCQ	35
MSQ	10
NAT	5
Total	50

Topics Covered

- ✔ Mineral & rock properties
- ✔ Structural geology
- ✔ Methods of access to deposits
- ✔ Underground drivages
- ✔ Drilling methods & machines
- ✔ Explosives & initiation systems
- ✔ Blast design practices & calculations
- ✔ Ground vibration & blast effects

Exam Preparation Tips

- ✔ First revise concepts, then attempt.
- ✔ Focus on diagrams and numerical practice.
- ✔ Practice time-bound questions.
- ✔ Analyze your mistakes.
- ✔ Try to solve without looking at options.
- ✔ Improve weak areas and revise regularly.

"Practice is the bridge between concepts and success."

GATE 2027
MINING ENGINEERING (MN)
DAY - 17

MINING GEOLOGY & MINE DEVELOPMENT

FORMULA + FACT SHEET

Key Formulas | Important Facts | Quick Revision

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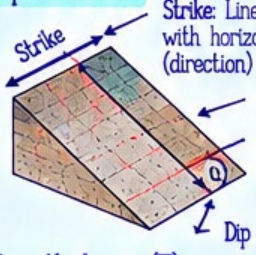
Mining Knowledge Today A Better Tomorrow

1. Mineral / Rock Identification

Property	Key Points
Colour	Useful but not reliable (can vary)
Streak	Colour of powdered mineral
Lustre	Metallic / Non-metallic
Hardness	Mohs scale (1–10)
Cleavage	Planes of weakness
Fracture	Irregular break (conchoidal, uneven)
Specific gravity	Mineral density (g/cc)
Other tests	Acid test (calcite – effervescence), Magnetic test (magnetite)

2. Geological Structures

Dip & Strike



Strike: Line of intersection with horizontal plane (direction)

Dip: Maximum inclination (perpendicular to strike)

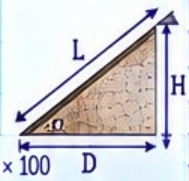
True thickness (T)

$$T = t \times \sin\theta$$

t = apparent thickness
θ = dip angle

3. Access Methods (Tunnels/Inclines/Shafts)

Parameter	Formula / Relation
Length of incline (L)	$L = \frac{H}{\sin\alpha}$
Horizontal distance (D)	$D = \frac{H}{\tan\alpha}\tan\alpha$
Vertical depth (H)	$H = L \times \sin\alpha$
Gradient (%)	$\text{Gradient} = \frac{H}{D} \times 100$
Use	Inclines – for shallow to medium depth Shafts – for deep deposits Tunnels (adits) – for near surface access



4. Drilling Machines

Type	Application	Hole Diameter
Hand drilling	Small works	< 50 mm
Percussion	Small to medium	50 – 100 mm
Rotary (top-hammer)	Medium to large	65 – 165 mm
DTH	Large diameter, deep holes	100 – 300 mm
Rotary-percussive	Hard rocks	100 – 300 mm

5. Explosives – Important Facts

Properties	High energy, adequate strength, suitable sensitivity, stability, water resistance
Types	Cartridge explosives, Bulk explosives, Slurry explosives
Common explosives	ANFO, Emulsion, Dynamite, Gelignite, Slurry
Initiation systems	Electric, Non-electric (NONEL), Electronic detonators
Key terms	VOD – Velocity of detonation RBS – Relative bulk strength Sensitivity – ease of initiation

6. Blast Design Formulas

Burden (B)	$B = K_b \times D$
Spacing (S)	$S = K_s \times B$ (usually 1.0 – 1.5 B)
Stemming (T)	$T = K_t \times B$ (usually 0.7 – 1.0 B)
Sub-drilling (J)	$J = K_j \times B$ (usually 0.2 – 0.3 B)
Charge per hole (Q)	$Q = q \times L$ q = linear charge concentration (kg/m), L = charge length (m)
Total explosive (Q_{total})	$Q_{total} = n \times Q$ n = number of holes
Powder factor (PF)	$PF = \frac{W}{V}$ (kg/m³) W = total explosive (kg) V = volume of rock (m³)

7. Ground Vibration Formulas

Scaled distance (SD)

$$SD = \frac{D}{\sqrt{W}}$$

D = distance from blast (m)
W = maximum charge per delay (kg)

Empirical prediction equation

$$PPV = K\,(SD)^{-n}$$

PPV = peak particle velocity (mm/s)
K, n = site constants

Typical allowable PPV (mm/s)

Residential buildings	5 – 10
Industrial buildings	10 – 25
Reinforced concrete	25 – 50
Underground openings	25 – 50

Keep PPV within prescribed safe limits.

8. Useful Constants & Typical Values

Parameter		Typical Range
Rock density (ρ)		2.4 – 2.8 g/cc
Uniaxial compressive strength (UCS)		50 – 250 MPa
RMR (Rock mass rating)		0 – 100
Typical burden/spacing ratio		1.0 – 1.5
Stemming ratio (T/B)		0.7 – 1.0
Sub-drilling ratio (J/B)		0.2 – 0.3
Powder factor (PF)	Soft rock	0.2 – 0.4 kg/m³
	Medium rock	0.4 – 0.6 kg/m³
	Hard rock	0.6 – 0.8 kg/m³
Typical VOD		3000 – 6000 m/s

9. Comparison Tables

Explosives Comparison

Explosive	RBS	VOD (m/s)	Water Resistance	Use
ANFO	1.0	3200	Poor	Dry holes
Dynamite	1.2	4500	Moderate	General
Emulsion	1.1 – 1.3	4000 – 5000	Good	Wet/Dry
Slurry	0.9 – 1.1	3000 – 4500	Good	Wet holes
Gelignite	1.4	7500	Poor	Special

Drilling Methods Comparison

Method	Hole Diameter	Penetration Rate	Best Suited For
Percussion	50–100 mm	Low	Soft–medium rock
Rotary	65–165 mm	Medium	Medium–hard rock
DTH	100–300 mm	High	Hard rock, deep holes
Top-hammer	65–165 mm	High	Surface / benches

10. Quick Facts for GATE

- ✓ Galena (PbS) – most common gangue mineral in metallic ores.
- ✓ Strike is always perpendicular to dip direction.
- ✓ Tunnels (adits) are used for near-surface deposits.
- ✓ ANFO is the most widely used bulk explosive.
- ✓ Larger scaled distance → lower PPV.
- ✓ Powder factor increases with rock hardness.
- ✓ Proper blast design reduces vibration, fly rock and overbreak.
- ✓ Mine development improves access, productivity and safety.

11. Key Takeaways

- ✓ Understand and remember key formulas.
- ✓ Practice numerical problems regularly.
- ✓ Use typical values for quick estimation.
- ✓ Draw neat diagrams for strike, dip and blast design.
- ✓ Focus on concept-based and application-oriented questions.
- ✓ Combine geology + development + blasting for better scoring.

"Formulas in hand,
Confidence in mind,
Success in GATE!"

Revise
Practice
Solve
Improve
Score Higher!

GATE 2027
MINING ENGINEERING (MN)

DAY - 18

MINING GEOLOGY & MINE DEVELOPMENT

FULL LENGTH MOCK TEST

Mixed MCQ + MSQ + NAT + Numericals + Diagrams + Complete Revision

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Total Questions: 20
Time: 60 Minutes
Max Marks: 100

1. MCQ – Mineralogy [1 Mark]

Which of the following is NOT a common gangue mineral in metallic ore deposits?

(A) Quartz (B) Calcite
(C) Feldspar (D) Galena

2. MCQ – Structural Geology [1 Mark]

In a bedding plane, the true dip is 40° towards N60°E. What is the strike direction?

(A) N30°E (B) N60°W
(C) N30°W (D) N60°E

3. MCQ – Mine Development [1 Mark]

Which method of access is generally preferred for steeply dipping ore bodies?

(A) Adit (B) Vertical shaft
(C) Incline (D) Decline

4. MCQ – Drilling [1 Mark]

Which drilling method is most suitable for large diameter holes in hard rock?

(A) Percussion (B) Rotary
(C) DTH (D) Top-hammer

5. MCQ – Explosives [1 Mark]

ANFO is mainly composed of:

(A) Ammonium nitrate + Fuel oil
(B) Ammonium nitrate + Aluminium
(C) Nitroglycerin + Ammonium nitrate
(D) RDX + TNT

6. MCQ – Ground Vibration [1 Mark]

Peak particle velocity (PPV) due to blasting is mainly measured in:

(A) m/s (B) mm/s
(C) cm/s (D) Hz

7. MSQ – Correct Statements [2 Marks]

Which of the following statements are correct regarding underground coal mining?

(A) Room and pillar method is suitable for thick coal seams.
(B) Longwall mining provides higher recovery and productivity.
(C) Goaf is the void left after extraction.
(D) Shrinkage stoping is used for tabular orebodies.

Select the correct option:
(A) A, B and C (B) B, C and D
(C) A, C and D (D) A, B, C and D

8. MSQ – Drill & Blast [2 Marks]

Which of the following factors increase fragmentation (smaller size)?

(A) Higher powder factor
(B) Closer spacing
(C) Proper stemming
(D) Lower charge diameter

Select the correct option:
(A) A, B and C (B) B, C and D
(C) A, C and D (D) A, B, C and D

9. MSQ – Mining Geology [2 Marks]

Which of the following are indicators of a good ore deposit?

(A) Favourable structure and continuity
(B) High grade and sufficient tonnage
(C) Simple geometry
(D) Absence of faults

Select the correct option:
(A) A, B and C (B) B, C and D
(C) A, C and D (D) A, B, C and D

10. NAT – Short Answer (Integer) [2 Marks]

A vertical depth of a deposit is 250 m. It is accessed through a decline driven at 1 in 7 gradient. What is the length of the decline (in metres)? (Round off to nearest integer)

Answer: _____ m

11. NAT – Concept Based (Integer) [2 Marks]

A blast produces a PPV of 12 mm/s at a distance of 100 m. Using the SD concept ($n = 1.6$), estimate the PPV (in mm/s) at 50 m.

Answer: _____ mm/s

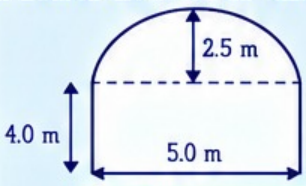
12. NAT – Quick Calculation [2 Marks]

A blast hole of 115 mm diameter and 3.0 m depth is charged with explosive of density 1200 kg/m³ and charge concentration 0.8 kg/m. Find the total charge (in kg).

Answer: _____ kg

13. Numerical – Volume Calculation [4 Marks]

A tunnel of horseshoe section (width = 5.0 m, height to springing = 4.0 m, radius of top = 2.5 m) is driven for 120 m. Find the volume of excavation.



Answer: _____ m³

14. Numerical – Drill Hole Pattern [4 Marks]

For a bench of 10 m height, burden = 2.5 m, spacing = 3.0 m and hole diameter = 115 mm. Calculate:
(i) No. of holes for a 50 m long bench,
(ii) Total explosive required (kg) if charge concentration = 0.8 kg/m and stemming = 25% of hole depth.

Answer:
(i) No. of holes = _____
(ii) Total explosive = _____ kg

15. Numerical – Powder Factor [4 Marks]

A blast uses 300 kg of explosive and produces 1500 m³ of rock. Calculate the powder factor (kg/m³).

Answer: _____ kg/m³

16. Geological Interpretation [4 Marks]

A bed strikes N40°E and dips 30°SE.
(i) Draw the strike and dip on a neat sketch.
(ii) What will be the dip direction in quadrant form?

Answer:
(i) Sketch: (draw below)
(ii) Dip direction: _____

17. Conceptual – Short Answer [4 Marks]

(a) Differentiate between rotary and DTH drilling. (2 points)

(b) Mention any four environmental effects of blasting. (any 4 points)

18. Long/Numerical [6 Marks]

A sandstone bench of 12 m height is to be blasted. Burden = 3.0 m, spacing = 3.5 m, stemming = 0.8 m, hole diameter = 115 mm, charge concentration = 0.9 kg/m. The bench length is 70 m.
(i) Prepare a suitable blast pattern (sketch).
(ii) Calculate number of holes and total explosive.
(iii) Estimate the powder factor if 2800 m³ of rock is broken.

19. NAT – Identification [2 Marks]

Name the explosive which is water-gel based and commonly used in wet conditions.

