2h – No documents – No calculators – Argument your answers with text, equations and schematics if needed – Good luck!

I General knowledge of the lectures / 4pts

I.1 Consider an RLC circuit driven by an external ac voltage vd = Vd sin (ω_d + ϕ). Vd is the amplitude, ω_d the angular driving frequency and ϕ a phase term. Represent schematically the amplitude of the current oscillations I as a function of ω_d for 3 values of R: $R_1 << R_2 << R_3$

I.2 Represent the magnetic field B_M created by a ferromagnetic material as a function of an external magnetic field B_{ext}. We assume that in the initial conditions, the sample produces no magnetic field and that the temperature is bellow the Curie temperature.

I.3 An incident unpolarized electromagnetic wave of intensity I0 encounters a polarizing sheet (polarizing direction at angle θ).
- What is the intensity after the sheet?
- What is the intensity after we add a second perpendicular polarizing sheet (polarizing direction at θ+90°)?

I.4 You want to cook a meal with a solar oven. The solar oven is made of a concave spherical mirror facing the sun (radius of curvature = 2 m). Where should you place your meal for an efficient baking?

I.5 Explain the principle of Huygens.

I.6 You want to observe two objects with an optical microscope that are difficult to resolve. Assuming you can tune the wavelength of the monochromatic source that illuminate your sample, how could you improve your image?

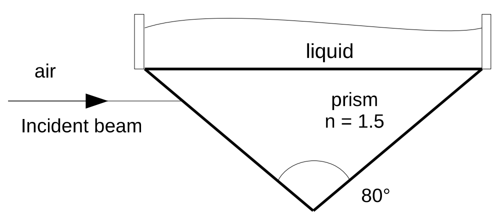
II Laws of Snell - Descartes / 4pts

II.1 Give the three laws of Snell – Descartes and illustrate the laws with a schematic drawing.

II.2 Calculate the refracted angles (if they exist) for the two following cases:
- Incident angle = 40° from medium of index 1.0 to medium of index 1.5
- Incident angle = 75° from medium of index 1.5 to medium of index 1.3

Useful values: asin((1.0/ 1.5) sin (40°)) ≈ 25° and asin(1.3 / 1.5) ≈ 60°

II.3 Consider an isosceles prism of index 1.5 and base angle 80°. A ray of light parallel to the top face encounters the left side. The top face can be covered by liquid. You have two liquid samples: water (n = 1.3) and a highly concentrated solution of sugar (n = 1.5). Explain how this optical setup can determine which liquid is above the prism.



III Electromagnetic waves /4 pts

Consider a linearly polarized plane electromagnetic wave. Electric field and magnetic field are defined as follows:

$$\vec{E} = E_m \sin(ky - \omega t)\vec{e}_z$$
$$\vec{B} = B_m \sin(ky - \omega t)\vec{e}_x$$

E_m and B_m are the respective amplitude of the electric and magnetic fields, k is the magnitude of the wavevector and omega the angular frequency. $\vec{e}_x$ and $\vec{e}_z$ are unitary vectors of the Ox and Oz axis.

III.1 Calculate the expression of the Poynting vector and deduce the direction of propagation of the wave.

III.2 Calculate the expression of the intensity I.

IV Geometrical optics /4 pts

We have a thin lens of focal length f = +4 cm, a real object of height h = +1 cm is placed at a distance p = +5 cm of the lens.

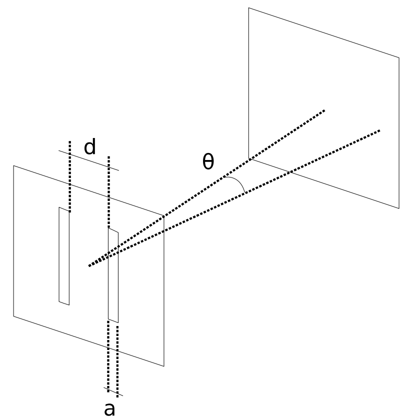
IV.1 Find the position i of the image. Is the image real or virtual? Larger or smaller than the object? Reversed or with the same orientation than the object?

IV.2 Verify your calculation with a schematic drawing showing particular rays.

V Diffraction and interference /4 pts

An incident monochromatic plane wave (λ = 400 nm) encounters a double-slit aperture on a screen. The width of the slits is a = 1.6 µm and the distance between the slits is d = 8 µm. The resulting pattern is observed on another distant screen. Intensity on this screen, as a function of θ (the angle represented in the schematic bellow) follows:

$$I_\theta = I_m \cos^2(\frac{d\pi}{\lambda}\sin\theta)\sin_c^2\left(\frac{a\pi}{\lambda}\sin\theta\right)$$



Where I_m is the maximum intensity.

V.1 From your knowledge of interference and diffraction, identify in the formula the term associated to interference and the term associated to diffraction.

V.2 Represent schematically the intensity as a function of θ.

V.3 Find the expression for the angles θ corresponding to bright interference fringes.

V.4 Find the expression for the angles θ corresponding to minimums of diffraction

V.5 How many bright fringes are located in the central peak? In the first side peak?

Useful values:

x	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.9	0.95	1.00
asin (x) (°)	0.0	2.9	5.7	8.6	11.5	14.5	17.5	20.5	23.6	26.7	30.0	33.4	36.9	40.5	44.4	48.6	53.1	58.2	64.2	71.8	90.0