DUT – RU International School
of Information Science & Engineering

Topic

SUMMARY

Lecture Course (online)
Dalian, 2021

So far we have considered…

- Introduction to Physics ***(topic 01)***
- Mechanics ***(topic 02, parts 1-3)***
- Electricity and Magnetism ***(topic 03, parts 1-2)***
- Thermal Physics ***(topic 04)***
- Vibrations and Waves ***(topic 05)***
- Light and Optics ***(topic 06)***
- Modern Physics ***(topic 07)*** **[optional]**

Kinematics | Mechanics

The arbitrary 3-D **motion** of a point particle is characterized by:

- position vector $\vec{r}(t) = (x, y, z)$
- velocity vector $\vec{v}(t) = \dot{\vec{r}}(t) = (\dot{x}, \dot{y}, \dot{z})$
- acceleration vector $\vec{a}(t) = \dot{\vec{v}}(t) = \ddot{\vec{r}}(t) = (\ddot{x}, \ddot{y}, \ddot{z})$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{v} = \frac{d\vec{r}}{dt}$$

Method of coordinates	**Natural method**
for more details see **Topic 02-1 (80-84)**	for more details see **Topic 02-1 (85-88)**

Free falling objects

Projectile motion

Uniform circular motion

simplest types of motion

can be considered WITHOUT integration / differentiation

for more details see
Topic 02-1 (40-45)
Topic 02-1 (67-76)
Topic 02-1 (92)

Dynamics | Mechanics

Newton's Laws

The 1st law or Galilei's law of inertia

The 2nd law or the equation of motion

The 3rd law or action equals reaction

for more details see **Topic 02-2**

inertial reference frames only !!!

$$\boxed{m\frac{d\vec{v}}{dt} = \vec{F}}$$

the fundamental equation of dynamics

$$\vec{F} = \sum_{i=1}^{n} \vec{F}_i$$

superposition principle

Galilean transformation:

$$\begin{cases} \vec{r} = \vec{r}\,' + \vec{v}_0 t\,' \\ t = t\,' \end{cases}$$

Switching to non-IRF:

$$m\vec{a}\,' = \vec{F} + \vec{F}_{in} + \vec{F}_{cf} + \vec{F}_{Cor}$$

for more details see **Topic 02-2 (35-42)**

$$\boxed{\vec{F}_{in} = -m\vec{a}_0}$$

inertial force (translational motion)

$$\boxed{\vec{F}_{cf} = m\omega^2\vec{\rho}}$$

centrifugal force

$$\boxed{\vec{F}_{Cor} = 2m[\vec{v}\,' \times \vec{\omega}]}$$

Coriolis force

Other Concepts | Mechanics

$$dW = \vec{F}\cdot d\vec{r} = F_x\,dx + F_y\,dy + F_z\,dz$$

$$\boxed{W = \int_{r_i}^{r_f} dW = \int_{x_i}^{x_f} F_x\,dx + \int_{y_i}^{y_f} F_y\,dy + \int_{z_i}^{z_f} F_z\,dz}$$

general case: work done by a varying force

$$P = \frac{dW}{dt} \quad \text{(instantaneous power)}$$

$$P = \vec{F}\cdot\vec{v}$$

power

for more details see **Topic 02-3 (4-12)**

conservative forces → $\boxed{\vec{F} = -\nabla U}$

non-conservative forces **X**

force and potential energy

finite **motion** infinite

for more details see **Topic 02-3 (14-28)**

Systems with varying mass →

$$\boxed{m\frac{d\vec{v}}{dt} = \vec{F} + \underbrace{\frac{dm}{dt}\vec{u}}_{\text{reactive force } \mathbf{R}}}$$

Meshchersky equation
(fundamental equation of dynamics of a mass point with variable mass)

for more details see **Topic 02-3 (31-35)**

Coulomb's Law, Capacitors | Electricity

$$\vec{F} = k\,\frac{q_1 q_2}{r^2}\,\hat{r}$$

Coulomb's law

$$e = 1.602 \times 10^{-19}\,\mathrm{C}$$

elementary charge

$$q = ne, \qquad n = \pm 1, \pm 2, \pm 3, \ldots,$$

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\,\hat{r}$$

electric field vector

point charges

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

potential

For more complicated systems (both discrete and continuous)