Answer: _____

20. Mixed – Revision [2 Marks]

Name the mining method best suited for a thin, steeply dipping, high-grade vein deposit.

Answer: _____

All the Best!
Revise • Practice • Improve
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MINING ENGINEERING (MN)

MINE SURVEYING

DAY - 1

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Levels & Levelling – Fundamentals

"Measure the ground, plan the future."

1. Principle of Levelling

- Levelling is the process of determining the relative elevations (Reduced Levels) of points on the earth's surface.
- It is based on the principle that a level surface is always horizontal.
- The line of collimation (line of sight) of a level is made horizontal by a spirit level.

"A level line is a horizontal line, and all points on a level line are at the same elevation."

2. Important Terms

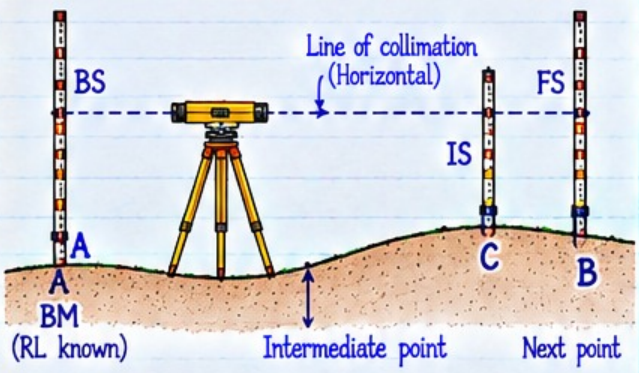
- **Datum** : An arbitrary reference surface from which all elevations are measured (usually Mean Sea Level).
- **Benchmark (BM)** : A fixed point of known RL.
- **Reduced Level (RL)** : Elevation of a point with respect to datum.
- **Back Sight (BS)** : First staff reading taken after setting up the instrument.
- **Intermediate Sight (IS)** : Any other staff reading at intermediate points.
- **Fore Sight (FS)** : Last staff reading before shifting the instrument.

3. Levelling Instrument



Auto Level (Most commonly used)

4. Levelling Setup and Staff Readings



Typical levelling operation

5. Methods of Levelling

(a) Height of Instrument (HI) Method

- Find Height of Instrument (HI)
  HI = RL of BM + BS
- RL of other points = HI – staff reading

Example:

RL of BM (A) = 100.000 m
BS on A = 1.265 m
HI = 100.000 + 1.265
= 101.265 m
IS on C = 1.850 m
RL of C = 101.265 – 1.850
= 99.415 m
FS on B = 2.435 m
RL of B = 101.265 – 2.435
= 98.830 m

(b) Rise and Fall Method

- Find the rise or fall between successive points.
- Add rise to previous RL or subtract fall to get next RL.

Example:

From	To	Staff Reading (m)	Rise (m)	Fall (m)	RL (m)
A	C	1.265	–	–	100.000
	C	1.850	–	0.585	99.415
C	B	2.435	–	0.585	98.830

Rise = Previous reading – Current reading
Fall = Current reading – Previous reading

6. Arithmetic Check

- Sum of BS – Sum of FS = Last RL – First RL
- ΣBS – ΣFS = RL (last) – RL (first)
- This is used to check the accuracy of levelling calculations.

"If the arithmetic check fails, recheck your readings and calculations."

7. Types of Levelling

- **Simple levelling** – RLs of nearby points.
- **Differential levelling** – RLs of distant points.
- **Fly levelling** – Transfer of RL between BMs.
- **Profile (Longitudinal) levelling** – Along a line.
- **Cross-sectional levelling** – At right angles.
- **Reciprocal levelling** – Across obstacles (rivers, valleys).
- **Precise levelling** – High accuracy work.

8. Applications

- ✓ Preparation of contour maps.
- ✓ Design of surface and underground mine layouts.
- ✓ Determination of depth, height and volume.
- ✓ Planning of haul roads, drainage and structures.
- ✓ Monitoring of subsidence and mine deformation.
- ✓ General surveying and mapping in mining projects.

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MINE SURVEYING

DAY - 2

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Levelling – Calculations & Errors

"Accurate levelling leads to better designs, safer mines and lower costs."

1. Arithmetic Check in Levelling

- For a closed levelling the following checks must be satisfied:

$$\Sigma BS - \Sigma FS = RL\ (last) - RL\ (first)$$

$$\Sigma Rise - \Sigma Fall = RL\ (last) - RL\ (first)$$

- If last point is same as first point (closed loop):

$$\Sigma BS = \Sigma FS \quad and \quad \Sigma Rise = \Sigma Fall$$

- If not equal → Error in levelling (calculations or observations).

2. Reciprocal Levelling

- Used across obstacles like rivers, valleys, roads to eliminate errors due to curvature, refraction and collimation.
- Take two sets of observations with instrument on both sides.

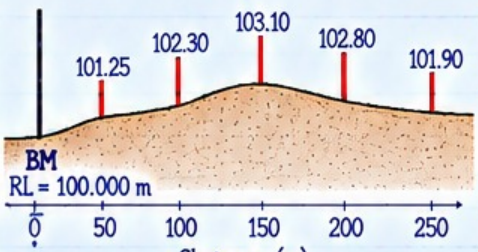


True difference in level:

$$\Delta h = \frac{1}{2}\left[(a_1 - b_1) + (a_2 - b_2)\right]$$

3. Profile Levelling (Longitudinal)

- Carried out along a line to obtain RLs at regular chainages.
- Used for roadways, haul roads, pipelines, trenches, surface layouts etc.



Profile Levelling

4. Fly Levelling

- Transfer of RL from one known BM to another distant BM without considering intermediate points.
- Used for quickly establishing RLs over long distances.
- Used in reconnaissance surveys.



Fly Levelling

5. Curvature and Refraction

- Due to earth's curvature and atmospheric refraction, the line of sight is not truly horizontal, causing error in long sights.
- Combined correction (C) is given by:

$$C = -0.0673\ D^2$$

(D in km, C in metres)

- Negative sign indicates the line of sight is above the true horizontal.
- For small distances (< 0.3 km), the correction is usually negligible.
- For long sights, apply correction to observed staff reading.

6. Common Levelling Errors

Type of Error	Effect / Remedy
Instrumental errors	Collimation error, faulty levelling screws, staff error → proper adjustment & calibration
Natural errors	Curvature, refraction, wind, temperature → use reciprocal levelling, apply corrections
Personal errors	Parallax, wrong staff reading, booking mistakes → careful observation & recording
Arithmetic errors	Wrong calculations → check ΣBS, ΣFS and ΣRise, ΣFall
Staff not vertical	Gives higher reading → keep staff vertical (use staff level)

7. Numerical Example – Arithmetic Check

Find the missing FS and check the arithmetic condition.

Station	BS	IS	FS	RL (m)
A (BM)	1.560	–	–	100.000
1	–	0.865	–	–
2	–	1.275	–	–
3	–	–	1.485	–

Solution:

HI = 100.000 + 1.560 = 101.560 m

RL of 1 = 101.560 − 0.865 = 100.695 m

RL of 2 = 101.560 − 1.275 = 100.285 m

FS = 101.560 − 1.485 = 100.075 m

Check: ΣBS = 1.560, ΣFS = 1.485

ΣBS − ΣFS = 0.075 = RL (last) − RL (first)

= 100.075 − 100.000 = 0.075 ✓

8. Numerical Example – Curvature & Refraction

A staff reading is taken at a distance of 2 km. Find the combined curvature and refraction correction.

Solution:

$$C = -0.0673\ D^2$$

$$= -0.0673 \times (2)^2$$

$$= -0.0673 \times 4$$

$$= -0.2692\ m$$

Corrected reading = Observed reading − 0.269 m
(i.e., reduce the staff reading)

Key Takeaways

- ✓ Always perform arithmetic checks.
- ✓ Use reciprocal levelling for long sights.
- ✓ Apply curvature & refraction corrections.
- ✓ Profile levelling is used for road/underground alignment.
- ✓ Minimize personal and instrumental errors.

9. Important Formulas (Quick Revision)

- $\Sigma BS - \Sigma FS = RL\ (last) - RL\ (first)$
- $\Sigma Rise - \Sigma Fall = RL\ (last) - RL\ (first)$
- $C = -0.0673\ D^2$ (D in km)
- Reciprocal levelling: $\Delta h = \frac{1}{2}\left[(a_1 - b_1) + (a_2 - b_2)\right]$
- HI = RL of BM + BS
- RL = HI − Staff reading
- For closed loop: ΣBS = ΣFS

"Small errors in levelling can lead to big mistakes in mining projects. Be accurate!"

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MINE SURVEYING

DAY - 3

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Tacheometry — Fundamentals

"Quick measurement, greater coverage."

1. What is Tacheometry?

- Tacheometry is a rapid surveying method to determine horizontal distance, vertical distance and elevation difference indirectly using a tacheometer and a staff.
- It is very useful for rough surveys, large areas and inaccessible terrain.

Principle: Measure the intercept on a staff using stadia hairs and use it to compute distance and elevation difference.

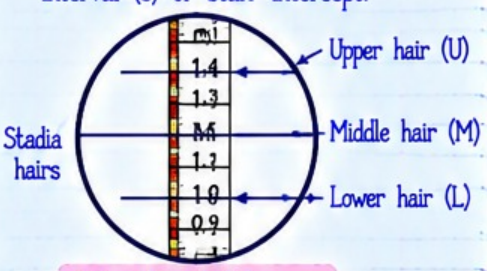
2. Tacheometer



Modern tacheometer (theodolite with stadia hairs)

3. Stadia Method

- Three horizontal hairs are provided in the diaphragm: upper (U), middle (M) and lower (L).
- The difference between upper and lower staff readings is called the stadia interval (s) or staff intercept.



View through telescope

4. Stadia Constants

General equation: $D = Ks + C$

K = Multiplying constant (normally 100)
C = Additive constant (normally 0)
s = Staff intercept (U – L)
D = Horizontal distance (for horizontal sight)

Type of Instrument	K	C
Cincinnati tacheometer	100	0
Cooks tacheometer	100	0
Anallactic lens (modern)	100	0
Some older instruments	100	few cm

In most modern instruments, K = 100 and C = 0.

5. Horizontal Distance (D)

(a) Horizontal line of sight ($\theta = 0°$)

$$D = Ks + C$$

If K = 100 and C = 0 → $D = 100\,s$

(b) Inclined line of sight ($\theta \neq 0°$)

$$D = Ks\cos^2\theta + C\cos\theta$$

If K = 100, C = 0 → $D = 100\,s\cos^2\theta$

D = Horizontal distance (m)
s = Staff intercept (m)
θ = Vertical angle (+ ve for elevation, – ve for depression)

6. Elevation Difference (V)

(a) With vertical angle

$$V = \left(\frac{Ks}{2}\right)\sin 2\theta + C\sin\theta$$

If K = 100, C = 0 → $V = 50\,s\sin 2\theta$

(b) Using staff readings

$$V = D\tan\theta$$

RL of staff station = RL of instrument + HI (or height of instrument) ± V

Use '+' when the staff point is higher than instrument (elevation).
Use '–' when the staff point is lower than instrument (depression).

7. Numerical Example

In a tacheometric survey with anallactic lens (K = 100, C = 0), the staff readings are: U = 2.325 m, M = 1.865 m, L = 1.405 m. The vertical angle θ = +5°. Find (i) horizontal distance and (ii) elevation difference.

Solution:

$s = U - L = 2.325 - 1.405 = 0.920$ m

(i) $D = 100\,s\cos^2 5°$
$= 100 \times 0.920 \times (0.9962)^2$
$= 91.3$ m (approx)

(ii) $V = 50\,s\sin 2 \times 5°$
$= 50 \times 0.920 \times \sin 10°$
$= 7.99$ m (approx)

8. Advantages & Limitations

Advantages

- ✓ Quick and economical.
- ✓ Useful for large and inaccessible areas.
- ✓ No chaining required.
- ✓ Suitable for rough topographical surveys.
- ✓ Provides both distance and elevation difference simultaneously.

Limitations

- ✗ Less accurate than chain and EDM methods.
- ✗ Affected by atmospheric conditions (refraction, curvature).
- ✗ Not suitable for precise engineering work.
- ✗ Requires clear line of sight.

