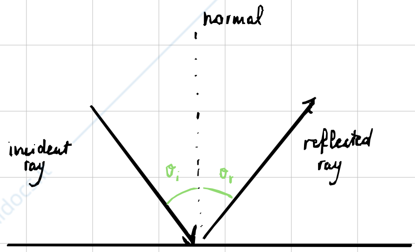
Geometrical optics

light can be reflected, refracted, diffracted and can interfere

$c = \lambda f$

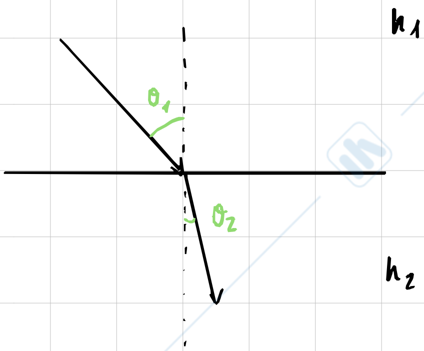
- REFLECTION



$\theta_i = \theta_r$

angles are measured with respect to the normal, not the surface.

- REFRACTION



θ changes $\longrightarrow \lambda \longrightarrow v$

velocity depends on medium

$v = c/$

n = refractive index $= \dfrac{c}{v}$

$\lambda = \lambda$

Snell - Cartesio law of refraction

$$\boxed{n_1 \sin\theta_1 = n_2 \sin\theta_2}$$

if $\theta_2 = 90°$ I can find $\theta_1 = \theta_\ell$ = limit angle over which I have total reflection

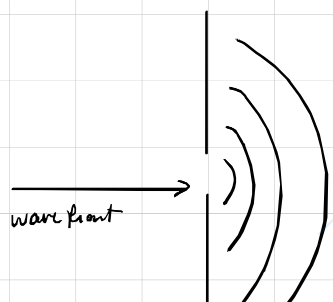
$\theta_2 = 90°$

$n_1 \sin\theta_\ell = n_e \cdot 1 \longrightarrow \sin\theta_\ell = \dfrac{n_e}{n_1}$

- DIFFRACTION

Huygens:

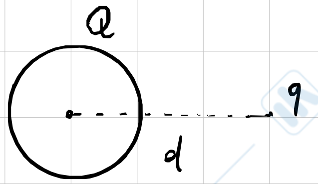
wave nature of light



the slit serves as a secondary source of waves

Electrostatics

Coulomb's law: $F_e = \frac{k|q_1||q_2|}{r^2}$ $\quad k = 9 \cdot 10^9$



$$F_e = \frac{k(\underbrace{\sigma 4\pi R^2}_{Q=\sigma A})(q)}{d^2}$$

Superpositional principle for forces $\longrightarrow$ remember to compute the x and y components

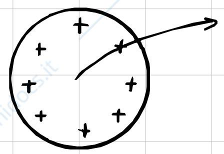
Eletric field

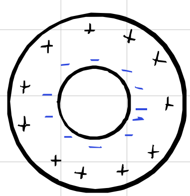
$$\vec{E} = \frac{\vec{F}}{|q_0|} = \frac{k|q||\cancel{q_0}|}{r^2|\cancel{q_0}|} = \frac{k|q|}{r^2}$$

if $+q_0$ $\quad \vec{F} \parallel \vec{E}$
if $-q_0$ $\quad -\vec{F} \parallel \vec{E}$

Superpositional principle for $\vec{E}$.

Conductors

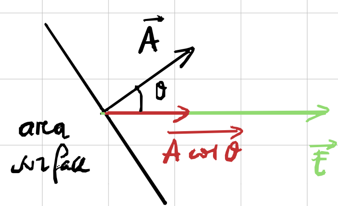




charge distributed on the outer surface

Flux

$\phi(\vec{E}) = \vec{E} \cdot \vec{A} = EA\cos\theta$



$\phi(\vec{E}) = \frac{\sum Q}{\varepsilon_0}$ Gauss' law $\longrightarrow$ $EA = \frac{Q}{\varepsilon_0}$

