EE1.el3 (EEE1023): Electronics III

Mechanics lecture 11

Revision

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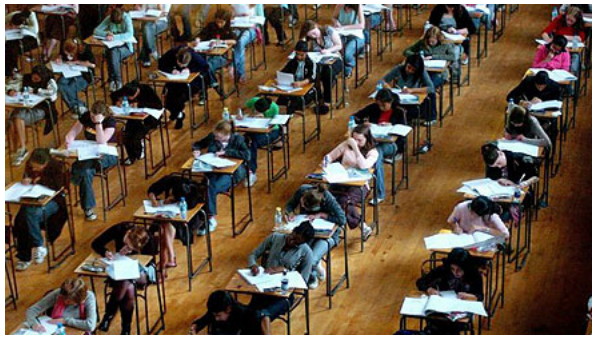

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Review of mechanics topics

- Physical quantities and dimensions
- Static forces
- Kinematics
- Dynamics

Preparation for Revision

- What is **mechanics**?
  - organize the main topics that we have covered

- What are the key equations
  - identify general formulae
  - understand every symbol's meaning

Physical quantities and dimensions

Base quantities and dimensions:

Quantity	Dim.	Unit	Symbol
mass	M	kilogram	kg
length	L	metre	m
time	T	second	s
current	I	ampere	A
temperature	Θ	kelvin	K
substance	N	mole	mol
luminosity	J	candela	cd

Checking formulae:

$$\dim(LHS) = \dim(RHS)$$

Scaling:

$$\dim(\textit{dimensionless quantity}) = \emptyset$$

Static forces

Fundamental forces: gravity, EM, weak & strong

Force vectors: line of action, components

$$F_x = \mathbf{F}.\mathbf{i}$$

Moments of forces:

$$\mathbf{M} = \mathbf{r} \times \mathbf{F}$$

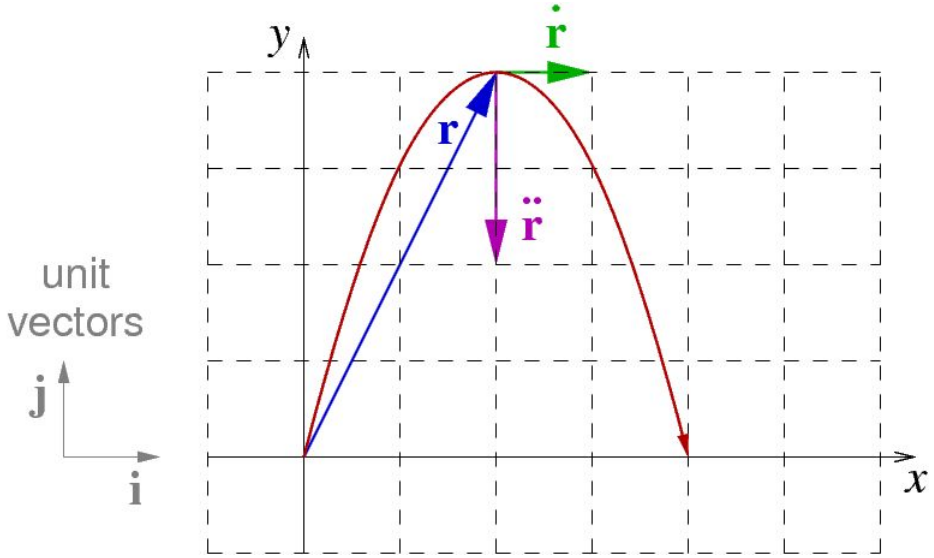
Equilibrium: zero resultant force and moment

$$\mathbf{R}_F = \sum_i \mathbf{F}_i = 0 \qquad \text{and} \qquad \mathbf{R}_M = \sum_j \mathbf{M}_j = 0$$