9. Key Takeaways

- Tacheometry uses stadia hairs and staff intercept.
- $D = Ks + C$ (horizontal sight)
- $D = 100\,s\cos^2\theta$ (with anallactic lens)
- $V = 50\,s\sin 2\theta$ (elevation difference)
- Stadia constants for modern tacheometer: K = 100, C = 0.
- Useful for rapid surveys in mining, hilly and inaccessible areas.
- Understand instrument, formulas and practice numericals.

"Measure more. Explore further."

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MINE SURVEYING

DAY - 4

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Tacheometry – GATE Numericals

"Practice more... Measure better!"

1. Key Formulae (Inclined Sight)

General equation: $D = K s \cos^2\theta + C \cos\theta$

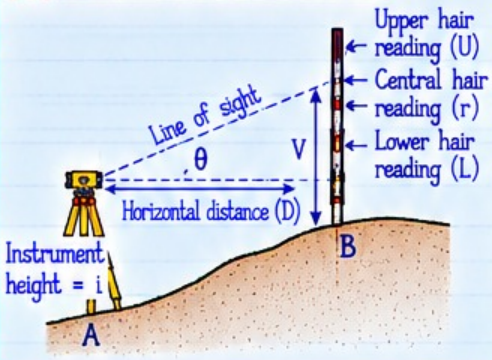
Vertical component: $V = K s \cos\theta \sin\theta + C \sin\theta$

Difference in elevation:

$$\Delta h = V + (i - r)$$

- D = Horizontal distance (m)
- V = Vertical distance between instrument axis and staff point (m)
- s = Staff intercept (m)
- θ = Angle of inclination
- i = Height of instrument (m)
- r = Staff reading at central hair (m)
- K = Multiplying constant (≈100)
- C = Additive constant (≈0 for anallactic lens)

2. Inclined Sight Diagram



For inclined sights, horizontal distance is obtained using $\cos^2\theta$ and vertical distance using $\cos\theta \sin\theta$.

3. Anallactic Lens (C = 0)

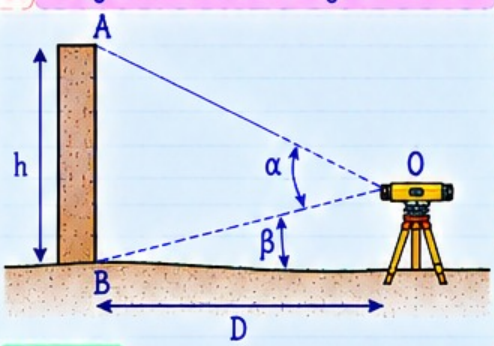
- In modern tacheometers, an anallactic lens is provided so that the additive constant C = 0.
- This eliminates the error due to focusing and makes the staff reading direct.
- Then the formulae reduce to:

$$D = K s \cos^2\theta$$

$$V = K s \cos\theta \sin\theta$$

- For most instruments, K = 100.
- So, $D = 100 s \cos^2\theta$ and $V = 100 s \cos\theta \sin\theta$

4. Tangential Method (Height/Distance)



Formula:

$$h = D (\tan\alpha - \tan\beta)$$

Used when base is not accessible.

5. RL Calculations using Tacheometry

- RL of staff station = RL of instrument axis + V – r

$$RL_B = RL_A + i + V - r$$

Where,

- RL_A = Reduced level of instrument station (m)
- i = Height of instrument (m)
- V = Vertical component from tacheometry (m)
- r = Staff reading at central hair (m)

6. Numerical Example 1 (Inclined Sight)

A tacheometer (K = 100, C = 0) is used with an inclined sight of 10°. Staff readings: U = 2.465 m, L = 1.235 m, r = 1.850 m. Height of instrument = 1.500 m. Find (i) Horizontal distance (D) (ii) Vertical distance (V) (iii) RL of staff station if RL of instrument station = 100.000 m.

Solution:

$s = U - L = 2.465 - 1.235 = 1.230$ m

$D = 100 \times 1.230 \times \cos^2 10°$
$= 100 \times 1.230 \times 0.9698$
$= 119.29$ m

$V = 100 \times 1.230 \times \cos 10° \times \sin 10°$
$= 100 \times 1.230 \times 0.9848 \times 0.1736$
$= 21.01$ m

$RL_B = 100.000 + 1.500 + 21.01 - 1.850$
$= 120.66$ m

7. Numerical Example 2 (Tangential Method)

Angles of elevation and depression to the top and bottom of a vertical cliff are 12° and 6° respectively. The horizontal distance from the instrument to the cliff is 150 m. Find the height of the cliff.

Solution:

$h = 150 (\tan 12° - \tan 6°)$
$= 150 (0.2126 - 0.1051)$
$= 150 \times 0.1075$
$= 16.13$ m

8. Numerical Example 3 (RL using Staff Readings)

A tacheometer (K = 100, C = 0) is used with an inclined sight of 5°. Staff readings: U = 1.965 m, L = 0.865 m, r = 1.415 m. Height of instrument = 1.350 m. If RL of instrument station = 250.000 m, find horizontal distance, vertical distance and RL of staff station.

Solution:

$s = 1.965 - 0.865 = 1.100$ m
$D = 100 \times 1.100 \times \cos^2 5° = 109.58$ m
$V = 100 \times 1.100 \times \cos 5° \times \sin 5°$
$= 9.57$ m
$RL_B = 250.000 + 1.350 + 9.57 - 1.415$
$= 259.51$ m

9. Common GATE Questions

- Horizontal distance for inclined sight.
- RL calculations using tacheometry.
- Height of tower/cliff using tangential method.
- Effect of anallactic lens.
- Finding K and C from field data.
- Comparison of tacheometric and EDM methods.

10. Key Takeaways

- ✓ Use $\cos^2\theta$ for horizontal distance.
- ✓ Use $\cos\theta \sin\theta$ for vertical distance.
- ✓ Anallactic lens makes C = 0.
- ✓ Tangential method is useful when base is inaccessible.
- ✓ Always check units and sign conventions.
- ✓ Practice numericals regularly.

"Surveying is not just about measurements, it's about seeing possibilities beyond the horizon."

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DAY - 5

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Triangulation

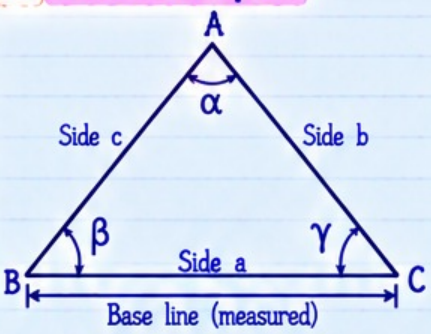
"Triangles today, accurate maps tomorrow."

1. What is Triangulation?

- Triangulation is the method of establishing the positions of points by measuring angles and a measured base line.
- It is widely used in large area surveying where direct linear measurement is not possible.
- Based on the principle of geometry that if one side and two angles of a triangle are known, the other sides and angles can be computed.

"Triangulation converts angles into distances and creates reliable control networks."

2. Basic Principle



If a, β and γ are known:

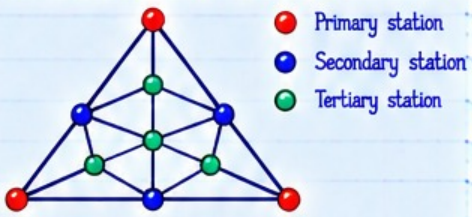
$$b = a \frac{\sin \beta}{\sin \alpha}, \quad c = a \frac{\sin \gamma}{\sin \alpha}$$

Angles are measured using theodolite and one side (base line) is measured accurately on ground.

3. Triangulation Systems

- **Primary (Main) Triangulation**
  → Large triangles covering large areas.
- **Secondary Triangulation**
  → Smaller triangles based on primary.
- **Tertiary Triangulation**
  → Still smaller triangles for detailed survey.

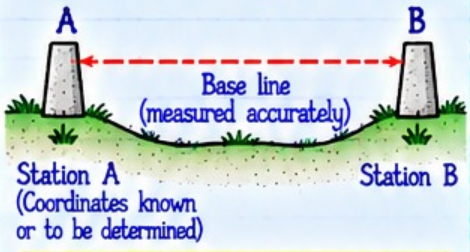
Hierarchy ensures accuracy from large scale to detailed mapping.



Triangulation network (hierarchy)

4. Stations and Baseline

- **Station** : A fixed point on ground whose position is to be determined.
- **Base line** : One side of a triangle measured accurately with chain, EDM or other precise instruments.
- The base line is the starting point for the entire triangulation network.

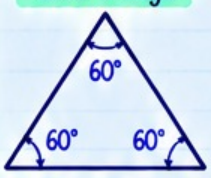


"A good base line is the key to a good triangulation network."

5. Well-Conditioned Triangles

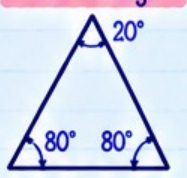
- Angles should be neither very small nor very large (ideally 30° – 120°).
- Triangles close to equilateral are most accurate.
- Avoid very acute or obtuse triangles.
- Well-conditioned triangles reduce the effect of angular measurement errors.

Good Triangle



Equilateral triangle (best condition)

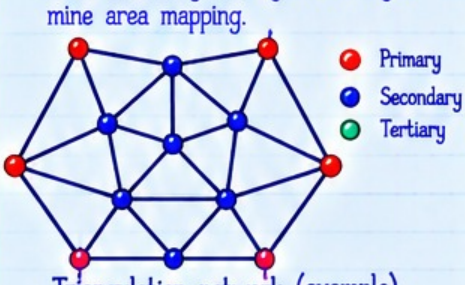
Poor Triangle



Angles too small/large (least accurate)

6. Triangulation Network

- A number of interconnected triangles covering the survey area.
- Provides control points for detail surveys.
- Networks can be single, double or multiple chains.
- Used for national surveys, mining lease boundary surveys and large mine area mapping.



Triangulation network (example)

7. Field Procedure

1. Reconnaissance survey – select suitable stations with intervisibility.
2. Mark and monument stations (permanent pillars).
3. Measure the base line accurately (chain/EDM).
4. Measure angles at each station using theodolite (repetition method).
5. Check and close the triangles.
6. Compute unknown sides and coordinates.
7. Prepare triangulation network and plot on plan/map.

8. Advantages and Limitations

Advantages

- ✓ Covers large and inaccessible areas.
- ✓ High accuracy.
- ✓ Provides control for detailed surveys.
- ✓ Useful for mining lease and regional mapping.
- ✓ Can be extended to form large networks.

Limitations

- ✗ Requires clear intervisibility between stations.
- ✗ Time consuming and costly.
- ✗ Affected by atmospheric conditions (refraction).
- ✗ Requires precise instruments and skilled staff.
- ✗ Not suitable for very small areas.

9. Key Takeaways

- ✓ Base line is the foundation.
- ✓ Use well-conditioned triangles (30° – 120°).
- ✓ Angles are measured, distances are computed.
- ✓ Networks provide control for detailed surveys.
- ✓ Accuracy depends on instrument, observation and triangulation design.
- ✓ Essential for large area surveys in mining projects.

"Triangulation builds the framework for precise mapping."

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MINE SURVEYING

DAY - 6

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Errors & Adjustments

"Find the error, make the correction, improve the map."

1. Types of Errors

Systematic Errors

- Occur due to definite causes.
- Follow a definite pattern (same magnitude and sign).
- Can be identified, estimated and corrected.
- **Examples:** wrong instrument calibration, tape standard error, improper adjustments.

Random Errors

- Occur due to accidental and unpredictable causes.
- Vary in magnitude and sign.
- Cannot be eliminated, but can be reduced by repeated observations and statistical methods.
- **Examples:** reading errors, atmospheric variations, small personal errors.

Gross Errors

- Blunders due to carelessness.
- Abnormally large compared to other observations.
- Must be detected and eliminated.

Examples: wrong staff reading, miscounting, booking mistakes.

2. Sources of Errors

Instrumental Errors

- Imperfect instrument design.
- Collimation error, level bubble error, eccentricity.
- Wear and tear, poor adjustments.
- **Example:** non-parallel line of sight and bubble axis.

Observational Errors

- Parallax, improper focusing.
- Misreading the staff/tape.
- Personal equation (reaction time).
- Wrong booking.
- Unfavourable weather conditions.

Natural Errors

- Atmospheric refraction.
- Temperature variations.
- Wind, pressure and humidity effects.
- Earth curvature.

