

# Physics: Quick reference

Vishvas Vasuki

September 29, 2009

See [1].

## Part I

# Movement, forces, work, energy

## 1 Kinematics

Displacement  $s$ : a vector. Mass  $m$ , time  $t$ . Speed, velocity  $v = \frac{ds}{dt}$ , momentum  $= mv$ .

## 2 Mechanics

Acceleration  $a = \frac{dv}{dt}$ .

### 2.1 Force

$F = ma$ ; so the rate of change of momentum. A vector too.

Forces occur in pairs: Action, reaction; when one body exerts a force on another, an equal force is exerted by that other body on it.

Conservation of momentum.

Normal forces, friction.

### 2.2 Modelling

Simplification, a body as a particle; free body diagrams. Center of mass; center of gravity.

### 2.3 Circular motion

Perpendicular forces, angular velocity  $\omega$ , relationship with  $v$ , Angular acceleration, torque. The wheel.

## 3 Forces

### 3.1 Gravity

#### 3.1.1 Newton's model

The law of gravity:  $F = k \frac{m_1 m_2}{r^2}$ . Usually accurate enough in daily life.

**Drawbacks** There is instantaneous action at a distance. But, according to special theory of relativity, no information can be transmitted faster than the speed of light; but if newton's law was an accurate model, you would have a gravitational telegraph which can transmit information instantaneously.

#### 3.1.2 Curvature in space-time model

Mass curves space-time. Objects move through this curved space-time.

**Gravitational waves** An object oscillating in a small space causes waves in space-time.

Evidence of existence: Massive stars revolving around each other moving closer to each other, losing energy; matches theoretical prediction of energy dissipated as gravitational waves.

#### 3.1.3 Application of Newton model

**Gravity exerted by spherical objects** An important special case. If sphere is symmetric in density, it turns out that using point mass located at the center of the sphere is an equally accurate model.

**Object falling through air, close to planetary surface** Model: Acceleration due to gravity is constant: relative change in  $r$  is insignificant.

Air resistance, terminal velocity.

## 4 Energy

Work  $w = \int_a^b f ds$ , energy, power. The law of conservation of energy. Potential and kinetic energy. Heat. Escape velocity.

## 5 Thermodynamics

Molecular motion. Thermodynamic equilibrium is an equivalence relation.

Closed thermodynamic system: Change in the internal energy  $U = (\text{Enthalpy})$  Heat supplied + work done.

Work/ energy:  $PV = nRT$ . Engines: external combustion and internal combustion.  $PV$  curve; cyclical processes, Isothermic and adiabatic processes. Area

of a cycle: No perfect engine law. Carnot cycle. Refridgeration and compressors. The total entropy of any isolated thermodynamic system tends to increase over time, approaching a maximum value. Definition of Absolute Zero temperature. Boltzmann distribution of energy at temperature T. Heat: Conduction, convection, radiation. Stefan Boltzmann law. Radiation and absorption spectra.

## 6 Electricity

Charge: attraction and repulsion. The inverse square law. Lines of force, flux. Find charge inside a surface: Gauss' law. Electric potential energy; electric potential. Potential contours, electric field. Potential difference and force.

### 6.1 Magnetism

The Hall effect. Magnetic field B as force per unit moving charge:  $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ ; Relative direction of B. Natural magnets: electric dipoles. Electromagnets. Construction of electric motors and mechanical electricity generators. AC and DC.

## 7 Quantum mechanics

Matter waves. Quanta: Photoelectric effect.

## 8 Relativity

Conservation of energy and mass.

## Part II

# Modelling important situations

## 9 Periodic Motion

Longitudinal and transverse waves. Frequency, amplitude. Equation for displacement about a point; relationship with circular motion.

## 10 Hydrodynamics

Incompressible fluids. Bernoulli's law relates density, gravity, fluid velocity. Flight of airplanes and helicopters. Buoyancy. Viscosity.

## 11 Electric circuits

Electric current, resistivity, conductance. Resistance in a wire related to resistivity, thickness and length: The molecular view.  $V=IR$ . Heat generated by resistance. Kirchoff's law of voltage and current in loops: linear equations solved using linear algebra [2]. Capacitors. Capacitance: charge stored, potential difference; plate surface area, distance, dipole moment. Electric transmission using earth and a wire.

## 12 Electronics

Semiconductors. Silicon, germanium. Positive and negative doping. Diodes: The np junction. .5V to .7V barrier. Forward bias. Reverse bias: breakdown after 5V. Transistors: pnp and npn. Operational Amplifiers.

## References

- [1] David Halliday, Robert Resnick, and Jearl Walker. *Extended , Fundamentals of Physics, 6th Edition*. Wiley, June 2000.
- [2] Gilbert Strang. *Linear Algebra and its applications, 4e*. Thomson Brooks/Cole, 2006.