SUPERPOSITION PRINCIPLE

for more details see
Topic 03-1 (4-30)

These expressions can also be used as starting points in case of continuous distribution of charges!

$$\vec{E} = -\nabla V$$

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

CAPACITORS

$$q = CV$$

$$C = \frac{\varepsilon_0 A}{d}$$

$$C = \kappa C_{\mathrm{air}}$$

$$U = \frac{q^2}{2C}$$

$$U = \tfrac{1}{2} C V^2$$

$$u = \tfrac{1}{2}\varepsilon_0 E^2$$

for more details see
Topic 03-1 (31-42)

Electric Current & Circuits | Electricity

LOOP RULE: The algebraic sum of the changes in potential encountered in a complete traversal of any loop of a circuit must be zero.

RESISTANCE RULE: For a move through a resistance in the direction of the current, the change in potential is $-iR$; in the opposite direction it is $+iR$.

EMF RULE: For a move through an ideal emf device in the direction of the emf arrow, the change in potential is $+\mathscr{E}$; in the opposite direction it is $-\mathscr{E}$.

JUNCTION RULE: The sum of the currents entering any junction must be equal to the sum of the currents leaving that junction.

$$\boxed{i = \frac{dq}{dt}}$$

electric current

$$\boxed{R = \frac{V}{i}}$$

Ohm's law

$$\boxed{i = \frac{\mathscr{E}}{R + r}}$$

$$\boxed{V_b - V_a = \frac{\mathscr{E}}{R + r}}$$

+

Series and Parallel Resistors and Capacitors

Let us summarize the equivalence relations

Series	Parallel
Resistors	
$R_{eq} = \sum_{j=1}^{n} R_j$	$\frac{1}{R_{eq}} = \sum_{j=1}^{n} \frac{1}{R_j}$
Same current through all resistors	Same potential difference across all resistors
Capacitors	
$\frac{1}{C_{eq}} = \sum_{j=1}^{n} \frac{1}{C_j}$	$C_{eq} = \sum_{j=1}^{n} C_j$
Same charge on all capacitors	Same potential difference across all capacitors

59

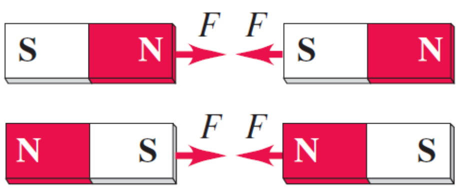
=

for more details see **Topic 03-1 (44-65)**

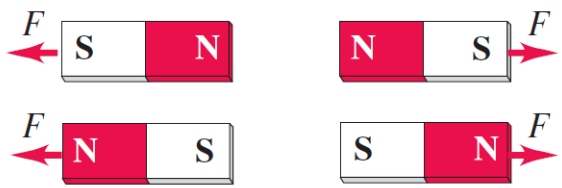
successful completion of any problem

Magnetic Forces and Fields | Magnetism

Opposite poles attract.



Like poles repel.



Magnetic field lines are **NOT** the “lines of force” !!!

for more details see **Topic 03-2 (4-24)**

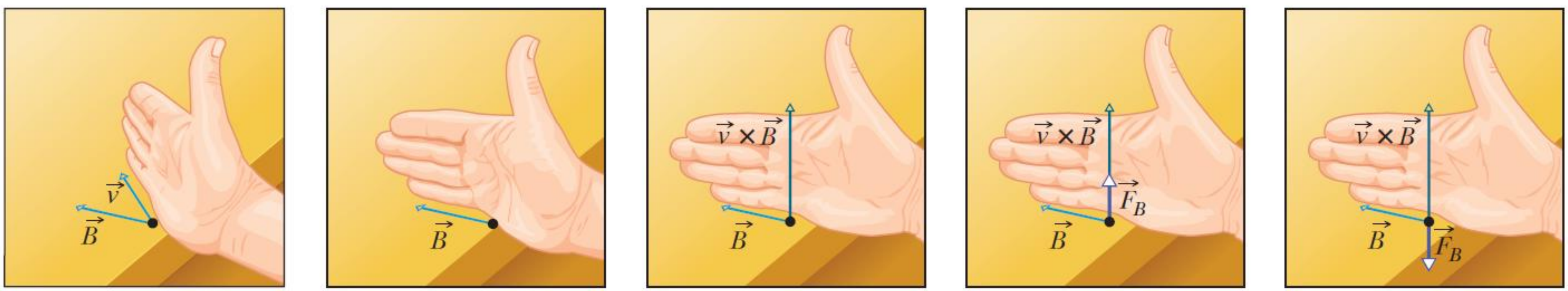
$$\boxed{\vec{F} = q\vec{v} \times \vec{B}}$$

