European Summer program
Physics II
list of exercises

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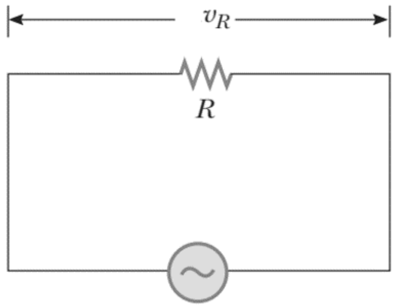
Chapter 31 - EM oscillations & alternating current

Problem 1 – rms value



An AC voltage source has an output of $v = (2.00 \times 10^2\ V)\sin(2\pi f t)$. This source is connected to a 100 Ω resistor as in the figure.

→ Find the rms voltage and rms current in the resistor.

Problem 2 - A Purely Capacitive AC Circuit

An $8.00\ \mu F$ capacitor is connected to the terminals of an AC generator with an rms voltage of $1.50\ \times 10^2\ V$ and a frequency of $60.0\ Hz$.

→ Find the capacitive reactance and the rms current in the circuit.

Problem 3 - An RLC Circuit

A series RLC AC circuit has resistance $R = 2.50 \times 10^2\ \Omega$, inductance $L\ = 0.600\ H$, capacitance $C\ = 3.50\ \mu F$, frequency $f\ = 60.0\ Hz$, and maximum voltage $V_{max}\ = 150\ V$.

1) Find the impedance in the circuit
2) Find the maximum current in the circuit
3) Find the phase angle in the circuit
4) Find the maximum voltages across the elements

Problem 3 bis - A Circuit in Resonance

Calculate the average power delivered to the series RLC circuit described in the previous example.

Problem 4 - A Circuit in Resonance

Consider a series RLC circuit for which $R = 1.50 \times 10^2\ \Omega$, $L = 20.0\ mH$, $V_{rms} = 20.0\ V$, and $f = 796\ s^{-1}$.

1) Determine the value of the capacitance for which the rms current is a maximum.

2) Find the maximum rms current in the circuit.

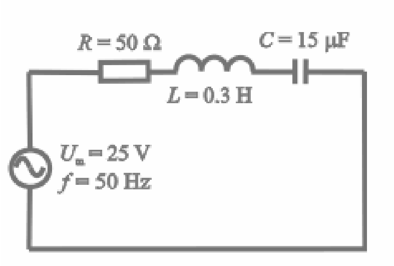
Problem 5 - Distributing Power to a City

A generator at a utility company produces $1.00 \times 10^2\ A$ of current at $4.00 \times 10^3\ V$. The voltage is stepped up to $2.40 \times 10^5\ V$ by a transformer before being sent on a high-voltage transmission line across a rural area to a city. Assume that the effective resistance of the power line is $30.0\ \Omega$ and that the transformers are ideal.

1) Determine the percentage of power lost in the transmission line.

2) What percentage of the original power would be lost in the transmission line if the voltage were not stepped up?

Problem 6 – RLC with phasors



An AC circuit is composed of a serial connection of:

- a resistor with resistance $50\ \Omega$,
- a coil with inductance $0.3\ H$
- and a capacitor with capacitance $15\ \mu F$.

The circuit is connected to an AC voltage source with amplitude $25\ V$ and frequency $50\ Hz$.

→ Determine the amplitude of electric current in the circuit and a phase difference between the voltage and the current

Problem 7 - Transformer

A transformer has 500 turns of the primary winding and 10 turns of the secondary winding.

a) Determine the secondary voltage if the secondary circuit is open and the primary voltage is 120 V.

b) Determine the current in the primary and secondary winding, given that the secondary winding is connected to a resistance load 15 Ω?

Chapter 32 - Maxwell's Equations & Magnetism of Matter

Problem 8 - Magnetic Field of a Straight Conductor inside a Solenoid

A long solenoid with 10 turns per centimeter and a radius of 7 cm located in vacuum carries a current of 20 mA. A straight conductor positioned along the axis of the solenoid carries a current of 6 A