3. Precision vs Accuracy

Accuracy

- Closeness of a measured value to the true value.
- Affected by systematics.
- **Example:** True length = 100 m
  Measured = 100.1 m
  (High accuracy).



High accuracy (near true value)

Precision

- Closeness of repeated measurements to each other.
- Indicates consistency.
- Affected by random errors.
- **Example:** Repeated readings = 99.8 m, 99.9 m, 99.8 m
  (High precision).



High precision (consistent readings)

A survey should be both precise and accurate for reliable results.

4. Propagation of Errors

If a quantity Q is a function of measured quantities (x, y, z ....) with small errors, the probable error in Q is given by:

$$\Delta Q = \sqrt{\left(\left(\frac{\partial Q}{\partial x}.\Delta x\right)^2 + \left(\frac{\partial Q}{\partial y}.\Delta y\right)^2 + \left(\frac{\partial Q}{\partial z}.\Delta z\right)^2 + \ldots\right)}$$

For simple cases:

- $Q = x \pm y \rightarrow \Delta Q = \sqrt{\Delta x^2 + \Delta y^2}$
- $Q = x \times y \rightarrow \frac{\Delta Q}{Q} = \sqrt{\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2}$
- $Q = \frac{x}{y} \rightarrow \frac{\Delta Q}{Q} = \sqrt{\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2}$

Larger number of observations reduces random errors ($\Delta \propto 1/\sqrt{n}$).

5. Least Squares Adjustment

- Used to obtain the most probable values of observations.
- Minimizes the sum of squares of errors (Σv^2) minimum).
- Condition equations are formed based on geometry/field observations.
- More weight is given to precise observations.

Basic Equation

$$v = Ax - L$$

Normal Equation

$$(A^T P A)\, x = A^T P L$$

- A = Coefficient matrix
- P = Weight matrix ($P = 1/\sigma^2$)
- L = Observed values
- x = Corrections/unknowns
- v = Residuals (errors after adjustment)

Result: Most probable (best) values of unknowns.

6. Adjustment of a Closed Traverse

- In a closed traverse, theoretical $\Sigma Lat = 0$ and $\Sigma Dep = 0$.
- If there is a misclosure, distribute the corrections to make the traverse closed.

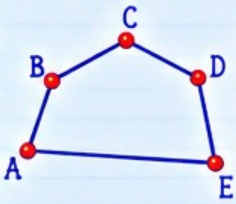
Bowditch (Compass) Rule

$$\text{Correction to latitude} = -(\Sigma Lat) \times \left(\frac{\text{Length of side}}{\text{Total length}}\right)$$

$$\text{Correction to departure} = -(\Sigma Dep) \times \left(\frac{\text{Length of side}}{\text{Total length}}\right)$$

After adjustment:

$\Sigma Lat = 0$ and $\Sigma Dep = 0$



A properly adjusted traverse gives consistent coordinates and a reliable map.

7. Detection of Gross Errors

- Check for unusually large or odd readings.
- Use arithmetic checks (e.g., $\Sigma BS - \Sigma FS$).
- Repeat doubtful observations.
- Compare with nearby stations or alternative methods.
- Plot on plan – look for abnormal closure.

"Always verify your data before adjustment."

8. Practical Tips to Minimize Errors

- ✓ Use well-maintained and calibrated instruments.
- ✓ Take multiple readings and use mean values.
- ✓ Avoid parallax (proper focusing).
- ✓ Observe under favourable weather conditions.
- ✓ Use standardized procedures and field books.
- ✓ Cross-check calculations and apply arithmetic checks.
- ✓ Train the team and maintain consistency.

9. Key Takeaways

- Errors are inevitable, but can be identified, reduced and adjusted.
- Understand the type and source of error.
- Apply proper correction and adjustment methods.
- Precision and accuracy are essential for reliable surveying.
- Least squares method provides the best estimates.
- Careful field work and good practices minimize errors.

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MINE SURVEYING

DAY - 7

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Correlation of Underground & Surface Surveys

"One Mine – One Coordinate System"

1. What is Correlation?

- Correlation is the process of establishing a common reference between surface and underground surveys.
- It ensures that underground workings are correctly located with respect to surface features on the same coordinate system.
- Essential for safe, accurate and efficient mine planning and production.

"Correlation connects the mine below the ground with the world on the surface."

2. Purpose of Correlation

- To transfer surface control points to underground.
- To locate underground workings on surface plans and vice-versa.
- To ensure accuracy in mine planning, ventilation, drainage and development.
- To avoid deviation and intersection errors between surface and underground workings.
- To provide a unified mine map for design, production and safety.

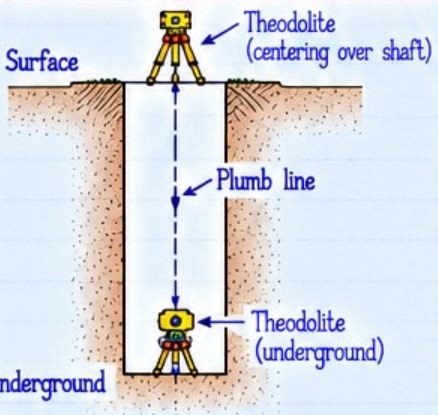
Accurate correlation = Safe mining + Better planning + Cost efficiency

3. Methods of Correlation

1. Shaft Correlation (Plumb line / Gyro / Optical)
2. Inclined Shaft Correlation (Using measured angles & distances)
3. Borehole (Raise/Winze) Correlation (Using drilling and survey instruments)
4. Traverse Correlation (Extending surface and underground traverses to common points)

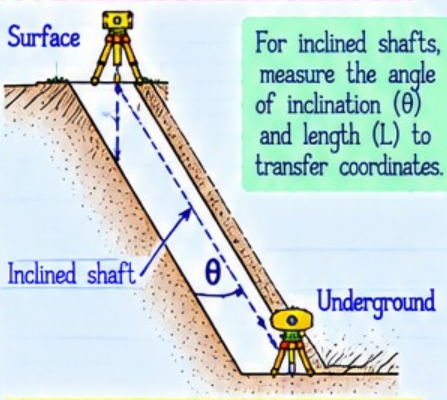
Choose method based on mine type, shaft inclination, depth and required accuracy.

4. Shaft Correlation (Vertical Shaft)



- A plumb line is suspended in the shaft.
- Surface and underground theodolites are centered on the same plumb line.
- Coordinates are transferred through the shaft.

5. Inclined Shaft Correlation



For inclined shafts, measure the angle of inclination (θ) and length (L) to transfer coordinates.

Horizontal and vertical components:

$$\Delta H = L \cos \theta$$
$$\Delta V = L \sin \theta$$

6. Surface – Underground Reference Transfer

- Transfer of known surface coordinates (E, N, RL) to underground stations.
- Can be done through shafts, boreholes or inclined openings.
- Common reference points are created both on surface and underground.
- Use EDM, theodolite, gyro compass or plumb line depending on conditions.

Coordinate Transfer

$$E_u = E_s + \Delta E$$
$$N_u = N_s + \Delta N$$
$$RL_u = RL_s - \Delta V$$

Where,
E = Easting
N = Northing
RL = Reduced Level
Δ = Difference obtained from survey

7. Bearing / Azimuth Transfer

- Transfer of true bearing/azimuth from surface to underground.
- Methods: Gyro-theodolite, solar observations, or using aligned shafts and traverses.
- Check for local attraction in compass methods.

Use of Gyro Compass

- ✔ Provides true north.
- ✔ Suitable for underground use.
- ✔ Helps in transferring azimuth without magnetic errors.



8. Correlation Procedure (General)

1. Establish surface control points (using triangulation/GPS/total station).
2. Transfer points to underground (through shaft, borehole or incline).
3. Measure angles, distances and RLs accurately.
4. Compute underground coordinates.
5. Check with independent observations (e.g., additional shaft/borehole).
6. Adjust for errors and close the network.
7. Plot on common coordinate system and verify on plan.

"Measure → Transfer → Compute → Check → Adjust → Map"

9. Key Takeaways

- ✔ Correlation ensures surface and underground surveys are in the same coordinate system.
- ✔ Shafts, boreholes and traverses are used for correlation.
- ✔ Accurate transfer of coordinates, bearings and RLs is essential.
- ✔ Gyro compass gives true north underground.
- ✔ Always check and adjust for errors.
- ✔ Correlation is the backbone of safe and efficient mine development.

"Good correlation today prevents big problems tomorrow."

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MINE SURVEYING

DAY - 8

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Underground Surveying – Fundamentals

"Map the unseen, plan the future"

1. Why Underground Surveying?

- To establish accurate control for mine planning, development, production and safety.
- To map underground workings (drifts, levels, stopes, shafts).
- To provide connection with surface surveys (correlation).
- To monitor ground movement, subsidence and convergence.

"Underground surveying makes the invisible mine, visible on paper."

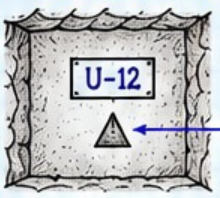
2. Underground Control Surveys

- Control points are established at suitable locations (main traverses and junctions).
- Provide a framework for detailed surveys.
- Can be established by:
  - ✓ Traversing (most common)
  - ✓ Transfer of surface control (through shafts)
  - ✓ Gyro compass/Total station in long workings

"Control stations should be stable, easily accessible and well marked."

3. Underground Stations

- **Permanent stations** → fixed for long term use (pillars, walls, floors, roof bolts).
- **Temporary stations** → used for short duration (marked by paint/chalk).
- **Station marking:** chiselled mark + station number.
- Should be located at safe, stable and convenient places (intersections, level ends, near drives).

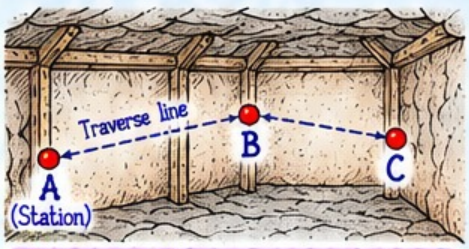


Example of station mark on wall

Chiselled mark with station number

4. Traversing Underground

- A series of connected straight lines between survey stations.
- Used to establish control and to map the workings.
- Measure linear distance and direction (bearing/azimuth) between stations.
- **Types:** Main traverse, subsidiary traverse, detail traverse.



Underground traverse in a mine drive

5. Direction / Bearing

- Direction is the orientation of a line with respect to a reference.
- Bearing is the horizontal angle measured from a reference meridian (usually magnetic north).

Types of Bearing

1. **Magnetic Bearing (MB)** – with respect to magnetic north (using compass).
2. **True Bearing (TB)** – with respect to true north (using gyro/theodolite).
3. **Grid Bearing** – with respect to grid north (used in large mines).
4. **Back Bearing** = Fore Bearing ± 180°

Always apply local magnetic declination when using compass.

6. Chain / Tape Surveying

- Chain or steel tape is used to measure horizontal distance underground.
- Suitable for underground development and short distances.
- Tape should be checked for errors due to temperature, pull and sag.



Steel tape

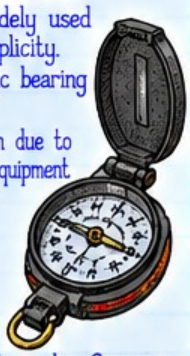
Chain (20 m / 30 m)

Precautions:

- ✓ Keep tape in line and horizontal.
- ✓ Avoid tape sag.
- ✓ Apply necessary corrections (if required).
- ✓ Use standard length and check regularly.

7. Compass Applications

- Magnetic compass is widely used underground due to simplicity.
- Used to measure magnetic bearing of traverses and drives.
- Affected by local attraction due to magnetic minerals, electric equipment and steel structures.
- Always check for local attraction (by taking fore and back bearings).



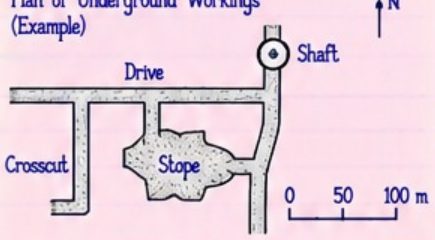
Prismatic Compass

In areas of high magnetic disturbance, use gyro compass or total station.

8. Underground Mine Plans

- Underground surveys are plotted on plan and section to show:
  - ✓ Development workings (drives, crosscuts, raises, winzes, stopes).
  - ✓ Control stations and traverses.
  - ✓ Ventilation, drainage and other services.
  - ✓ Used for mine planning, production monitoring and safety.