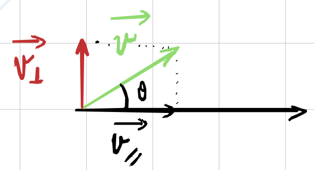
Electric field lines
- radiate outward from the charge in all directions
- straight lines (never cross each other) pointing away from the center
- density of lines decreases with distance (weaker field)

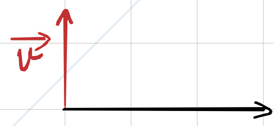
$\vec{E}$ of a point charge

Magnetism

[tesla]

$F = qvB\sin\theta = q\vec{v} \times \vec{B}$





$\vec{v} \; // \; \vec{B}$

$\sin 0° = 0$

$F = 0\,N$

MRU

$\vec{v}_\perp \perp \vec{B}$

$\sin\theta$

helicoidal motion

$\vec{v} \perp \vec{B}$

$\sin 90° = 1$

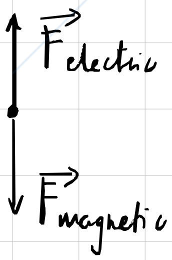
$F = max$

MCU

$\frac{mv^2}{R} = qvB$

1) fingers $\longrightarrow \vec{v}$
2) palm $\longrightarrow \vec{B}$
3) thumb $\longrightarrow \vec{F}$

(+q thumb verse
−q opposite)



$qE = qvB \longrightarrow v = \frac{E}{B}$

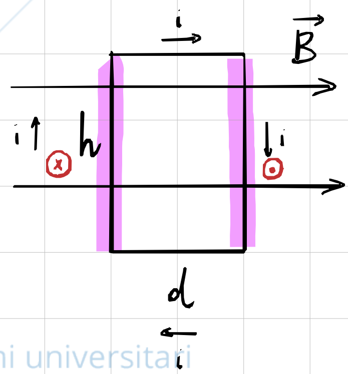
Current wires are subjected to magnetic $\vec{F}$

$F = qvB\,sen\theta =$

$= i\Delta t\, vB\,sen\theta =$

$= i\frac{L}{v}\, vB\,sen\theta = iLB\,sen\theta$

Rectangular loops (sp

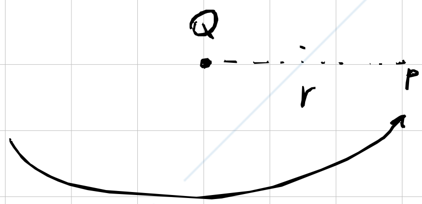


Electromagnetic problems

Very easy

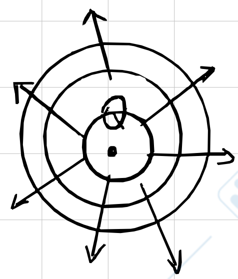
1) Point charge electric field

$Q = +5 \cdot 10^{-9}\ C$



- Electric field at $r = 0{,}2\ m$

$$E = \frac{kQ}{r^2} = 1{,}13 \cdot 10^{3}\ \frac{N}{C}$$

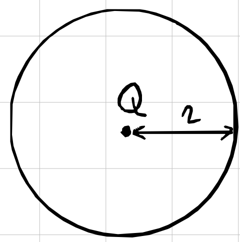


- $E = 1000\ N/C$, x ?

$$E = \frac{kQ}{x^2} \longrightarrow x = \sqrt{\frac{kQ}{E}} = 0{,}21\ m$$

2) Flux through a closed surface

$R = 0{,}5\ m$
$Q = 3 \cdot 10^{-8}\ C$ (at the center)



- $\phi(\vec{E})$ through the surface?

$$\text{Gauss's law} = \phi(\vec{E}) = \frac{\Sigma Q}{\varepsilon_0} = EA$$

$$E = \frac{Q}{\varepsilon_0 A} \cdot A = 3{,}4 \cdot 10^{3}\ N/C$$

$\vec{E}$	$\phi(\vec{E})$
$\downarrow$	$\downarrow$
N/C	$\frac{N \cdot m^2}{C}$
V/m	$V \cdot m$

- $R' = 2R = 1\ m \longrightarrow E'$ is the same

the flux only depends on the enclosed charge, no
on the shape or the size of the surface

- [x] Problems of thermodynamics pdf
- [x] Problems of fluids
- [x] Problems of waves
- [x] See favourite messages (magnetic ...)
- [x] Polarization
- [x] Dipoles
- [x] moment conservation
- [ ] differential vectors pdf
- [x] problema work-stokes
  grave
- [x] Condensator in // ...