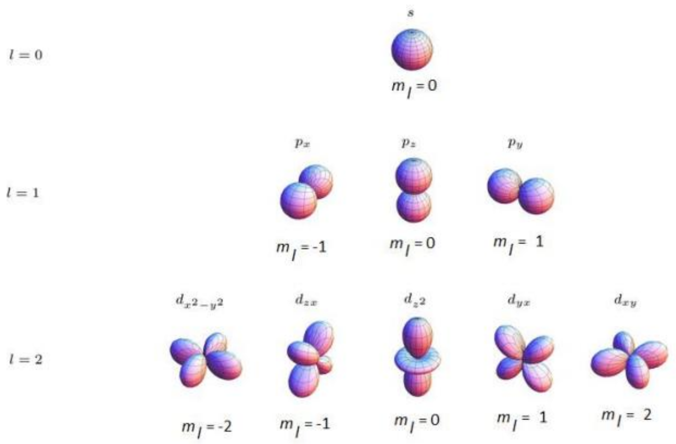
At what distance from the axis of the solenoid does the vector of the total B-field form an angle of 45° with the axis of the straight conductor? What is the magnitude of the B-field at this position.

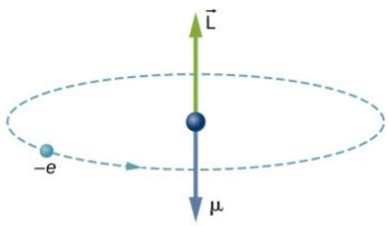
Problem 9 – orbital Magnetic dipole moment

The magnetic momentum of the electron is related to its orbital angular momentum L. For the hydrogen atom, this quantity is related to the orbital angular quantum number l and $m_l = (-l; -l+1 \ldots 0, l-1; l)$ the orbital magnetic quantum number

The states are given in spectroscopic notation, which relates a letter (s $(l = 0)$, p $(l = -1)$, d $(l = 2)$, etc.) to a quantum number

What is the magnitude of the orbital dipole magnetic moment $\vec{\mu}$ of an electron in the hydrogen atom in the (a) s state, (b) p state, and (c) d state? (Assume that the spin of the electron is zero.)





(b) Hydrogen atom

Problem 10 – Electron Spin and Radiation

A hydrogen atom in the ground state is placed in an external uniform magnetic field ($B = 1.5T$).

Knowing the Einstein formula E=hf (h: Planck constant = 6.63 10^{-34} J.s), determine the frequency of radiation produced in a transition between the spin-up and spin-down states of the electron.

Chapter 33 - Electromagnetic Waves

For all problem we give:

$\mu_0 = 4\pi \times 10^{-7} \mathrm{H/m}$; $\epsilon_0 = 8.85 \times 10^{-12} \mathrm{F/m}$ and $c = 3 \times 10^8 \mathrm{m.s^{-1}}$

Problem 11 – Wavelengths and frequencies

Two microwave frequencies are authorized for use in microwave ovens: 900 and 2560 MHz.

1) Calculate the wavelength of each.
2) Which frequency would produce smaller hot spots in foods due to interference effects?

A radio station utilizes frequencies between commercial AM and FM.

3) What is the frequency of a 11.12-m-wavelength channel?

Combing your hair leads to excess electrons on the comb.

4) How fast would you have to move the comb up and down to produce red light?

Some radar systems detect the size and shape of objects such as aircraft and geological terrain.

5) Approximately what is the smallest observable detail utilizing 500-MHz radar?

Problem 12 – Speed of light

Verify that the correct value for the speed of light *c* is obtained when numerical values for the permeability and permittivity of free space are entered into the equation $c^2 = \frac{1}{\mu 0 \epsilon 0}$

Problem 13 – Helium-neon lasers

Assume the helium-neon lasers commonly used in student physics laboratories have power outputs of 0.250 mW.

1) If such a laser beam is projected onto a circular spot 1.00 mm in diameter, what is its intensity?
2) Find the peak magnetic field strength.
3) Find the peak electric field strength.

Problem 14 – Solar-Powered Homes

Assume that the Sun delivers an average power per unit area of about $1.00 \times 10^3\ W/m^2$ to Earth's surface.

1) Calculate the total power incident on a flat tin roof $8.00\ m$ by $20.0\ m$.

Assume that the radiation is incident normal (perpendicular) to the roof.

2) Calculate the peak electric field of the light.
3) Compute the peak magnetic field of the light.

Problem 15 – Clipper Ships of Space

Aluminized mylar film is a highly reflective, lightweight material that could be used to make sails for spacecraft driven by the light of the sun. Suppose a sail with 1 by 1 km side square area orbiting the Sun at a distance of $1.50 \times 10^{11}\ m$. The sail has a mass of $5.00 \times 10^3\ kg$ and is tethered to a payload of mass $2.00 \times\ 10^4\ kg$.