only charged moving particles are affected

Cross $\vec{v}$ into $\vec{B}$ to get the new vector $\vec{v} \times \vec{B}$.

Force on positive particle

Force on negative particle



current-carrying wires as well

$$\vec{F}_B = i\vec{L} \times \vec{B}$$

$$d\vec{F}_B = i\, d\vec{L} \times \vec{B}$$

crooked (non-straight) wire

Sources of Magnetic Field | Magnetism

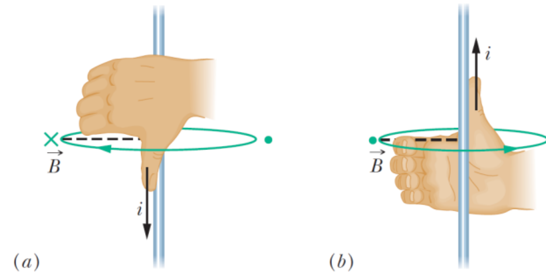
for more details see
Topic 03-2 (25-37)

sources: moving charges and current-carrying wires

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$$

Biot-Savart law:

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l}\times\hat{r}}{r^2}$$



+ SUPERPOSITION PRINCIPLE

$$B = \frac{\mu_0 i}{2\pi R}$$

straight wire

$$B = \frac{\mu_0 i\phi}{4\pi R}$$

arc wire

To find the force on a current-carrying wire due to a second current-carrying wire, first find the field due to the second wire at the site of the first wire. Then find the force on the first wire due to that field.

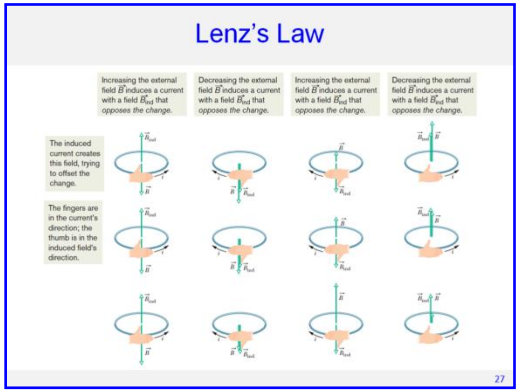
Parallel currents attract each other, and antiparallel currents repel each other.

Induction and Inductance | Magnetism

Faraday's law of induction: an emf is induced in the loop at the left in both figures when the number of magnetic field lines that pass through the loop is changing.

$$\mathscr{E} = -\frac{d\Phi_B}{dt}$$

An induced current has a direction such that the magnetic field due to *the current* opposes the change in the magnetic flux that induces the current.



$$\mathscr{E}_L = -L\frac{di}{dt}$$

self-induction

for more details see
Topic 03-2 (38-49)

magnetic energy

$$U_B = \frac{1}{2}Li^2$$

$$u_B = \frac{B^2}{2\mu_0}$$

for more details see
Topic 03-2 (53-54)

Laws of Thermodynamics | Thermal Physics

0: If bodies A and B are each in thermal equilibrium with a third body T, then A and B are in thermal equilibrium with each other.

1: The internal energy E_{int} of a system tends to increase if energy is added as heat Q and tends to decrease if energy is lost as work W done by the system.