Plan of Underground Workings (Example)



9. Key Takeaways

- ✓ Underground surveying provides control for safe and efficient mining.
- ✓ Traversing is the backbone of underground control.
- ✓ Stations should be stable, well marked and accessible.
- ✓ Compass, chain/tape and total station are commonly used instruments.
- ✓ Mine plans help in visualization, planning and monitoring.
- ✓ Always check for local attraction and apply necessary corrections.

"Accurate underground surveys drive safer mines and higher productivity."

MINE SURVEYING

DAY – 9

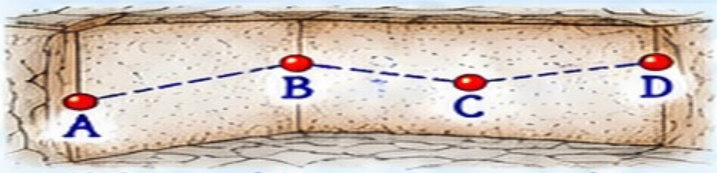
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Underground Surveying – Advanced

"Precision underground, productivity above ground."

1. Underground Traverses

- A sequence of connected survey lines whose lengths and directions are measured underground.
- Used to establish control and to map mine workings.
- **Types:** Main traverse, subsidiary traverse, detail traverse.
- Traverses are measured using compass, theodolite or total station depending on accuracy required.
- Ensure good station spacing, visibility and stability.



Underground traverse in a mine drive

2. Theodolite Observations

- Used for precise angular measurements underground.
- Measure horizontal angles, vertical angles and bearings.
- Provide higher accuracy compared to compass.
- **Procedure:**

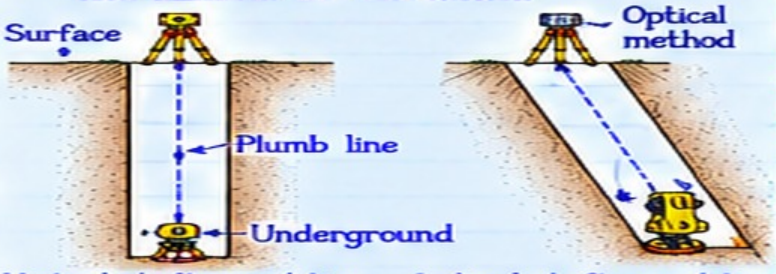
1. Set up and centre the theodolite.
2. Take backsight (BS) and foresight (FS) readings.
3. Measure horizontal and vertical angles.
4. Repeat observations to minimize errors.
5. Apply necessary corrections.



Theodolite setup underground

3. Shaft / Plumb-line Methods

- Used to transfer surface control points to underground and vice-versa.
- Plumb line is suspended in the shaft.
- Optical or gyro methods may be used for better accuracy.
- Ensure stability, temperature control and minimal air movement.



Vertical shaft correlation using plumb line

Inclined shaft correlation (using theodolite)

4. Closure Checks

- To ensure accuracy of traverse measurements.
- Angular misclosure:

$$\Sigma\theta_{theo} = (n - 2) \times 180°$$

Angular misclosure = $\Sigma\theta_{obs} - \Sigma\theta_{theo}$

- Linear misclosure:

$$e = \sqrt{(\Sigma\Delta E)^2 + (\Sigma\Delta N)^2}$$

- Relative precision:

$$1 : \left(\frac{\text{Perimeter}}{e}\right)$$

- Acceptable limits depend on the accuracy required.

5. Underground Coordinates

- Coordinates (E, N, RL) are computed from traverse data.
- Used for preparing mine plans, sections and
- Coordinate computation (for a line):

$$\Delta E = L \cos\theta$$
$$\Delta N = L \sin\theta$$

Where,
L = Length of line
θ = Bearing (azimuth)
ΔE = Easting increment
ΔN = Northing increment

6. Mine-Survey Problems

- Compute missing lengths, bearings and coordinates.
- Check closure and adjust data.
- Plot underground traverse on plan.
- Solve shaft correlation problems.
- Convert observed data to plan coordinates.
- Typical numerical problems may involve combined surface and underground surveys.

7. Key Takeaways

- ✓ Underground traverses provide the framework for mine mapping.
- ✓ Theodolite preparing hjine accuracy than compass.
- ✓ Shaft correlation transfers control between surface and underground.
- ✓ Always check closure and adjust errors.
- ✓ Accurate underground coordinates are essential for safe and efficient mining.
- ✓ Practice numerical problems regularly.

"Accurate underground surveys today, safer and smarter mines tomorrow."

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MINE SURVEYING

DAY - 10

Curves & Contouring

"From curves to contours, we shape the map."

1. Types of Curves

- **Horizontal Curves** → Change direction in plan (used in roads, railways and mine haul roads).
- **Vertical Curves** → Change gradient in vertical plane.
- **Simple Curves** → Single arc of constant radius (most common).
- **Compound Curves** → Two or more simple curves with different radii turning in the same direction.
- **Reverse Curves** → Two curves with opposite directions.

2. Horizontal Curves

- Used to provide a gradual change in direction.
- Main elements (Simple Circular Curve):



R = Radius of curve
Δ = Deflection angle (°)

$T = R \tan\left(\frac{\Delta}{2}\right)$

$L = \frac{\pi R \Delta}{180}$

$LC = 2R \sin\left(\frac{\Delta}{2}\right)$

PC – Point of Curvature
PT – Point of Tangency
L – Length of curve
LC – Long chord

"Curves provide smooth and safe alignment."

3. Vertical Curves

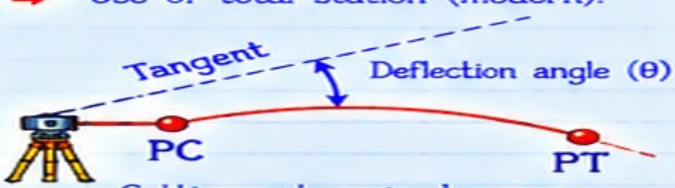
- Used to provide a gradual change in gradient between two different grades.
- **Types:** Summit curve (crest) and Valley curve (sag).



g_1, g_2 = Gradients (%)
L = Length of vertical curve
PVC = Point of Vertical Curvature
PVI = Point of Intersection
PVT = Point of Vertical Tangency

4. Setting-out Methods

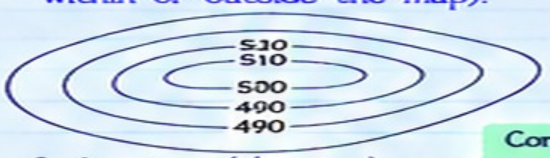
- Chain and offset method (approximate).
- Theodolite method (more accurate).
- Tangent angle method.
- Rankine's deflection angle method.
- Use of total station (modern).



Setting out a simple curve (by deflection angles)

5. Contours – Definition

- A contour is a line joining points of equal elevation (reduced level).
- Contours show the shape and relief of the ground surface on a map.
- They are always closed (either within or outside the map).



Contour map (plan view)

6. Characteristics of Contours

- ✓ Contour lines always close.
- ✓ Do not intersect (except in overhanging cliffs).
- ✓ Spacing indicates slope:
  - Close spacing → steep slope
  - Wide spacing → gentle slope
  - Equal spacing → uniform slope
- ✓ Perpendicular to line of maximum slope.
- ✓ Form V-shapes pointing upstream in valleys.
- ✓ Form U-shapes pointing downhill on ridges.
- ✓ Continuous and smooth.

Contours help us visualize the topography."

7. Interpolation of Contours

- Used to locate points of required RL between two known contours.
- Methods: Estimation, proportional distance method.

$$\text{Distance} = \left(\frac{RL - RL_1}{RL_2 - RL_1}\right) \times D$$

RL = Required reduced level
RL_1, RL_2 = Known contour levels
D = Distance between contours

8. Contour Maps in Mining

- Used for mine planning, drainage design, haul road alignment and surface development.
- Help in locating benches, dumps, dams and other surface features.
- Contours are plotted from levelling or total station data.
- Required contour interval depends on scale and terrain.

9. Key Takeaways

- ✓ Curves provide smooth and safe alignments.
- ✓ Understand elements and setting-out methods.
- ✓ Contours represent ground surface and help in planning.
- ✓ Contour maps are essential for mine design and drainage.
- ✓ Practice numerical problems and map interpretation.

"Good maps begin with good contours."

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MINE SURVEYING

DAY - 11

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Mining Knowledge Today A Better Tomorrow

Photogrammetry

"From Photographs to Precise Maps"

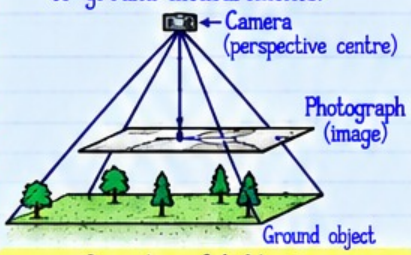
1. What is Photogrammetry?

- Photogrammetry is the science of obtaining reliable measurements and information about objects from photographs.
- It uses photographs (mainly aerial or satellite) to prepare maps, plans and 3D models.
- Widely used in mining, civil engineering, geology and environmental studies.

"Measure the Earth without touching it."

2. Basic Principle

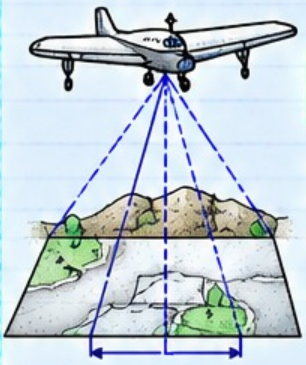
- A photograph is a central perspective projection of the ground.
- Points on the ground are projected to points on the photograph through the camera lens (perspective centre).
- Geometric relationships allow us to convert image measurements to ground measurements.



Geometry of light gives measurements from images.

3. Aerial Photographs

- Taken from aircraft or drones with specially designed cameras.
- Types:
  - Vertical photographs (camera axis vertical)
  - Oblique photographs (camera axis inclined)
  - High altitude and low altitude photographs



Vertical photo (used for mapping)

- ✔ Large area coverage
- ✔ Quick data collection
- ✔ Useful for inaccessible areas
- ✔ Cost effective

4. Scale of a Photograph

- Scale = ratio of distance on photograph to the corresponding distance on ground.

$$\text{Scale (S)} = \frac{\text{Distance on photo (d)}}{\text{Distance on ground (D)}} = \frac{1}{n}$$

- Scale depends on flying height (H) and focal length (f).

$$n = \frac{H}{f}$$

Where,
H = Flying height above ground
f = Focal length of camera

- Larger flying height → Smaller scale (more area covered).

5. Stereoscopic Vision

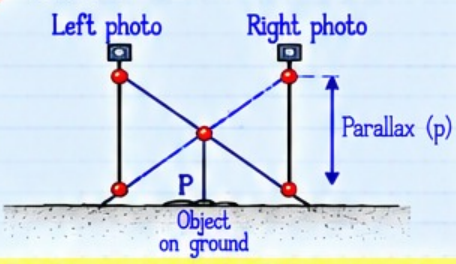
- Two overlapping photographs taken from slightly different positions give a 3D view.
- Stereoscope is used to view the pair of photographs.
- Allows measurement of height, relief and shape of terrain.



Two photos → Three-dimensional world.

6. Parallax

- Parallax is the apparent displacement of a point due to a change in camera position.
- Types:
  - Total parallax (Pt)
  - Relative parallax (Pr)
  - Absolute parallax (Pa)
- Used to determine elevations and contours.

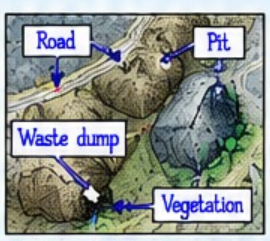


Parallax → Key to height measurement.

7. Photo Interpretation

- Identification and analysis of features on aerial photographs.
- Elements used for interpretation:

1. Tone / colour
2. Shape
3. Size
4. Pattern
5. Shadow
6. Texture
7. Association
8. Site and situation



Interpretation helps to extract meaningful information from photos.

8. Applications in Mining

- ✔ Preparation of mine plans and topographic maps.
- ✔ Identification of geological structures (faults, folds, lineaments).
- ✔ Estimation of reserves and pit volumes.
- ✔ Planning of haul roads, dumps and infrastructure.
- ✔ Monitoring of mine development and environmental impact.
- ✔ Useful for inaccessible or hazardous areas.