1) If the intensity of sunlight is $1.34\ \times 10^3\ W$ and the sail is oriented perpendicular to the incident light, what radial force is exerted on the sail?
2) About how long would it take to change the radial speed of the sail by 1.00 km/s?

Assume that the sail is perfectly reflecting.

Problem 16 – Integrated Concepts

What capacitance is needed in series with an 800µH inductor to form a circuit that radiates a wavelength of 196 m?

Problem 17 –

If electric and magnetic field strengths vary sinusoidally in time, being zero at t=0, then $E = E_0 sin(\omega t)$ and $B = B_0 sin(\omega t)$. Let $f = 1.00 GHz$ here.

1) When are the field strengths first zero?
2) When do they reach their most negative value?
3) How much time is needed for them to complete one cycle?

Problem 18 – Radar exposure

Suppose the maximum safe intensity of microwaves for human exposure is taken to be 1.00W/m^2

1) If a radar unit leaks 10.0 W of microwaves (other than those sent by its antenna) uniformly in all directions, how far away must you be to be exposed to an intensity considered to be safe? Assume that the power spreads uniformly over the area of a sphere with no complications from absorption or reflection.
2) What is the maximum electric field strength at the safe intensity? (Note that early radar units leaked more than modern ones do.

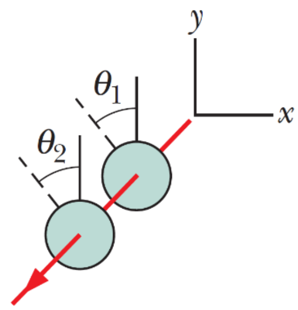
This caused identifiable health problems, such as cataracts, for people who worked near them.)

Problem 19 – let's do some math !

This electromagnetic wave in a vacuum is studied : $\vec{E} = E_0 \cos(\alpha z) \sin(\omega t - kx)\overrightarrow{u_y}$

Calculate the magnetic field

Problem 20 – Polarization



A beam of light, with intensity 43 W/m^2 and polarization parallel to a y axis, is sent into a system of two polarizing sheets with polarizing directions at angles of $\theta_1 = 70°$ and $\theta_2 = 90°$ to the y axis.

What is the intensity of the light transmitted by the two-sheet system?

Chapter 34 – Geometric optics

Problem 21 – Snell's laws

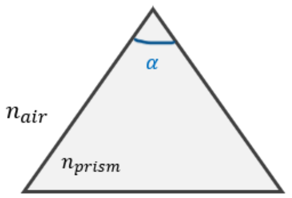
1) Give the 3 laws of Snell-Descartes. Draw a schematic case.
2) Calculate the refracted angle for the 3 following cases. Indicate the reflected angle:

   $\theta_1 = 30°$; $n_1 = 1$; $n_2 = 1{,}5$

   $\theta_1 = 70°$; $n_1 = 1$; $n_2 = 1{,}4$

   $\theta_1 = 60°$; $n_1 = 1{,}3$; $n_2 = 1$

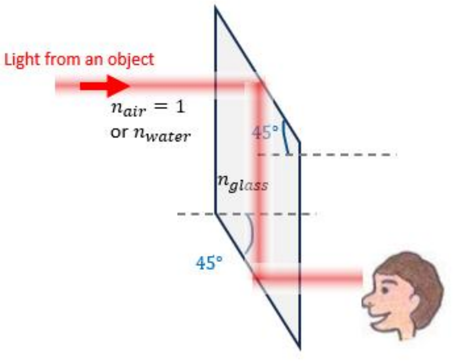
Problem 22 – Prism



We have a triangular prism with top angle $\alpha = 60°$. n_{prism} is 1.52 and n_{air} is 1. An incident beam forms $\theta_1 = 30°$ with the normal of the left side.

1) Calculate θ_2
2) Demonstrate that $\theta_2 + \theta_3 = 60°$ (θ_3 is the incident angle on the inside right side of the prism)
3) Is there a refracted ray on the right side of the prism? If yes, calculate θ_4 (the refracted angle on the outside right side)
4) Calculate the total deviation $\mathcal{D}$ of the ray ($\mathcal{D} = (\theta_1 - \theta_2) + (\theta_4 - \theta_3)$)

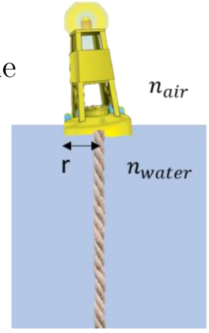
Problem 23 – Periscope



A periscope is made of a single block of glass of index $n_{glass} = 1{,}5$.

