DEFINITIONS

Mechanics

The language of motion, forces, moments, energy and the models used to describe them.

47 definitions **5** subtopics By Lucas Potrykus

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HOW TO USE THIS

Each definition gives the exact meaning of a word or symbol. Where there is a symbol, it is shown next to the name, with how to say it out loud. Most definitions have a short example.

Learn definitions word for word: in proofs and in exams, the precise wording is what earns the marks.

Searchable online, with links to every topic, at lemmamathematics.com/definitions.

MODELS AND UNITS

More in **Kinematics**

Mathematical model

A simplified mathematical description of a real situation, built on assumptions, used to make predictions and then refined.

Particle

An object treated as a single point: its size is ignored, so it cannot rotate and air resistance can be neglected.

Rigid body and lamina

A rigid body has size but does not bend or deform. A lamina is a flat object whose thickness is ignored.

Light

A light object (such as a string or rod) is modelled as having zero mass, so the tension is the same throughout it.

Inextensible

A string that does not stretch, so connected objects move with the same speed and acceleration.

Smooth and rough

A smooth surface or pulley has no friction; a rough one does.

Uniform

A uniform rod or lamina has its mass spread evenly, so its centre of mass is at its geometric centre.

Rod and beam

A rod is a long, thin rigid body whose width is ignored; a beam is a rod that may bend in reality but is modelled as rigid.

Units with negative powers

$\mathrm{m\,s^{-2}}$

SAY *metres per second squared*

A negative power means "per". So $\mathrm{m\,s^{-1}}$ is metres per second, and a moment is measured in newton metres, $\mathrm{N\,m}$.

> EXAMPLE
> $1\ \mathrm{N} = 1\ \mathrm{kg\,m\,s^{-2}}$.

More in **Forces and Newton's laws**

Newton

N

The SI unit of force: the force giving a mass of 1 kg an acceleration of $1\ \mathrm{m\,s^{-2}}$, so $1\ \mathrm{N} = 1\ \mathrm{kg\,m\,s^{-2}}$.

KINEMATICS

More in **Kinematics**

Displacement and distance

Displacement is the vector position relative to a starting point (it can be negative); distance is the total length travelled (never negative).

Velocity and speed

Velocity is the rate of change of displacement, a vector; speed is its magnitude.

Acceleration

The rate of change of velocity. Deceleration (retardation) is acceleration opposite to the direction of motion.

The suvat letters

s, u, v, a, t

SAY *suvat*

Displacement, initial velocity, final velocity, acceleration and time, for motion with **constant** acceleration. Five equations link them, each missing one letter.

> EXAMPLE
> $v^2 = u^2 + 2as$ has no t.

Velocity–time graph

The gradient is the acceleration and the area under it is the displacement. On a displacement–time graph the gradient is the velocity.

Variable acceleration

When acceleration is not constant: $v = \frac{\mathrm{d}s}{\mathrm{d}t}$, $a = \frac{\mathrm{d}v}{\mathrm{d}t}$, and integrate to go back, using initial conditions for the constants.

Projectile

An object moving freely under gravity alone. Its horizontal velocity is constant and its vertical acceleration is g downwards, so its path is a parabola.

Time of flight, range and maximum height

For a projectile launched from ground level: the time until it lands, the horizontal distance travelled by then, and the greatest height reached (where the vertical velocity is zero).

FORCES AND NEWTON'S LAWS

More in **Forces and Newton's laws**

Force

A push or pull, measured in newtons. A vector, so it has a direction.

Common force letters

R, T, F, W

SAY *reaction; tension; friction; weight*

Usual names in force diagrams: R (or N) the normal reaction, T tension (or thrust), F friction, W weight.

Acceleration due to gravity

g

SAY *g*

About $9.8\,\mathrm{m\,s^{-2}}$ near the Earth's surface. A body of mass m has weight $W = mg$.

> EXAMPLE
> A $5\ \mathrm{kg}$ mass weighs $49\ \mathrm{N}$.