"Photogrammetry provides a wider view for better mining decisions."

9. Key Takeaways

- ✔ Photogrammetry uses photographs to make measurements.
- ✔ Aerial photos provide large area coverage.
- ✔ Scale and geometry are essential.
- ✔ Stereoscopic vision and parallax help in 3D measurements.
- ✔ Photo interpretation extracts useful information.
- ✔ Widely applied in mine planning, reserve estimation and monitoring.

"A picture from the sky tells a bigger story."

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MINE SURVEYING

DAY - 12

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Mining Knowledge Today A Better Tomorrow

Theodolite, EDM & Total Station

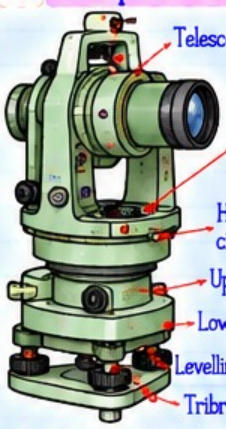
"Precise Instruments for Accurate Mine Surveys"

1. Theodolite – Introduction

- A theodolite is a precision instrument used to measure horizontal and vertical angles.
- Widely used in surveying, mine surveys, engineering and construction.
- Types: Transit theodolite, Non-transit theodolite, Digital theodolite.

"Measure angles with precision, map the world with confidence."

2. Components of a Theodolite



1. Telescope
2. Vertical circle
3. Horizontal circle
4. Standards
5. Upper & lower plates
6. Levelling screws
7. Foot screws
8. Tribrach

3. Temporary Adjustments

1. Setting up the instrument on tripod.
2. Centering – bring the instrument exactly over the station point.
4. Levelling – using plate levels and foot screws.
4. Focusing – first eyepiece, then object.
5. Elimination of parallax – no relative movement between cross-hair and image.

Temporary adjustments are done every time the instrument is set up at a new station.

4. Permanent Adjustments

1. Plate level adjustment – axis of plate level ⊥ vertical axis.
2. Collimation adjustment – line of collimation ⊥ horizontal axis.
3. Horizontal axis adjustment – horizontal axis ⊥ vertical axis.
4. Vertical circle adjustment – index error should be zero.
5. Optical plummet adjustment – optical axis coincides with vertical axis.

"Permanent adjustments ensure theodolite is in perfect working condition."

5. Angle Measurement

Horizontal Angle Measurement

- Measured in horizontal plane.
- Computed as difference of circle readings at two directions.
- Methods: Repetition method, Reiteration method.

Horizontal angle (θ) = Reading at B – Reading at A

Vertical Angle Measurement

- Measured in vertical plane.
- Positive for elevation (+), negative for depression (–).
- Used to determine difference in level and slope distance.

Vertical angle (α) = Reading – Zero correction

6. EDM – Principles

- EDM (Electronic Distance Measurement) uses electromagnetic waves (light or microwave) to measure distance.
- Distance is calculated from the travel time or phase difference of the signal.
- Common wavelenghts: Infrared, visible light, microwave.

$$\text{Distance (D)} = \frac{c \times t}{2}$$

Where,
c = speed of light ($\approx 3 \times 10^8$ m/s)
t = time of travel

Advantages

- ✓ High accuracy (mm level).
- ✓ Fast measurement.
- ✓ Not affected by rough terrain.
- ✓ Can measure long distances.
- ✓ Used in total stations.

7. Total Station

- A total station is an advanced electronic surveying instrument that combines:
  - ✓ Electronic theodolite (angle measurement)
  - ✓ EDM (distance measurement)
  - ✓ On-board computer (data storage and processing)

"Total Station = Theodolite + EDM + Computer"



Key Features:

- Measures angles, distances and coordinates.
- Stores data electronically.
- Allows real-time computation.
- Easy data transfer to computer (CAD/GIS).
- Widely used in mine surveys, construction and mapping.

8. Total Station Workflow

1. Set up instrument on tripod.
2. Centering and levelling.
3. Input station details (height, code).
4. Aim at target (prism or reflectorless).
5. Measure angle and distance.
6. Automatically compute and store coordinates (E, N, RL).
7. Download data to software for mapping and analysis.



From field measurement → to digital mine map

9. Key Takeaways

- ✓ Theodolite measures angles accurately.
- ✓ Temporary and permanent adjustments are essential.
- ✓ EDM measures distance using electromagnetic waves.
- ✓ Total station combines angle, distance and data processing.
- ✓ Widely used in mine surveying for accurate mapping and volume estimation.
- ✓ Modern instruments improve speed, accuracy and productivity.

"Right instrument + Correct method = Accurate survey = Safer and more productive mines."

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MINE SURVEYING

DAY - 13

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Mining Knowledge Today A Better Tomorrow

GPS, Remote Sensing & Astronomical Survey

"From Satellites to Stars – For a Better Earth and Safer Mines"

1. GPS – Introduction & Principles

- GPS (Global Positioning System) is a satellite-based navigation system that provides accurate position, velocity and time.
- Developed and maintained by the U.S. Department of Defense (DoD).
- Works on the principle of trilateration using signals from multiple satellites.
- Each satellite transmits coded signals with accurate time information.

"GPS gives your position anywhere on the Earth, anytime."

2. Satellite Positioning

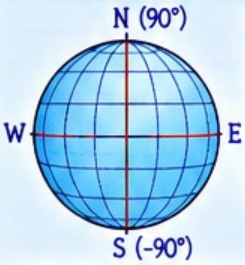
- Minimum 4 satellites required for 3D positioning (X, Y, Z) and time.
- Position is calculated by measuring time taken by signals to reach the receiver.
- **Methods:**
  1. Absolute positioning
  2. Differential GPS (DGPS)
  3. Real Time Kinematic (RTK)
  4. Precise Point Positioning (PPP)



Trilateration using multiple satellites

3. Coordinate Systems

- **Geographic Coordinate System** – Latitude (ϕ), Longitude (λ), Height (h)
- **Projected Coordinate System** – e.g., UTM (Universal Transverse Mercator)
- **Datum** – Reference surface (e.g., WGS-84)
- Used for mapping, mine planning and integration with GIS.

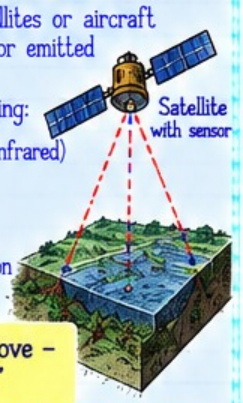


Latitude (ϕ)
– North (+), South (–)
Longitude (λ)
– East (+), West (–)
Height (h)
– Above reference ellipsoid

Accurate coordinates → Better mapping → Safer mining operations

4. Remote Sensing – Basics

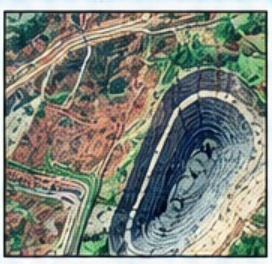
- Remote sensing is the science of obtaining information about the Earth's surface without physical contact.
- Uses sensors on satellites or aircraft to capture reflected or emitted radiation.
- Types of remote sensing:
  1. Optical (visible, near-infrared)
  2. Thermal infrared
  3. Microwave (RADAR)
  4. LiDAR (Light Detection and Ranging)



"See the Earth from above – Plan better below."

5. Image Interpretation

- Interpretation of satellite/aerial images helps in identifying geological and surface features.
- Elements of interpretation:
  1. Tone / Colour
  2. Texture
  3. Pattern
  4. Shape
  5. Size
  6. Shadow
  7. Association
  8. Site and Situation



Satellite image of an open-cast mine (False colour composite)

"Images reveal what the ground hides."

6. Applications in Mining

- Geological mapping and structure identification
- Exploration of mineral deposits
- Monitoring land use, land cover and environmental impact
- Mine planning and boundary demarcation
- Subsidence and deformation monitoring
- Integration with GIS for decision support

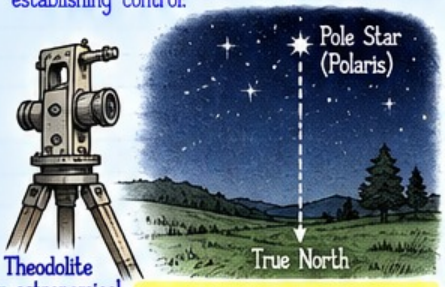
Commonly Used Remote Sensing Data

- Landsat (optical)
- Sentinel (optical)
- ASTER (optical + thermal)
- SRTM (DEM)
- LiDAR (high resolution topography)
- RADAR (all weather)

"Remote sensing gives a broader view for smarter mining."

7. Astronomical Survey – Introduction

- Astronomical surveying uses the observation of celestial bodies (Sun, stars) to determine direction, position and time.
- Mainly used to determine true north (azimuth).
- Important in large area surveys and for establishing control.

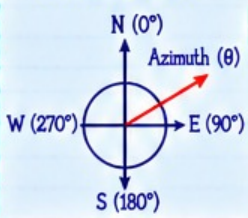


Theodolite for astronomical observations

"The stars guide the surveyor."

8. Azimuth & Time Concepts

- Azimuth – Horizontal angle measured from true north, in clockwise direction (0° – 360°).
- True North – Based on astronomical observations.
- Time is determined using local apparent time (from Sun) and converted to standard time.



Time Concepts

1. Local time
2. Standard time
3. Universal Time (UT)
4. Sidereal time
5. Equation of time

Azimuth is the backbone of direction in surveying."

9. Key Takeaways

- ✓ GPS provides accurate, all-weather positioning.
- ✓ Coordinate systems and datum are essential for mapping.
- ✓ Remote sensing helps in exploration, planning and environmental monitoring.
- ✓ Image interpretation requires practice and knowledge of features.
- ✓ Astronomical observations help in determining true north and azimuth.
- ✓ Integration of modern tools (GPS, RS, GIS) improves accuracy and efficiency in mine surveying.

"Modern technology and ancient stars work together for a safer tomorrow."

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MINE SURVEYING

DAY - 14

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Mine Surveying – 25 GATE Numericals

"Practice Today, Solve Tomorrow, Crack GATE 2027"

1. Levelling

A staff reading on a BM is 1.245 m. The reading on a point is 2.135 m. If RL of BM is 100.000 m, find RL of the point.

2. Levelling (Rise & Fall)

Given consecutive staff readings: 1.865 m, 0.965 m, 1.475 m, 1.205 m.
Find RLs using Rise & Fall method. RL of first point = 250.000 m.

3. Tacheometry

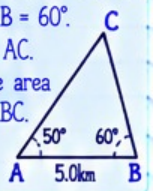
Stadia readings: upper = 2.435 m, lower = 1.265 m, central = 1.850 m.
Multiplying constant (K) = 100, additive constant (C) = 0.
Find horizontal distance and RL difference if staff is vertical and vertical angle = 5°.

4. Tacheometry (Inclined staff)

Stadia readings: upper = 3.125 m, lower = 2.025 m. K = 100, C = 0.
Staff held normal to line of sight.
Vertical angle = 10°.
Find the horizontal distance and vertical difference.

5. Triangulation

In a triangle ABC, AB = 5.0 km, ∠A = 50°, ∠B = 60°.
Find BC and AC.
Also, find the area of triangle ABC.



6. Triangulation (Network)

In a triangulation figure, AB = 4.2 km, ∠A = 45°, ∠B = 55°. Find AC, BC and the coordinates of C if A (1000, 1000) and B (5200, 1000).

7. Errors (Propag. of Errors)

A measured distance is 500.0 m with an error of ±0.2 m. Another distance is 300.0 m with an error of ±0.1 m. Find the resultant distance and its probable error.

8. Errors (Closure)

In a compass traverse of 5 sides, the latitude and departure misclosure is 0.25 m. Total traverse length is 1250 m.
Find the relative precision.

9. Correlation

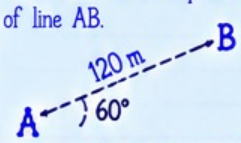
A surface point has coordinates (E = 5000 m, N = 7000 m). The corresponding underground point is at a depth of 480 m directly below.
Find the underground coordinates.