Kinematics

Acceleration, velocity and displacement vectors:

$$\ddot{\mathbf{r}}(t) = \frac{d\,\dot{\mathbf{r}}(t)}{dt} = \frac{d^2\,\mathbf{r}(t)}{dt^2}$$



Rotational motion:

$$\dot{\mathbf{r}} = \boldsymbol{\omega} \times \mathbf{r}$$

Dynamics

Newton's laws of motion

1. Inertia: no force, constant velocity
2. Change: force causes change of momentum, $\mathbf{F} = \dfrac{d(m\dot{\mathbf{r}})}{dt}$
3. Opposition: equal and opposite forces

Work

$$W = \int \mathbf{F}.\mathbf{dr} + \int \mathbf{T}.\mathbf{d}\theta$$

for conservative forces $\oint \mathbf{F}.\mathbf{dr} = 0$

and potential energy $U = -\int \mathbf{F}.\mathbf{dr}$

Simple Harmonic Motion

$$m\ddot{\mathbf{x}} + k\mathbf{x} = 0$$

Revision questions

1. The Surrey Space Rocket weighs 10 tonnes (10^4 kg) at launch and produces a constant thrust of $\mathbf{F} = 120\mathbf{j}$ kN.

   (a) What are the dimensions of acceleration?

   (b) What is the SI unit for acceleration?

   (c) What is its initial acceleration as a vector $\ddot{\mathbf{y}}$ at lift off? [Assume $g = 9.81\,\mathrm{ms}^{-2}$.]

   (d) After some time, it attains an altitude of 1 km. What is the mechanical work done by the rocket?

   (e) Assuming no variation in the gravitational field at that distance, calculate the potential energy.

   (f) Assuming no losses due to non-conservative (drag) forces but a reduced mass of 9.6 tonnes, estimate the rocket's kinetic energy and hence its speed $\dot{y}$.

Revision questions

2. Later in its mission, the docking module ($m_D = 1$ tonne) approaches the International Space Station (ISS). The displacement of its centre of gravity (CoG) relative to the docking point at the origin prior to contact at t=0 is $\mathbf{x}(t) = (2 - 0.05t)\mathbf{i} + vt\mathbf{j}$. However, a point P at the other end of the ISS has a displacement $\mathbf{r}$ that varies over time due to its rotation in orbit:

$$\mathbf{r}(t) = -10\cos\omega t\mathbf{i} - 10\sin\omega t\mathbf{j} \qquad (1)$$

where $\omega = 2\pi \times 10^{-3}\mathbf{k}\,\mathrm{s}^{-1}$.

(a) Give a vector expression for the velocity of point P over time.

(b) What is the instantaneous (vector) velocity of P at $t = 0$?

(c) Given $\mathbf{x}(t)$'s position on contact, what is the magnitude of the vertical velocity component v needed to match the ISS's rotation?

Revision questions

2.(d) Immediately after contact, the module's displacement is $\mathbf{x}(t) = 2\mathbf{i} + vt\mathbf{j}$. What is the change in the module's momentum?

(e) Given that the angular inertia of the docking module is $I = 8m_D/3$, what would be the burn duration d required to increase the docking module's angular velocity about its CoG from $0\,\mathrm{s}^{-1}$ to $\omega\,\mathrm{s}^{-1}$ from a pair of thrusters with a combined torque strength of $T = 100\,\mathrm{Nm}$?

Summary of Revision

1. Dimensional analysis
   - Base quantities
   - Formula checking
   - Scaling
2. Static forces
   - Fundamental forces
   - Force vectors
   - Moments of forces
   - Equilibrium
3. Kinematics of motion
   - Acceleration, velocity and displacement
   - Rotational motion
4. Dynamic forces
   - Newton's laws of motion
   - Work, conservative forces and potential energy
   - Simple harmonic motion

Preparation for Acoustics (semester 2)

- What is a **sound wave**?
  - look up a definition of sound and its properties

- Example of a device for manipulating sound
  - write down or draw your example
  - explain how it modifies the sound