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Short Notes — Engineering Mechanics

BTEUP Diploma • 1st Semester (First Year — Common Curriculum, All 41 Branches) •

Short Notes

Session 2026-27

Short Revision Notes — prepared by KAMALDNP Academy from the official BTEUP 2026-27 syllabus. This is NOT a BTEUP board paper or publication.

These **short revision notes** cover the four units of Engineering Mechanics from the official BTEUP 2026-27 syllabus for the first year. Each unit gives the definitions, formulas and steps that a short or five-mark answer needs, in plain English and in syllabus order.

Use them for **quick revision** before the exam: read one unit, cover the page and recall the formulas, then practise the likely question given at the end of each unit. These are revision notes only — always study the full theory and numericals from your textbook and class notes as well.

Forces & Equilibrium

Topics: Types of forces; resultant and equilibrant; conditions of equilibrium.

Types of forces

A **force** is a push or pull that changes, or tries to change, the state of rest or uniform motion of a body. It is a vector quantity, measured in newton (N), and is fully described by magnitude, direction, point of application and line of action.

Main types asked in exams:

- **Contact forces** — act through direct contact, such as normal reaction, friction and tension in a rope.
- **Body forces** — act without contact, such as weight due to gravity and magnetic force.
- **Coplanar forces** — all forces act in one plane; non-coplanar forces act in different planes.
- **Concurrent forces** — lines of action meet at one point; **parallel forces** have parallel lines of action.
- **Collinear forces** — act along the same line.

In most first-year problems you deal with coplanar concurrent forces, so always draw a clear free-body diagram first.

Resultant and equilibrant

The **resultant** is a single force that produces the same effect as a given system of forces acting together. The **equilibrant** is a single force equal in magnitude to the resultant, opposite in direction and acting along the same line, so it balances the system.

For two forces P and Q acting at a point with angle θ between them, the resultant R is given by the parallelogram law:

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta}$$

Direction: $\tan \alpha = Q \sin \theta / (P + Q \cos \theta)$, where α is the angle of R with P .

- If $\theta = 0^\circ$, $R = P + Q$ (maximum).
- If $\theta = 180^\circ$, $R = |P - Q|$ (minimum).
- If $\theta = 90^\circ$, $R = \sqrt{P^2 + Q^2}$.

For more than two forces, resolve each force into horizontal and vertical components, add them as ΣF_x and ΣF_y , and use $R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$.

Conditions of equilibrium

A body is in **equilibrium** when it remains at rest, or moves with uniform velocity, under the action of forces — that is, the resultant force and resultant moment on it are both zero.

For coplanar forces the three conditions are:

- $\Sigma F_x = 0$ — algebraic sum of horizontal components is zero.
- $\Sigma F_y = 0$ — algebraic sum of vertical components is zero.
- $\Sigma M = 0$ — algebraic sum of moments about any point is zero.

For concurrent forces only the first two conditions are needed, because the moment condition is automatically satisfied. **Lami's theorem** is a shortcut for three concurrent forces in equilibrium: each force is proportional to the sine of the angle opposite to it, $P / \sin \alpha = Q / \sin \beta = R / \sin \gamma$. Equilibrium may be stable, unstable or neutral depending on whether the body returns to, moves away from, or stays in its new position after a small disturbance.

Likely question: Two forces of 30 N and 40 N act at a point at an angle of 60° between them. Find the magnitude and direction of the resultant, and state the conditions of equilibrium for coplanar forces.

Friction

Topics: Laws of friction; angle of friction; friction in simple machines.

Laws of friction

Friction is the tangential force that opposes the relative motion, or tendency of motion, between two surfaces in contact. The limiting value just before sliding starts is called **limiting friction**.

Laws of dry (Coulomb) friction:

- Friction always acts opposite to the direction of motion or impending motion.
- Limiting friction is directly proportional to the normal reaction: $F = \mu R$, where μ is the coefficient of friction and R is the normal reaction.
- It is independent of the area of contact, for the same surfaces and load.
- It depends on the nature and roughness of the surfaces in contact.
- Kinetic (sliding) friction is slightly less than static limiting friction and is nearly independent of velocity at low speeds.

Remember: friction is self-adjusting up to its limiting value — it equals the applied force until F reaches μR .

Angle of friction

When a body is on the point of sliding, the resultant of the normal reaction R and limiting friction F is inclined to the normal at an angle called the **angle of friction**, denoted by ϕ .

From the force triangle: $\tan \phi = F / R = \mu R / R = \mu$, so $\mu = \tan \phi$. This is the most important result of this topic and is asked directly in exams.

- **Angle of repose** — the maximum inclination of a plane at which a body placed on it just begins to slide down by its own weight. It is equal to the angle of friction.
- Larger ϕ means rougher surfaces and greater friction.
- Typical values: μ is about 0.1 for smooth metal surfaces and 0.3 to 0.5 for rough surfaces.

Diagram in words: draw the normal vertical, R upward, F horizontal opposing motion, and the resultant tilted from R by angle ϕ towards the friction side.

Friction in simple machines

In every simple machine some effort is wasted in overcoming friction at joints, threads and contact surfaces. That is why the actual mechanical advantage is always less than the ideal value calculated from velocity ratio alone.

- **Screw jack:** friction between screw and nut decides whether the jack is self-locking; it holds the load without unwinding when the helix angle is less than the friction angle.
- **Inclined plane:** effort to push a load up is more than $W \sin \theta$ because friction acts down the plane; effort to lower is less because friction then helps.
- **Bearings and axles:** axle friction creates a resisting moment; lubrication reduces μ and improves efficiency.