Thermodynamics

°C	
K	°C + 273,15
°F	$\frac{9}{5}$ °C + 32

1 : 4,186 = cal : J

1 : 4186 = Cal : J

heat capacity C : $C \cdot \Delta T = Q$ $\quad C = \frac{Q}{\Delta T}$

specific heat c : $c \cdot m \cdot \Delta T = Q$ $\quad c = \frac{Q}{\Delta T \cdot m}$ =

$Q = cm\Delta T$ $\quad c_{water} = 4186 \frac{J}{kg \cdot K}$

Heat transfer mechanisms :

$R = \frac{d}{k}$

- Conduction : Fourier's law $\quad P = \frac{kA\Delta T}{d}$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{d} = \frac{A\Delta T}{R}$

- Convection Newton's law $\quad P = hA(T_{surface} - T_{fluid})$
- Radiation Stefan-Boltzmann's law $\quad P = \epsilon \sigma A(T_{object}^4 - T_{amb}$

Latent heat = L = heat transfered for a change in phase by

Simple harmonic motion

Spring-mass system

Hooke's law : $\vec{F}_{spring}$ = restoring force toward equilibrium $= -k\vec{x}$

$$-kx = ma$$

$$-k\cancel{x} = m(-w^2\cancel{x}) \longrightarrow w^2 = \frac{k}{m} \longrightarrow w = \sqrt{\ }$$

displacement : $x(t) = A\cos(wt+\phi)$

velocity : $v(t) = -wA\sin(wt+\phi)$

acceleration : $a(t) = -w^2A\cos(wt+\phi)$

$$w = \sqrt{\frac{k}{m}} \longrightarrow T = \frac{2\pi}{w} = 2\pi\sqrt{\frac{m}{k}}$$

Conservation of energy

$-A$	$x = 0$	$+A$
PE	KE	PE
$v = 0$	$v = max$	$v = 0$
$a = -max$	$a = 0$	$a = -max$

$$KE + PE = E_{tot}$$

$$\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}$$

Problems thermodynamics

1) $37°C \longrightarrow \frac{9}{5} \cdot 37 + 32 \quad °F$

$\longrightarrow + 273,15 \quad K$

2) $m = 70\,kg$

$\Delta T = 2°C$

$c = 3500 \; J/kg \cdot K$

$Q = mc\Delta T = 4,9 \cdot 10^5 \; J$

3) $m = 250 \; mL = 0,25\,L = 0,25\,kg$ $\quad c = 4186 \; J/kg \cdot K$

$\Delta T = 20°C$

$Q = 2,1 \cdot 10^4 \; J$

4) Conduction $\quad$ rate of heat loss $\frac{Q}{\Delta t} = P?$

$d = 2\,mm = 2 \cdot 10^{-3}\,m$

$k = 0,4 \; W/m \cdot K$

$A = 1,8\,m^2$

$\Delta T = 4°C$

$P = \frac{kA\Delta T}{d} = 1,44\,kW$

5) $A = 1,8\,m^2$ $\quad$ in KELVIN $\quad \epsilon = 0,97$

$T = 33°C \quad T_{ambient} = 20°C$

$P_{radiation} = \epsilon \sigma A (T_{object}^4 - T_{ambient}^4) = 1,4 \cdot 10^2\,W$

6) $m = 500\,mL = 0,5\,kg$ $\quad Q?$

$L_v = 2,4 \cdot 10^6 \; J/kg$ $\quad Q = mL = 1,2 \cdot 10^6\,J$

$T = 37°C = 310\,K$

7) $m = 0,5\,L = 0,5\,dm^3 = 0,5 \cdot 10^{-3}\,m^3$

$T_1 = 20°C = 293\,K \quad T_2 = 37°C = 310\,K$

$p = 1\,atm$ constant $\quad V_2?$

$pV = nRT \longrightarrow nRT_1 \; - \; nRT_2 \quad V_1 \quad V_2 \quad \rightarrow V_2 = V_1 \, T_2 = 5$