1) Does the observer see a reversed image?
2) Does it works under water ? $n_{water} = 1{,}33$

Problem 24 – Buoy



A buoy is floating in the sea attached by a rope on the seafloor. We assume that the buoy is a disk with a radius r=4m and n_{water}=1,25.

What is the length h of rope that an external observer in air cannot see?

Problem 25 – Spherical mirror

An object AB(+10cm in size) is placed in front of a concave spherical mirror (r=+1.2m). The distance beteew the object and the mirror is +1m.

→ Find the position of the image. Is the image real or virtual ? Reversed or on the same orientation than the object ? Larger or smaller than the object ?

1) Verify your calculation with a schematic drawing
2) Same Question but with a convexe mirror (r=-1.2 m), AB=+20cm and p=+0.6m
3) Same question than 2) but with values of 1).

Problem 26 – Thin lens

A)

We have a converging lens of image focal distance f=$f_i = \overline{OF_i} = -\overline{OF_o} = +3cm$

1) Find the position of the image of an object AB (+2cm) for object distances p=+4cm; +2cm and -10cm (in the last case the object is virtual, on the right side)
2) Is the image real or virtual ? Reversed or not ? Larger or smaller than the object ?
3) Verify your calculation with a schematic drawing of particular rays

B)

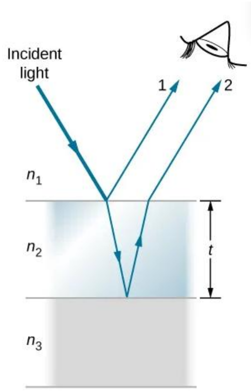
1) Same question than A)1) but with a diverging lens (f=-3cm) and p=5cm, then p=-1.45cm
2) Same question than A)2) but with the images of B)1)

Chapter 35-36 – Interferences and diffraction

Problem 27 - Finding a Wavelength from an Interference Pattern

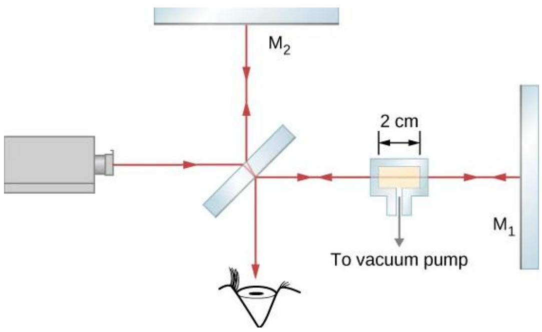
Suppose you pass light from a He-Ne laser through two slits separated by 0.0100 mm and find that the third bright line on a screen is formed at an angle of 10.95° relative to the incident beam. What is the wavelength of the light?

Problem 28 - Calculating the Thickness of a Nonreflective Lens Coating



Sophisticated cameras use a series of several lenses. Light can reflect from the surfaces of these various lenses and degrade image clarity. To limit these reflections, lenses are coated with a thin layer of magnesium fluoride, which causes destructive thin-film interference. What is the thinnest this film can be, if its index of refraction is 1.38 and it is designed to limit the reflection of 500nm light, normally the most intense visible wavelength? Assume the index of refraction of the glass is 1.52?

Problem 29 - Measuring the Refractive Index of a Gas



In one arm of a Michelson interferometer, a glass chamber is placed with attachments for evacuating the inside and putting gases in it. The space inside the container is 2 cm wide. Initially, the container is empty. As gas is slowly let into the chamber, you observe that dark fringes move past a reference line in the field of observation. By the time the chamber is filled to the desired pressure, you have counted 122 fringes move past the reference line. The wavelength of the light used is 632.8 nm.

→ What is the refractive index of this gas?

Problem 30 – Double slit

We perform a double slit experiment with $\lambda = 405nm$. Distance between the two slits d is $19.44\mu m$ and slit width is $a = 4.05\mu m$.

1) How many bright fringes are in the central peak of the diffraction envelope?
2) Same question for the 1st side peak