10. Correlation (Shaft)

A shaft is vertical. The surface collar coordinates are (E = 2500 m, N = 4000 m, RL = 350 m).
The plumb line offset underground is 0.15 m east and 0.10 m north at a depth of 600 m. Find underground coordinates.

11. Underground Surveying

In an underground traverse, AB = 120 m, bearing = 60°.
Find latitude and departure of line AB.



12. Underground Surveying

A closed underground traverse has the following latitudes and departures (in m):
ΣLat = +0.40, ΣDep = −0.30,
Total length = 2000 m.
Find the relative precision.

13. Underground Coordinates

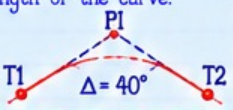
Starting from A (E = 0, N = 0), the following traverse is made:
AB = 100 m, 0°
BC = 150 m, 90°
CD = 100 m, 180°
Find coordinates of D.

14. Curves (Simple Curve)

Radius = 300 m,
Intersection angle (Δ) = 30°.
Find:
(i) Tangent length (T)
(ii) Length of curve (L)
(iii) Long chord (LC)
(iv) Mid-ordinate (M).

15. Curves (Setting Out)

For a simple circular curve of R = 200 m, Δ = 40°, find the chainages of tangential points and the length of the curve.



16. Vertical Curves

Two gradients +2% and −3% are connected by a parabolic curve of length 400 m. Find the RL at 50 m intervals from the beginning of the curve.

17. Contouring

Spot levels at four corners of a square (side 100 m):
A = 100 m B = 110 m
C = 120 m D = 130 m
Interpolate the RL at the centre and draw contour values at 110 m and 120 m.

18. Contour Gradient

Contours are at 5 m interval. Distance between two successive contours on map = 20 mm. Scale = 1 : 5000.
Find the ground slope (gradient).

19. Theodolite

Upper and lower readings on a horizontal circle for a line are 45° 20′ and 225° 20′. Find the correct horizontal angle if index error is 2′ (additive).

20. Theodolite (Vertical)

Vertical circle reading to a target is 87° 30′ on a transit theodolite. Find angle of elevation or depression.



21. EDM

An EDM gives a measured distance of 1250.36 m.
Instrument constant = +0.20 m,
Scale factor = 1.0002.
Compute the corrected distance.



22. Total Station

A total station observation gives:
Slope distance = 250.125 m,
Vertical angle = 6° 30′
Horizontal angle = 120°
Instrument height = 1.50 m
Target height = 2.00 m
Find horizontal distance, vertical difference and RL of the target (RL of station = 300 m).

23. GPS

Coordinates from GPS:
Point A (E = 520000 m, N = 1820000 m, h = 240 m)
Point B (E = 520500 m, N = 1820500 m, h = 260 m)
Find horizontal distance, bearing (azimuth) from A to B and difference in height.



24. Mixed Problem

From a theodolite station, angle to a point = 60°, horizontal distance = 200 m, instrument height = 1.5 m, target height = 1.0 m, RL of station = 250 m.
Find RL of the point.

25. Advanced Problem

In a mine survey, surface coordinates of a shaft are (E = 3000, N = 4500, RL = 500).
An underground point is observed with total station at a depth of 650 m and horizontal offsets 20 m east and 30 m south.
Find the underground coordinates.

Key Takeaways

- ✓ Practice numericals from all major topics.
- ✓ Understand concepts, formulas and units.
- ✓ Improve speed and accuracy.
- ✓ Use diagrams for better visualization.
- ✓ Solve previous GATE questions.

Topics Covered (All in One)

1. Levelling
2. Tacheometry
3. Triangulation
4. Errors & Adjustments
5. Correlation
6. Underground Surveying
7. Curves & Contouring
8. Theodolite
9. EDM
10. Total Station
11. GPS & Astronomical Survey

"Numericals build confidence, and confidence cracks GATE."

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Study Practice Succeed

Solve Numericals → Strengthen Concepts → Score Higher → Safer Mines → Better Tomorrow

GATE 2027
MINING ENGINEERING (MN)

MINE SURVEYING

DAY - 15

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50 MCQ / MSQ / NAT

"Practice More, Score Higher"

1. (MCQ) Levelling

In a differential levelling, the backsight reading is 1.245 m and foresight reading is 1.785 m. If the RL of the BM is 100.000 m, the RL of the new point is:

(A) 100.540 m
(B) 99.460 m
(C) 99.245 m
(D) 100.785 m



2. (MCQ) Tacheometry

For a stadia tacheometer, the upper staff reading = 2.435 m, lower staff reading = 1.265 m, and multiplying constant (K) = 100. The horizontal distance is:

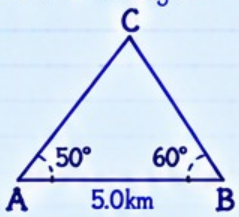
(A) 117.0 m
(B) 90.0 m
(C) 100.0 m
(D) 150.0 m

$$D = K(s)$$
$$s = (U - L)$$

3. (MCQ) Triangulation

In a triangle ABC, AB = 5.0 km, $\angle A = 50°$, $\angle B = 60°$. The length of BC is:

(A) 4.0 km
(B) 4.3 km
(C) 5.0 km
(D) 5.8 km



4. (MCQ) Errors

A measured length is 500.0 m with an error of ±0.2 m. The relative error is:

(A) 1 in 500
(B) 1 in 1000
(C) 1 in 2500
(D) 1 in 5000

$$\text{Relative error} = \frac{\text{Error}}{\text{True value}}$$

5. (MCQ) Correlation

During shaft correlation, the underground point is found to be 0.15 m east and 0.10 m north of the surface point. The horizontal displacement is:

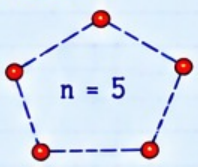
(A) 0.10 m
(B) 0.15 m
(C) 0.18 m
(D) 0.25 m

$$D_h = \sqrt{E^2 + N^2}$$

6. (MCQ) Underground Surveying

In an underground traverse, the sum of the interior angles of a closed traverse with 5 sides is:

(A) 540°
(B) 720°
(C) 900°
(D) 1080°



7. (MCQ) Curves

The radius of a simple circular curve is 300 m and the intersection angle is 30°. The length of the curve is (nearest metre):

(A) 78 m
(B) 157 m
(C) 314 m
(D) 471 m

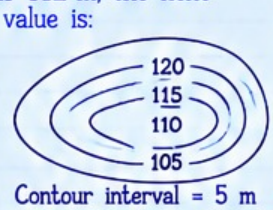
$$L = \frac{\pi R \Delta}{180}$$

R = Radius
Δ = Intersection angle (in degrees)

8. (MCQ) Contouring

The vertical interval between contours on a map is 5 m. If the RL at a point is 112 m, the next higher contour value is:

(A) 115 m
(B) 110 m
(C) 117 m
(D) 120 m



Contour interval = 5 m

9. (MCQ) Theodolite

In a theodolite observation, the face left reading is 45° 20′ and face right reading is 225° 20′. The correct horizontal angle is:

(A) 90°
(B) 100°
(C) 135°
(D) 180°

$$\text{Horizontal angle} = \frac{(FR - FL)}{2}$$

10. (MCQ) EDM / Total Station

An EDM measures the two-way travel time of a signal as 4 μs. If the speed of light is 3×10^8 m/s, the distance is:

(A) 300 m
(B) 600 m
(C) 1200 m
(D) 2400 m

$$D = \frac{c \times t}{2}$$

11. (MSQ) GPS

Which of the following are advantages of GPS in mine surveying? (More than one answer may be correct)

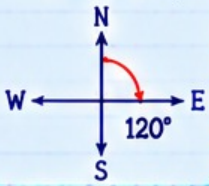
☐ (A) All-weather operation
☐ (B) High accuracy
☐ (C) Requires line of sight
☐ (D) Provides 3D coordinates



12. (NAT) Conceptual

The astronomical azimuth of a line is 120°. What is the reduced bearing of the line? (Answer in WCB format)

Ans: _____



Key Takeaways

- ✓ Practice from all major topics.
- ✓ Understand concepts before solving.
- ✓ Improve speed and accuracy.
- ✓ Focus on both conceptual and numerical.
- ✓ Revise formulas and diagrams.
- ✓ Attempt previous GATE questions.
- ✓ Prepare for MCQ, MSQ and NAT types.

Topics Covered

- ✓ Levelling
- ✓ Tacheometry
- ✓ Triangulation
- ✓ Errors & Adjustments
- ✓ Correlation
- ✓ Underground Surveying
- ✓ Curves & Contouring
- ✓ Theodolite
- ✓ EDM
- ✓ Total Station
- ✓ GPS & Astronomical Survey
- ✓ Mixed Conceptual + Numerical

"Small Practice Steps Today Lead to Big GATE Scores Tomorrow."

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MINE SURVEYING

DAY - 16

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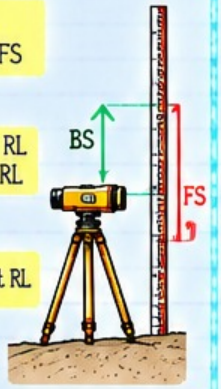
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Formula + Fact Sheet

"Key Formulae, Important Facts – Revise Fast, Score High"

1. Levelling Equations

- RL of point = RL of BM + Σ(BS) – Σ(FS)
- Height of Instrument (HI) method:
  - HI = RL + BS
  - RL (next point) = HI – FS
- Rise and Fall method:
  - Rise = Next RL – Previous RL
  - Fall = Previous RL – Next RL
- Check:
  - Σ(BS) – Σ(FS) = Last RL – First RL
- Use:
  - ✓ Check misclosure
  - ✓ Find RL of unknown points



2. Tacheometric Formulae

- Stadia distance (horizontal):

$$D = k\,s + C$$

k = multiplying constant (≈ 100)
s = staff intercept (upper – lower)
C = additive constant (≈ 0)

- Horizontal distance (inclined staff):

$$D = k\,s\cos^2\theta + C\cos\theta$$

- Vertical difference:

$$V = \frac{1}{2}\,k\,s\sin 2\theta + C\sin\theta$$

- Constants:
  - For most tacheometers, k = 100, C = 0

3. Error Relationships

- Relative error in a measured length:

$$\text{Relative error} = \frac{\text{Error}}{\text{True length}}$$

- If length = L and error = ± e,

$$\text{Relative error} = \pm\frac{e}{L}$$

- If Relative error = $\frac{1}{n}$

$$e = \frac{L}{n}$$

- Total error in a traverse (approx):

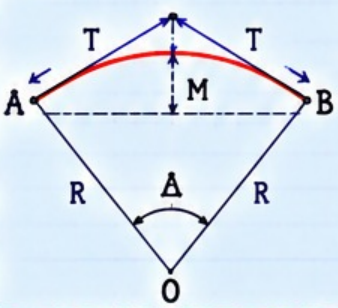
$$E = \sqrt{e_{lat}^2 + e_{dep}^2}$$

- Angular error (in radians) causes linear error:

$$e \approx L \times \theta \text{ (radians)}$$

4. Curve Equations

- Simple Circular Curve:
  - ✓ Tangent length: $T = R\tan(\Delta/2)$
  - ✓ Length of curve: $L = \pi R\Delta/180$
  - ✓ Long chord: $LC = 2R\sin(\Delta/2)$
  - ✓ Mid-ordinate: $M = R(1 - \cos(\Delta/2))$



R = Radius
Δ = Intersection angle
T = Tangent length
L = Length of curve
M = Mid-ordinate

5. Contour Facts

- ✓ Contour joins points of equal elevation.
- ✓ Contour interval (CI) = difference in elevation between successive contours.
- ✓ Contours never intersect (except vertical cliffs/overhangs).
- ✓ Close spacing → Steep slope.
- ✓ Wide spacing → Gentle slope.
- ✓ Concentric closed contours with higher values inside → Hill.
- ✓ Concentric closed contours with lower values inside → Depression.
- ✓ V-shaped contours point upstream in valleys.
- ✓ U-shaped contours point downhill in ridges.