2: If a process occurs in a *closed* system, the entropy of the system increases for irreversible processes and remains constant for reversible processes. It never decreases.

$$Q = cm\,\Delta T = cm(T_f - T_i)$$

increasing / decreasing temperature of an object

for more details see **Topic 04**

$$\Delta S = S_f - S_i = \int_i^f \frac{dQ}{T}$$

change of entropy

$$Q = Lm$$

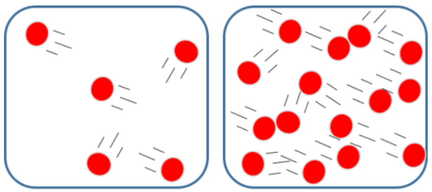
heat of transformation/combustion

$$dE_{\text{int}} = dQ - dW$$

The Law: $\Delta E_{\text{int}} = Q - W$

Process	Restriction	Consequence
Adiabatic	$Q = 0$	$\Delta E_{\text{int}} = -W$
Constant volume	$W = 0$	$\Delta E_{\text{int}} = Q$
Closed cycle	$\Delta E_{\text{int}} = 0$	$Q = W$
Free expansion	$Q = W = 0$	$\Delta E_{\text{int}} = 0$

Kinetic Theory of Gases & Ideal Gases | Thermal Physics



Ideal Gas   Non-Ideal Gas

$$\boxed{pV = nRT}$$

ideal gas law

$$\boxed{pV = NkT}$$

$$\boxed{v_{\text{rms}} = \sqrt{\frac{3RT}{M}}}$$

$$\boxed{K_{\text{avg}} = \tfrac{3}{2}kT}$$

$$\boxed{E_{\text{int}} = \tfrac{3}{2}nRT}$$

$$\boxed{Q = nC_V\,\Delta T}$$

$$\boxed{C_V = \tfrac{3}{2}R = 12.5\ \text{J/mol}\cdot\text{K}}$$

$$\boxed{Q = nC_p\,\Delta T}$$

$$\boxed{C_p = C_V + R}$$

$$\boxed{\Delta E_{\text{int}} = nC_V\,\Delta T}$$

$$\boxed{pV^{\gamma} = \text{a constant}}$$

$$\boxed{\gamma = C_p/C_V}$$

for more details see
Topic 04 (34-57)

			Some Special Results
Path	Constant Quantity	Process Type	($\Delta E_{\text{int}} = Q - W$ and $\Delta E_{\text{int}} = nC_V\Delta T$ for all paths)
1	p	Isobaric	$Q = nC_p\,\Delta T; W = p\,\Delta V$
2	T	Isothermal	$Q = W = nRT\ln(V_f/V_i);\ \Delta E_{\text{int}} = 0$
3	$pV^{\gamma}, TV^{\gamma-1}$	Adiabatic	$Q = 0;\quad W = -\Delta E_{\text{int}}$
4	V	Isochoric	$Q = \Delta E_{\text{int}} = nC_V\,\Delta T;\quad W = 0$

Vibrations

Displacement at time t

Phase

$$\underbrace{x(t)}_{\text{Displacement at time } t} = \underbrace{x_m}_{\text{Amplitude}} \cos\underbrace{(\omega t + \phi)}_{\text{Phase}}$$

Amplitude, Time, Angular frequency (ω), Phase constant or phase angle (ϕ)

$$\boxed{m\ddot{x} + kx = 0} \Rightarrow \boxed{x(t) = x_m \cos(\omega t + \phi)}$$

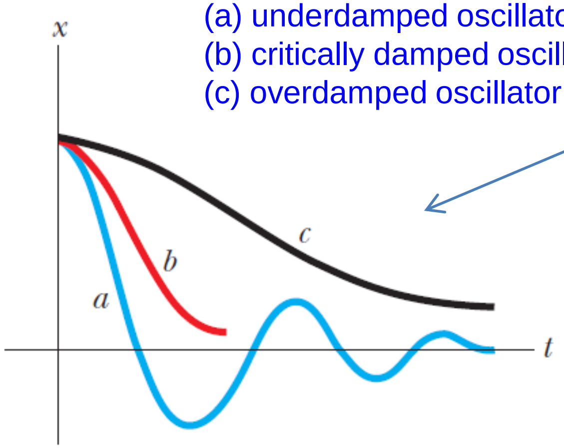
simple harmonic motion (SHM)

$$\omega = \sqrt{\frac{k}{m}} \qquad \boxed{T = \frac{2\pi}{\omega}}$$

for more details see **Topic 05 (4-10)**

$$\boxed{\ddot{\heartsuit} + \omega^2 \heartsuit = 0 \quad \Rightarrow \quad \heartsuit(t) = \heartsuit_m \cos(\omega t + \phi)}$$

