Classical Physics

- The world is a "clockwork."
- It is describable by *Laws*
- The Laws use:
  - The language of mathematics
  - Everyday words with precise definitions.
- Space and time are continuous
- Absolute space and absolute time
- All inertial reference frames are equivalent

Problem Solving

1. Carefully read the problem.
2. Draw a diagram, choose a coordinate system.
3. Guess the answer.
4. Cast the problem into equations.
5. Solve the equations to get an algebraic answer.
6. Substitute numbers and units into the solution.
7. Compare your answer to your guess.

Guessing an answer

- Order-of-magnitude calculations
- Dimensional analysis
- Fermi problems

Units

- Systems of units
- 4 fundamental ones
  - Length, mass, time, electric charge
  - All others derived from these
- Dimensional Analysis and Unit Conversion
  - Dimensions can be treated as algebraic quantities

Coordinate Systems

- Cartesian (Rectangular)
- Polar (Spherical)
- In principle, the choice is arbitrary
- In practice, some choices make your work much simpler

Scalars and Vectors

- Scalar: magnitude only
- Vector: magnitude and direction
  - Not part of the specification: a starting point.
  - Often specify with Cartesian components.
- Vector addition and subtraction
  - Just add Cartesian components.

Kinematics

Slopes - Derivatives

$$\vec{x} = \vec{f}(t)$$

$$\vec{v} = \frac{d\vec{x}}{dt} = \vec{g}(t)$$

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{x}}{dt^2} = \vec{h}(t)$$

Areas - Integrals

Constant Acceleration

$$\vec{v_f} = \vec{v_i} + \vec{a}\,t$$

$$\vec{x_f} = \vec{x_i} + \vec{v_i}\,t + \frac{1}{2}\vec{a}\,t^2$$

- Freely falling bodies
- Projectile
- Centripetal and Tangential acceleration

Newton’s Laws

$$\vec{F}_{total} = \frac{d\vec{p}}{dt} \qquad \vec{p} = m\vec{v} \qquad \vec{F}_{total} = \sum \vec{F}_i$$

$$\vec{F}_{1\ on\ 2} = -\vec{F}_{2\ on\ 1}$$

- True only in non-accelerating frames
- Inertial and Gravitational Mass

Ballistocardiogram (BCG)

Four Fundamental Forces

1. Gravitational
   - Caused by masses
2. Electromagnetic
   - Caused by electric charges
3. Nuclear (strong)
   - Holds the nucleus together
4. Weak
   - Governs radioactive decay

The *Field* Concept

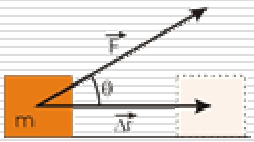
- Divides, say, the gravitational interaction into 2 parts:
  1. A mass M causes a gravitational field in all regions of space around it.
  2. The gravitational field causes a force on any mass m placed in it.

Systems and their Environment

- For many problems, you need to define the *system*.
  - The part of the universe outside the system is called the *environment*.
- Then, identify things (such as forces) from the environment that are acting on the system.

Work W

- For a constant force: $W = F\,\Delta r\cos(\theta)$
- In terms of the dot product:



$$W = \vec{F}\cdot\overrightarrow{\Delta r}$$

- For a non-constant force:

$$W_{net} = \int_{\vec{r}_i}^{\vec{r}_f} \sum \vec{F}\cdot d\vec{r}$$

Work – Kinetic Energy Theorem

Often allows us to solve problems without using Newton's Laws directly.

$$K \equiv \frac{1}{2} m v^2$$

$$W_{net} = \Delta K = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

Conservation of Energy

Energy has many forms:

- Kinetic
- Heat
- Potential
- Etc.

ΔE_{system} Change of energy of a system

$\sum H$ Energy transferred into the system

$$\Delta E_{system} = \sum H$$

Potential Energy U

- Scalar
- $\Delta U = -W$
- Arbitrary choice of where $U = 0$
- Energy stored in a system
  - Gravitational: mgh or $-G\,Mm/r$
  - Spring-mass: $\frac{1}{2} k x^2$
  - Electrostatic: $k\,Qq/r$
- $E_{mech} = U + K$

2 Different Kinds of Forces

- Conservative
  - The work done is independent of the path
  - One may define a potential energy U
  - $F_x = -\,dU / dx$
- Non-conservative
  - The work depends on the path
  - Potential energy is not definable

Equilibrium

- Stable Equilibrium: a local minimum in the potential energy
- Unstable Equilibrium: a local maximum in the potential energy

Conservation of Momentum

For an isolated system, the total momentum is conserved.

Impulse: $\vec{I} \equiv \sum \vec{F}\,\Delta t = \Delta \vec{p}$

Collisions

- Elastic
  - Forces between objects in system are conservative.
  - E_{mech} = K + U conserved
- Inelastic
  - Forces between objects in system are not all conservative.
  - E_{mech} not conserved.

Vector momentum is conserved in both cases.

Translation – Rotation Analogs

Translational Motion	Rotational Motion	Connection
s	θ	$s = r\,\theta$
v	ω	$v = r\,\omega$
a	α	$a_t = r\,\alpha$
m	$I = \Sigma\, m\, r^2$	

Rotational Motion

- Cross product: $\vec{C} = \vec{A} \times \vec{B}$
  - Magnitude = A B sin(θ)

More Analogs

$\vec{F}$	$\vec{\tau} = \vec{r} \times \vec{F}$
$\vec{p} = m\,\vec{v}$	$\vec{L} = I\,\vec{\omega} = \vec{r} \times \vec{p}$
$\vec{F} = \dfrac{d\,\vec{p}}{dt}$	$\vec{\tau} = \dfrac{d\,\vec{L}}{dt}$