6. Instrument Comparison

Instrument	Measures	Accuracy	Use
Dumpy Level	Horizontal line of sight	Moderate	Levelling
Automatic Level	Horizontal line of sight	High	Levelling (quick setup)
Theodolite	Horizontal & vertical angles	High	Traversing, angle measurement
EDM	Electronic distance	High	Distance measurement
Total Station	Angle + Distance + Data storage	Very High	Modern surveying, mapping
GPS (DGPS)	3D coordinates (X, Y, Z)	High (metre-cm level)	Large area surveying, control points

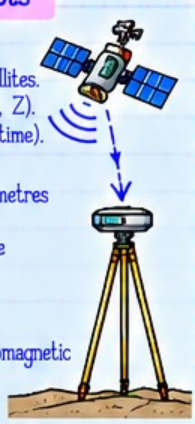
7. GPS / EDM Concepts

GPS – Key Points:

- ✓ Uses signals from multiple satellites.
- ✓ Provides 3D coordinates (X, Y, Z).
- ✓ Uses trilateration (distance + time).
- ✓ Types: SPS, DGPS, RTK.
- ✓ Accuracy: metres (SPS), centimetres (RTK).
- ✓ Used for control surveys, mine planning and GIS.

EDM – Key Points:

- ✓ Measures distance using electromagnetic waves (infrared / microwave).
- ✓ Distance: D = (c × t) / 2
- ✓ Very fast and accurate (mm level).
- ✓ Used in total stations and modern surveying.



8. Important Facts (Quick Revision)

- ✓ 1 chain = 20 m, 1 link = 0.2 m
- ✓ 1 acre = 4047 m², 1 hectare = 10,000 m²
- ✓ Bearing types: Whole Circle Bearing (0°–360°) & Quadrantal Bearing (0°–90°)
- ✓ Magnetic declination and local attraction affect compass bearings.
- ✓ Traverse closure error should be within permissible limits (e.g., 1 in 2000).
- ✓ Contour map is a projection of ground relief on a horizontal plane.
- ✓ Total station improves speed, accuracy and data handling.
- ✓ GPS is preferred for large area and inaccessible terrain.
- ✓ Mine surveys integrate surface and underground measurements.

"Formulae give you answers, concepts give you confidence."

9. Key Takeaways

- ✓ Memorize and practice important formulae.
- ✓ Understand the meaning of each term.
- ✓ Use diagrams for quick recall.
- ✓ Practice numericals from all topics.
- ✓ Compare instruments and know their applications.
- ✓ Keep important units and conversions in mind.
- ✓ Revise error analysis and adjustment concepts.
- ✓ Solve previous GATE questions.

"Revise Smart
Use Formulae
Apply Concepts
Score Higher in GATE 2027!"

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MINE SURVEYING

DAY - 17

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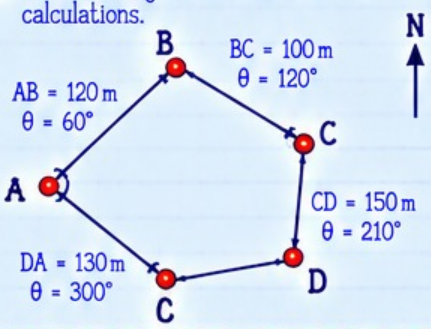
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Surveying Interpretation & Mixed Revision

"Combine Concepts, Solve Diagrams, Crack GATE 2027"

1. Survey Diagram Interpretation

- Identify stations, bearings, distances and elevations from the diagram.
- Understand symbols and conventions.
- Convert diagram information into calculations.



2. Field Book Interpretation

- A page from a level field book is given. Find RL of unknown points.

Station	BS (m)	IS (m)	FS (m)	RL (m)
BM1	1.245	-	-	100.000
P1	-	2.135	-	?
P2	-	1.875	-	?
P3	-	2.405	-	?
BM2	-	-	1.965	?

- Use: HI method (HI = RL + BS)
- RL (next) = HI − staff reading

Find missing RL values.

3. Traverse Calculation

- A closed traverse ABCDA has the following data. Find coordinates, closing error and relative precision.

Line	Bearing	Length (m)
AB	0°	120
BC	90°	100
CD	180°	120
DA	270°	100

Steps:

1. Compute latitudes and departures.
2. Find closing error (e_{lat}, e_{dep}).
3. Apply Bowditch (compass) rule.
4. Compute adjusted coordinates.

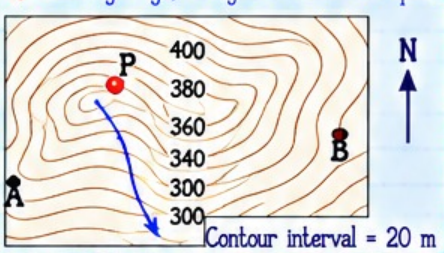
4. Levelling Problem (Field Data)

- Given field observations, compute the RLs of all points.

Station	BS	IS	FS	RL (m)
BM	2.135	-	-	250.000
A	-	1.865	-	?
B	-	2.015	-	?
C	-	1.945	-	?
D	-	-	2.250	?

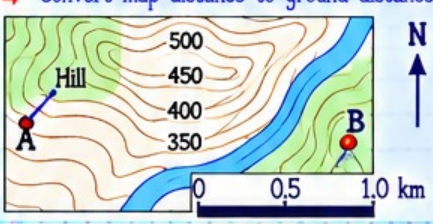
5. Contour Map Interpretation

- A contour map is given. Answer:
- Find the general slope direction.
- Estimate the height of point P.
- Find the gradient between two points.
- Identify ridge, valley and water flow path.



6. Map Interpretation

- From the given map extract:
- Distance between two points (using scale).
- Direction/bearing.
- Relative height and slope.
- Identify surface features (ridge/valley).
- Convert map distance to ground distance.



7. Instrument Selection

- Choose the most suitable instrument for the following situations:

1. Measuring horizontal and vertical angles for detailed survey.
2. Long distance measurement (1–5 km).
3. Quick mapping of large area.
4. Underground traverse.
5. High accuracy height measurement.
6. Real-time 3D mapping.


Theodolite

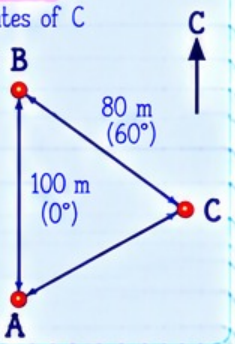

Total Station


EDM


GPS (DGPS)

8. Mixed GATE Level Problem

- From the figure, compute the coordinates of C using traverse data.
- AB = 100 m, bearing = 0°
- BC = 80 m, bearing = 60°
- If RL of A = 250 m and staff reading at B = 1.325 m, find RL of B.
- Find length and grade of the road from B to C.
- If the contour interval is 10 m, find the number of contours between RL 320 m and 400 m.



9. Contour & Gradient Problem

- Two points on a map have RLs 420 m and 360 m. The horizontal distance between them is 150 m. Find the gradient.
- If contour interval = 20 m, how many contours are crossed?
- Identify whether the slope is steep or gentle.

$$\text{Gradient} = \frac{(RL_1 - RL_2)}{\text{Horizontal distance}}$$

10. Common Diagram Questions

1. Identify instrument from diagram.
2. Read staff reading correctly.
3. Find missing distance/angle.
4. Interpret field book page.
5. Calculate true bearing from magnetic bearing (given declination).
6. Find area from coordinate data.
7. Solve numerical based on underground traverse diagram.
8. Interpret cross-section and contour profiles.

11. Key Takeaways

- ✓ Practice solving diagrams.
- ✓ Interpret field book, maps and contours.
- ✓ Strengthen traverse and level calculations.
- ✓ Know when to use which instrument.
- ✓ Revise important formulae and facts.
- ✓ Solve mixed conceptual + numerical questions.
- ✓ Improve speed and accuracy.
- ✓ Focus on previous GATE problems.

"Interpret. Calculate. Practice. Revision makes you Exam Ready!"

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MINE SURVEYING

DAY - 18

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Full Mine Surveying Mock Test

"Test Your Concepts – Revise – Get GATE Ready"

1. (MCQ) Levelling

The RL of a point is 125.360 m. A foresight reading of 1.245 m is taken from the same instrument. What is the height of instrument (HI)?

(A) 124.115 m
(B) 125.360 m
(C) 126.605 m
(D) 127.850 m

HI = RL + FS



2. (MCQ) Tacheometry

For a vertical staff, the staff intercept is 1.20 m, multiplying constant K = 100 and additive constant C = 0. If the staff is held vertical, the horizontal distance is:

(A) 100 m
(C) 150 m
(D) 200 m

$D = K s + C$

3. (MCQ) Compass Survey

In a closed traverse, the interior angles are 72°, 88°, 110°, 90°. The closing error is:

(A) 0°
(B) 2°
(C) 4°
(D) 6°

Sum of interior angles = (n – 2) × 180°

4. (MSQ) Errors

Which of the following are sources of errors in distance measurement using EDM?

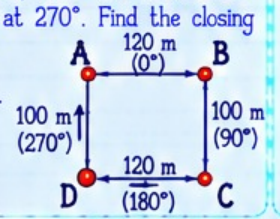
(A) Atmospheric conditions
(B) Instrument constant error
(C) Target reflector error
(D) Staff inclination
(E) Multipath effect

More than one option may be correct.

5. (NAT) Traverse Calculation

In a traverse ABCD, AB = 120 m at 0°, BC = 100 m at 90°, CD = 120 m at 180° and DA = 100 m at 270°. Find the closing error (in metres).

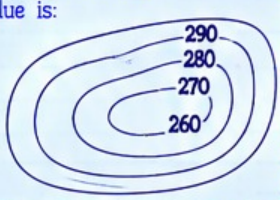
Ans: _____



6. (MCQ) Contouring

The contour interval of a map is 10 m. A spot level is 275 m. The next higher contour value is:

(A) 270 m
(C) 280 m
(D) 285 m



7. (MCQ) Instrument Selection

Which instrument is most suitable for high-accuracy 3D coordinate measurement in a large open-pit mine?

(A) Dumpy level
(C) Theodolite
(D) Total station



8. (MSQ) GPS



Which of the following statements about GPS are correct?

(A) Provides global positioning
(B) Requires line of sight
(C) Works on trilateration
(D) Accuracy is only in metres
(E) Used for mine planning and GIS

More than one option may be correct.

9. (NAT) Level Field Book

A page from a level field book is given. Find the RL of point B.

Station	BS (m)	IS (m)	FS (m)	RL (m)
A	1.865	-	-	100.000
B	-	2.135	-	?
C	-	-	1.245	?

Calculate RL of B: _____

10. (MCQ) Curve Setting Out

A simple circular curve has R = 300 m and Δ = 30°. The length of curve (L) is:

(A) 78.5 m
(B) 157.1 m
(C) 314.2 m
(D) 471.2 m

$$L = \frac{\pi R \Delta}{180}$$

11. (MSQ) Map Interpretation

From a topographic map, which of the following indicate a steep slope?

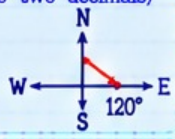
(A) Close contour spacing
(B) Wide contour spacing
(C) V-shaped contours
(D) Contours crossing
(E) Concentric contours

More than one option may be correct.

12. (NAT) Underground Surveying

Two underground stations are connected by a line of length 250 m with bearing 120°. Find the latitudes and departures. (Answer in metres, correct to two decimals)

Ans:
Latitude = _____
Departure = _____



13. (MCQ) Photogrammetry

The apparent displacement of an image due to central projection is called:

(A) Scale
(B) Parallax
(C) Relief
(D) Resolution

14. (NAT) Mixed Problem

A contour map has a contour interval of 20 m. Find the approximate gradient between two points A (RL 340 m) and B (RL 260 m) separated by a horizontal distance of 400 m.

Ans: Gradient = _____

Gradient = $\frac{\Delta h}{\text{Horizontal distance}}$

15. (MSQ) Concepts

Which of the following are true about Total Station?

(A) Measures angles and distances
(B) Stores data electronically
(C) Provides real-time coordinates
(D) Requires only one person for operation
(E) Cannot be used in underground mines

More than one option may be correct.

Key Takeaways

- ✓ Revise all important concepts and formulae
- ✓ Practice diagrams, numerical and instrument-based questions
- ✓ Improve speed and accuracy
- ✓ Focus on weak areas
- ✓ Be GATE ready!

"Practice Like an Engineer, Think Like a Topper!"

Topics Covered

- ✓ Levelling
- ✓ Tacheometry
- ✓ Traverse
- ✓ Errors
- ✓ Correlation
- ✓ Contouring
- ✓ Theodolite
- ✓ EDM
- ✓ Total Station
- ✓ GPS
- ✓ Photogrammetry
- ✓ Mixed Problems

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