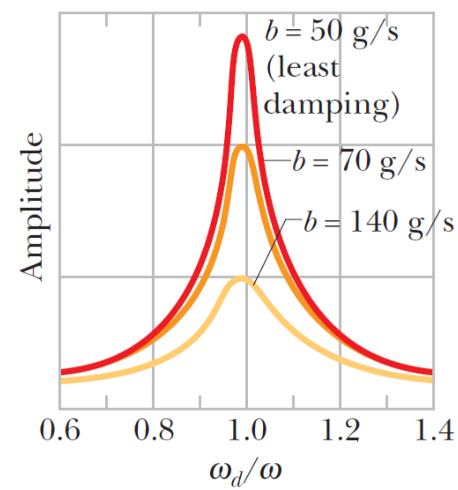
(a) underdamped oscillator;
(b) critically damped oscillator;
(c) overdamped oscillator



$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$

for more details see **Topic 05 (11-15)**

$$\boxed{m\ddot{x} + b\dot{x} + kx = f_d \sin \omega_d t}$$

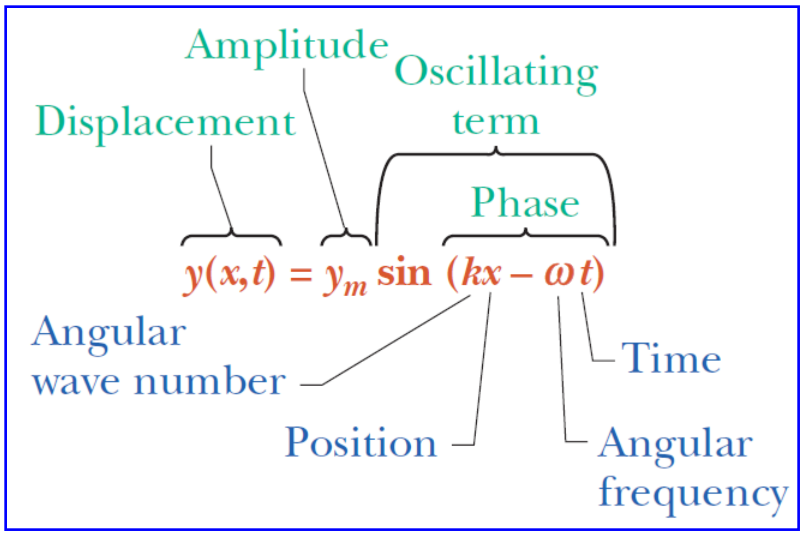


Waves

Types of waves

mechanical waves	electromagnetic waves	matter waves

transverse waves	longitudinal waves



$$y(x,t) = y_m \sin(kx - \omega t)$$

sinusoidal wave

$$k = \frac{2\pi}{\lambda}$$

$$\omega = \frac{2\pi}{T}$$

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

$$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$$

for more details see **Topic 05 (16-25)**

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

wave equation

$$y'(x,t) = y_1(x,t) + y_2(x,t)$$

SUPERPOSITION PRINCIPLE

Light and Optics

When light travelling in one medium encounters a boundary leading into a second medium, the processes of **reflection** and **refraction** can occur.

The **law of reflection**:
(deduced experimentally)

$$\theta_1' = \theta_1$$

the angle of reflection equals the angle of incidence

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Snell's law of refraction

for more details see **Topic 06 (4-11)**

REAL IMAGE

VIRTUAL IMAGE

$$M \equiv \frac{\text{image height}}{\text{object height}} = \frac{h'}{h}$$

magnification

$$M = \frac{h'}{h} = -\frac{q}{p}$$

converging lenses

diverging lenses

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

thin-lens equation

for more details see **Topic 06 (12-26)**

Flat mirrors:

1. The image is as far behind the mirror as the object is in front.
2. The image is unmagnified, virtual, and upright.


GOOD LUCK ...
... AND HAPPY NEW YEAR !