Weight and mass

Mass (kg) is the amount of matter; weight is the gravitational force on it, $W = mg$ newtons, acting vertically downwards.

Normal reaction

The force from a surface on an object, perpendicular to the surface.

Tension and thrust

Tension is the pulling force in a string or rod; thrust (compression) is the pushing force in a rod.

Friction

A force along a rough surface opposing the motion (or the tendency to move). It satisfies $F \le \mu R$, with equality when sliding or about to slide.

Coefficient of friction

μ

SAY *mu ("myoo")*

Friction satisfies $F \le \mu R$, with equality when the body is moving or on the point of moving (limiting friction).

> EXAMPLE
> On a rough plane with $\mu = 0.4$ and $R = 20\ \mathrm{N}$, friction can reach at most $8\ \mathrm{N}$.

Limiting equilibrium

An object on the point of moving: friction has its maximum value $F = \mu R$.

Equilibrium

An object is in equilibrium when the resultant force on it is zero (and, for a rigid body, the resultant moment too). It is at rest or moving at constant velocity.

Resultant force

The single force with the same effect as all the forces acting together: their vector sum.

Resolving

Splitting a force into components in two perpendicular directions: a force F at angle θ to a direction has component $F\cos\theta$ along it and $F\sin\theta$ perpendicular to it.

Newton's first law

An object stays at rest or moves with constant velocity unless a resultant force acts on it.

Newton's second law

$F = ma$

Resultant force = mass × acceleration: $F = ma$.

Newton's third law

If A exerts a force on B, then B exerts an equal and opposite force on A.

Connected particles

Particles joined by a light inextensible string (often over a smooth pulley), so they share the same acceleration and the tension is the same throughout the string.

MOMENTS AND CENTRES OF MASS

More in **Moments**

Moment

The turning effect of a force about a point: force × perpendicular distance from the point to the line of action. Units N m.

Pivot (fulcrum)

The point about which a body turns or could turn.

Equilibrium of a rigid body

The resultant force is zero and the total moment about **every** point is zero: clockwise moments equal anticlockwise moments.

On the point of tilting

A body about to turn about a support: the reaction at any other support has just become zero.

Couple

Two equal and opposite forces whose lines of action are different. It has a turning effect but no resultant force.

Centre of mass

The point where the whole mass of a body can be treated as acting. For particles, $\bar{x} = \dfrac{\sum m_i x_i}{\sum m_i}$.

MOMENTUM, WORK AND ENERGY

More in **Forces and Newton's laws**

Momentum

$m\mathbf{v}$

Mass × velocity, $m\boldsymbol{v}$: a vector, measured in N s (or kg m s^{-1}). In a collision the total momentum is conserved.

Impulse

The change in momentum, $\boldsymbol{I} = m\boldsymbol{v} - m\boldsymbol{u}$; for a constant force, force × time.

Coefficient of restitution

e

$e = \dfrac{\text{speed of separation}}{\text{speed of approach}}$ in a collision, with $0 \leq e \leq 1$. $e = 1$ is perfectly elastic and $e = 0$ perfectly inelastic.

Work done

Force × distance moved in the direction of the force, measured in joules (J).

Kinetic and potential energy

Kinetic energy is $\frac{1}{2}m\boldsymbol{v}^2$; gravitational potential energy is $\boldsymbol{mgh}$ relative to a chosen level. Without friction or other resistances, their total is conserved.

Power

The rate of doing work, measured in watts (W). For a vehicle, power = driving force × speed.

Hooke's law

The tension in an elastic string or spring is $\boldsymbol{T} = \dfrac{\lambda \boldsymbol{x}}{\boldsymbol{l}}$, where λ is the modulus of elasticity, $\boldsymbol{x}$ the extension and $\boldsymbol{l}$ the natural length. The elastic potential energy is $\dfrac{\lambda \boldsymbol{x}^2}{2\boldsymbol{l}}$.

Spotted a mistake, or a definition that should be here? Email lpotry31@gmail.com. More at lemmamathematics.com.