Efficiency falls as friction rises: **efficiency = useful work output / work input**. In numericals, first find the ideal effort without friction, then add the friction effect as directed in the question.

Likely question: State the laws of friction. Define angle of friction and prove that the coefficient of friction is equal to the tangent of the angle of friction.

Laws of Motion & Simple Machines

Topics: Newton's laws; levers, pulleys and inclined planes.

Newton's laws

Newton's first law (law of inertia): a body remains at rest or in uniform motion in a straight line unless acted upon by an external force. It defines force and explains inertia — the resistance of a body to change in its state.

Second law: the rate of change of momentum is proportional to the applied force and takes place in its direction. For constant mass this gives the central formula **$F = ma$** , force in newton, mass in kg, acceleration in m/s^2 . Weight follows from it: $W = mg$.

Third law: to every action there is an equal and opposite reaction, acting on two different bodies — for example, the ground pushes back when you walk.

- Equations of motion used with these laws: $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$.
- Always take a consistent sign convention in numericals.

Levers, pulleys and inclined planes

A **simple machine** lifts a load W with a smaller effort P . Key terms: **Mechanical Advantage, $MA = W / P$; Velocity Ratio, $VR = \text{distance moved by effort} / \text{distance moved by load}$; Efficiency, $\eta = MA / VR \times 100\%$ (also output work / input work).**

- **Lever:** a rigid bar turning about a fulcrum. $MA = \text{effort arm} / \text{load arm}$. Longer effort arm means less effort. Examples: crowbar, see-saw, handle.

- **Pulley system:** VR equals the number of rope segments supporting the movable block. A single fixed pulley only changes direction ($MA = 1$ ideally); movable pulleys multiply advantage.
- **Inclined plane:** $VR = \text{length of plane} / \text{height} = 1 / \sin \theta$. Effort without friction, $P = W \sin \theta$.

Ideal machine has $\eta = 100\%$; in a real machine η is always less due to friction.

Likely question: Define mechanical advantage, velocity ratio and efficiency of a machine and write the relation between them. A lever has an effort arm of 80 cm and a load arm of 20 cm — find its mechanical advantage.

Centre of Gravity & Moment of Inertia

Topics: Centre of gravity of simple shapes; moment of inertia in brief.

Centre of gravity of simple shapes

The **centre of gravity (CG)** is the point through which the whole weight of a body may be taken to act, in any position of the body. For a composite shape, divide it into simple parts, find each part's area and centroid, then use $\bar{x} = \sum a_i x_i / \sum a_i$ and $\bar{y} = \sum a_i y_i / \sum a_i$ from a chosen reference axis.

Standard positions to remember:

- **Rectangle / square:** at the intersection of diagonals, i.e. at $L/2$ and $B/2$.
- **Triangle:** on the median, at $h/3$ from the base ($2h/3$ from the apex).
- **Semicircle:** at $4r / 3\pi$ from the centre along the axis of symmetry.
- **Cone (solid):** at $h/4$ from the base on its axis.
- **Cylinder / sphere:** at the geometric centre.

For symmetrical shapes the CG lies on the axis of symmetry — state this first in every answer.

Moment of inertia in brief

Moment of inertia (MI) is the resistance of a section to bending and rotation. For an area it is $I = \sum a \cdot y^2$, measured in mm^4 or cm^4 . A larger MI means a stiffer, stronger section for the same material.

Standard results in brief:

- **Rectangle** ($b \times d$) about its base axis: $I = bd^3 / 3$; about its centroidal axis: $I = bd^3 / 12$.
- **Circle** (diameter D) about a diameter: $I = \pi D^4 / 64$.
- **Triangle** (base b , height h) about its base: $I = bh^3 / 12$; about centroidal axis parallel to base: $I = bh^3 / 36$.

Parallel axis theorem: $I = I_G + A \cdot h^2$, where I_G is MI about the centroidal axis, A is area and h is distance between axes. **Perpendicular axis theorem** (for flat plates): $I_z = I_x + I_y$. Section modulus $Z = I / y_{\max}$ links MI to bending strength.

Likely question: Find the centre of gravity of a T-section or L-section from a given reference axis, and write the moment of inertia of a rectangular and a circular section about their centroidal axes.

Quick Revision — One Line Each

- Force is a vector — magnitude, direction, point of application and line of action.
- Resultant of two forces: $R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta}$.
- Equilibrant is equal, opposite and collinear to the resultant.
- Equilibrium of coplanar forces needs $\Sigma F_x = 0$, $\Sigma F_y = 0$ and $\Sigma M = 0$.
- Limiting friction follows $F = \mu R$ and acts opposite to impending motion.
- Coefficient of friction equals tan of the angle of friction: $\mu = \tan \phi$.
- Angle of repose is equal to the angle of friction.
- Newton's second law gives $F = ma$; weight $W = mg$.
- $MA = W/P$, $VR = \text{effort distance} / \text{load distance}$, $\text{efficiency} = MA/VR \times 100\%$.
- CG of a triangle is $h/3$ from the base; of a semicircle $4r/3\pi$ from the centre.
- MI of rectangle about centroidal axis is $bd^3/12$; of circle about diameter is $\pi D^4/64$.
- Parallel axis theorem: $I = IG + Ah^2$.

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