Quantities describing motion:

displacement = change of position
velocity = rate of change of position
acceleration = rate of change of velocity
force: "a push or a pull"; action on body that produces acceleration if unbalanced by other forces.
mass: a measure of inertia, i.e. resistance to being accelerated

Except for mass, these are all vectors, i.e. quantities with both magnitude and direction.
Vectors can be represented as arrows with a given length and direction.
Vectors are added by placing one arrow after the other, like sequential displacements.
The **net force** on a body is the vector sum of the forces acting on the body.

centripetal acceleration: acceleration toward the center of circular motion

Newton's laws:

1. acceleration = 0 unless a net force acts on the body
2. acceleration = net force/mass, **a** = **F**/m or equivalently **F** = m**a**
3. If body A exerts a force on body B, then B exerts a force on A with equal magnitude and opposite direction.

Energy:

Energy is **conserved**: energy can transfer from one form to another, but is never created or destroyed.

Types of energy:
kinetic energy (energy of motion): 1/2 mv^2
potential energy (energy of configuration): can arise from any type of force: gravitational, electrical, nuclear,...

Work is transfer of energy from one system to another.

Work = Force times component of displacement in the direction of the force.

Mechanical advantage: doing the same work with a smaller force acting over a larger distance.

Power = work per unit time or, used more generally, energy per unit time.

SI (Systeme International) units:

quantity	**SI unit**	**name**
length	m	meter
time	s	second
mass	kg	kilogram
velocity	m/s	
acceleration	m/s^2	
force	N = kg m/s^2	newton
energy	J = Nm = kg m^2/s^2	joule
power	W = J/s	watt
pressure	Pa = N/m^2	pascal
temperature	K	kelvin
entropy	J/K	
volume	m^3	
particle density	$1/m^3$	
mass density	kg/m^3	

Gravity:

Force of **universal gravitational attraction**: magnitude Gm_1m_2/d^2, where d is the separation distance of the two masses.
Gravitational force of the earth at surface: F = mg, g = 9.8 m/s^2, toward center of earth.

Gravitational potential energy change near earth's surface: mgh, where h is change of height.

Friction:

Friction force between two surfases can be static (when there is no relative motion) or sliding.

Sliding friction does microscopic work that converts ordered energy into disordered, **thermal energy**.

Pressure and Temperature:

pressure = force per unit area

static fluid pressure = weight of fluid above unit area surface
Example:
Pressure from one meter of water above the surface of earth
= Water weight in a cubic meter/square meter
= (density)(volume)(acceleration due to gravity)/area
= (1000 kg/m^3)(1 m^3)(9.8 m/s^2)/(1 m^2)
= 9800 Pa

Atmospheric air pressure =~ 100,000 Pa.

Buoyancy force arises from pressure surrounding a body immersed in fluid or gas. Pressure is greater deeper down so there is a net force upward.

Archimedes' principle: Buoyancy force is equal to the weight of the displaced fluid.
(Why: if you replaced the fluid it would remain stationary, so the surrounding buoyancy force must balance it's weight.)

Absolute temperature is a measure of the average thermal energy per particle.

absolute zero:	0 K = -273 °C (degrees Celsius)
freezing of water:	0 °C = 273 K
boiling of water:	100 °C = 373 K
freezing of nitrogen:	63 K
boiling of nitrogen:	77 K
"room" temperature	295 K = 22 °C ≈ 72 °F

Ideal gas law: An ideal gas is a gas whose particles are far enough apart so that their interactions (except occasional collisions) and their intrinsic size are unimportant. The pressure of an ideal gas is proportional to number of particles per unit volume and to temperature:
$p = k\, n_{particle}\, T$, where k is ***Boltzmann's constant*** = 1.31 10^{-23} Pa m^3/K.

Avogadro's principle: The number of molecules in an ideal gas is completely determined by the volume, pressure and temperature of the gas, and is therefore independent of the type of molecule. This follows directly from the ideal gas law.

Thermal equilibrium: A state of of system in which there is no flow of thermal energy, and no macroscopic changes of system. Two systems are in equilibrium with each other if, when placed in contact, there is no flow of thermal energy between them. If a system A is in equilibrium with two other systems, B and C, then B and C are in equilibrium with each other. (This is sometimes called the **0^{th} Law of Thermodynamics**.)

Thermodynamics:

Heat: flow of thermal energy from one system to another. Sometimes heat also refers to thermal energy even when it is not flowing from one system to another.

Mechanisms of heat flow: **conduction**: microscopic collisions; **convection**: movement of heated fluid or gas, usually due to buoyancy; **radiation**: electromagnetic waves, generated by thermal motion of electric charges.

Specific heat: heat capacity per unit mass per degree kelvin. Specific heat of water: 4190 J/kg K.

Phase transition: change between solid, liquid, or gaseous states.
Latent heat of melting or fusion: energy to break bonds of solid; e.g. for water ice: 330,000 J/kg.
Latent heat of evaporation or vaporization: energy to break bonds of liquid; e.g. for water: 2,300,000 J/kg.

1^{st} Law of Thermodynamics: This is just another way of saying that energy is conserved, in the context where energy changes of a subsystem come either in the form of heat flow or work.

Entropy: a measure of disorder. The **2^{nd} Law of Thermodynamics**: "overall, things never get less messed up", i.e., the total entropy of the world never decreases. A r**eversible** process is one in which the total entropy stays constant, i.e. does not increase.

Entropy changes: When heat Q flows into (or out of) a system in equilibrium at temperature T, the entropy of the system increases (or decreases) by an amount Q/T. When heat Q flows from a warm body to a colder body, entropy increases, since Q/T_cold > Q/T_warm. The second law of thermodynamics implies that heat will not by itself flow from cold to warm, since that would decrease entropy.

Heat pump: device that does work W to move heat from cold body to warmer body. The heat added to the warmer body is Q_warm = Q_cold + W. The non-decrease of entropy implies Q_warm/T_warm is not less than Q_cold/T_cold. When the net change of entropy is zero, the heat pump is said to be "ideally efficient". *Example*: a freezer uses evaporation of a fluid to draw heat out of the colder system. Then a pump does work on the vapor, compressing it, so it can re-condense in a heat exchanger, giving up the heat it drew in plus the heat that came from the compression. The fluid then goes back into the cold region, and through an expansion valve to drop its pressure, so it can be evaporated again.

Heat engine: device that uses heat Q_warm from a warmer body to do work W, dumping some heat Q_cold into a cold body, Q_warm = Q_cold + W. The non-decrease of entropy implies Q_cold/T_cold is not less than Q_warm/T_warm. When the net change of entropy is zero, the heat engine is said to be "ideally efficient". *Example*: a car engine uses the heat from burning mixture of fuel and air to push on a piston, doing work, and dumping less heat into the surrounding environment.