Dipole

1) $N = 5 \cdot 10^{28} / m^3$

When an external field is applied, each molecule develops a dipole m...
of $p = 2 \cdot 10^{-30}\ C \cdot m$

- polarisation P of the dielectric material (insulator)

$$P = n p$$

2) $\varepsilon_r = 4$

$A = 100\ cm^2$

$d = 2\ mm$

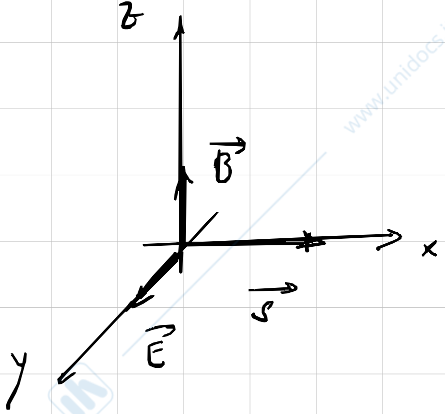
$\Delta V = 200V$

E between the plates?

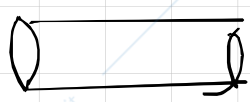
$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A \varepsilon_0 \varepsilon_r} \qquad E = \frac{V}{d}$$

$$C = \frac{A \varepsilon_0 \varepsilon_r}{d} \rightarrow Q = CV \longrightarrow E = \frac{CV}{A \varepsilon_0}$$

Poynting vector



$I = 1000\ W/m^2$ $\qquad A = 0{,}5\ m^2$



average $I = \frac{P}{A}$

$n_{air} = 1$ $\qquad n_1 \sin\vartheta_1 = n_2 \sin\vartheta_2$

$n_{...} = 1.5$

- Dipole

Polarisation P $\left[\frac{C}{m^2}\right] = n \quad p$

unit volume N/V   dipole moment

For a linear dielectric

$P = \varepsilon_0 \chi_0 E$

electric suscep

$\varepsilon = \varepsilon_0 \varepsilon_r$ $\varepsilon_r = 1 + \chi_0$

- electric displacement $D = \varepsilon_0 \varepsilon_r E \longrightarrow P = \varepsilon_0 (\varepsilon_r - 1) E$ polarisation

charge on a plate $= Q = CV = DA$

Cinematics

$v^2 = v_0^2 + 2as$

$$\begin{cases} x = V_{0x} t \\ y = y_0 + V_{0y} t - \frac{1}{2} g t^2 \end{cases} \qquad \begin{cases} V_x = V_{0x} \\ V_y = V_{0y} - g t \end{cases}$$

$$0 = \cancel{h} + V_{0y} t - \frac{1}{2} g t^2 < \begin{matrix} t = 0 \\ t = \frac{2 V_{0y}}{g} \end{matrix}$$

$$\text{gittata} = \frac{2 V_{0x} V_{0y}}{g}$$

$W_{tot} = \Delta KE$

Problems

- Harmonic motion - spring

$m = 0,12\ kg$ $\quad$ k?

$A_{spring} = 0,075\ m$ $\quad$ T?

$v_{max} = 0,524\ m/s$

$$v_{max} = wA \longrightarrow w = \frac{v_{max}}{A} = 7\ rad/s$$

$$w = \sqrt{\frac{k}{m}} \longrightarrow k = w^2 m = 5,86\ \frac{rad^2 \cdot kg}{s^2} \nearrow N/m$$

$$w = \frac{2\pi}{T} \longrightarrow T = \frac{2\pi}{w} = 0,9\ s$$

- Pendulum

$T = 1,6\ s$

$l_{max} = 0,2\ m = A$

θ ?

