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

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

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

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

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.

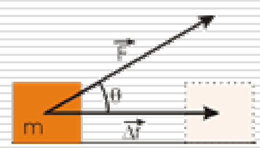
Systems and their Environment

- 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:

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



- 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

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

Basal Metabolism

Dimensional Analysis

Power

- P = dE / dt
  - Unit: J/s = watt W
  - P = **F** . **v**

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: ½ 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

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

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

Equilibrium

- $\Sigma\,\mathbf{F} = 0$
  $\Sigma\,\tau = 0$
- Stable Equilibrium: a local minimum in the potential energy
- Unstable Equilibrium: a local maximum in the potential energy

Example: forces on the leg, use of a cane.