$$w = \frac{2\pi}{T} \rightarrow T = \frac{2\pi}{w}$$

$$w = \sqrt{\frac{g}{L}} \rightarrow T = 2\pi\sqrt{\frac{L}{g}}$$

$$\sqrt{\frac{L}{g}} = \frac{T}{2\pi} \rightarrow L = \frac{T^2}{4\pi^2} g = 0,64\ m \qquad \theta = \frac{l}{L} = \frac{0,2}{0,64} = 0,3$$

$$rad : degrees = \pi : 180° \longrightarrow degrees = \frac{rad \cdot 180°}{\pi} = 18°$$

Problems provided by the professor

1) • $m = 0,5\ kg$ on a spring $\qquad \vec{F}_{spring} = -k\vec{x}$

$T = 2\ s$

Fluids

$$\rho = \frac{m}{V} \qquad \rho\,(\text{water}) = 1000\ kg/m^3$$

normal component

$$P = \frac{F_\perp}{A}$$

Pascal a pressure change is transmitted equally throughout the

$P_{atm} = 1\ atm = 1{,}01 \cdot 10^5\ Pa = 760\ mmHg = 1013\ mbar$

$101325\ Pa$

$1\ mbar = 100\ Pa$

Gauge pressure $P_{man} = P_{abs} - P_{atm}$

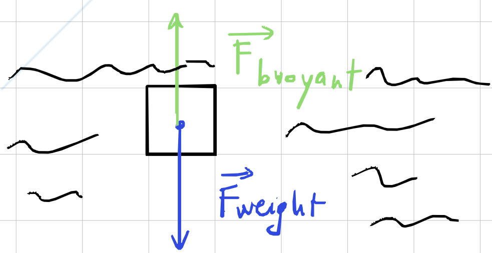
Hydrostatics

$$\Delta P = \frac{F_\perp}{A} = \frac{\text{weight}}{A} = \frac{m_{fluid}\, g}{A} = \frac{\rho V g}{A} = \frac{\rho A h g}{A} = \rho g h$$

ADDITIONAL HYDROSTATIC PRESSURE

$$\boxed{P = \underbrace{P_0}_{atm} + \rho g h}$$

Archimede



$F_{buoyant} = \rho_{fluid} V g$

$F_{weight} = \rho_{object} V g$

F_{weight} 100 degree of ρ_{object} 100

Problems:

1) Calculate buoyant force on a fully submerged

$m = 70 \, kg$

$\rho_{object} = 985 \, kg/m^3$

$\rho_{fluid} = 1000 \, kg/m^3$

$\rho = \frac{m}{V} \rightarrow V = \frac{m}{\rho}$

$$F_{buoyant} = \rho_{fluid} V g = 1000 \frac{\cancel{kg}}{\cancel{m^3}} \frac{70 \, kg}{985 \, \cancel{kg}} \cdot \cancel{m^3} \cdot 9,81 \frac{m}{s^2} = 6\ldots$$

$$= 6\ldots$$

$$F_{weight} = \rho_{object} V g = \cancel{985} \cdot \frac{70}{\cancel{985}} \cdot 9,81 = 687 \, N$$

that makes sense: it's mg = weight

$F_{buoyant} > F_{weight} \longrightarrow$ it float

$$\frac{F_{weight}}{F_{buoyant}} \cdot 100 = \frac{687}{697} \cdot 100 = 98,6 \% \text{ submerged}$$

2) $v_1 = 20 \, cm/s = 0,2 \, m/s$ $\qquad v_2$?

$diameter_1 = 4 \, mm = 4 \cdot 10^{-3} \, m$ $\qquad diameter_2 = 3 \cdot 10^{-3} \, m$

Conservation of mass (continuity equation) $\longrightarrow$ $\cancel{A_1 v_1 = A_2 v_2}$

$$A_1 v_1 = A_2 v_2 + A_2 v_2$$

$$A_1 v_1 = 2 A_2 v_2 \longrightarrow v_2 = \frac{A_1 v_1}{2 A_2} = \frac{4 \pi}{2 \cdot 4} \frac{d_1^2 v_1}{\pi d_2^2} = \frac{16 \cdot 10\ldots}{\cancel{2} \cdot 9 \cdot \ldots}$$

$$= 1,78 \cdot 10^{-1} \, m/s = 18 \, cm/s$$