Family name	First name	Matriculation number

☐ KSOP, M.Sc. Optics and Photonics
☐ other (please specify) ....

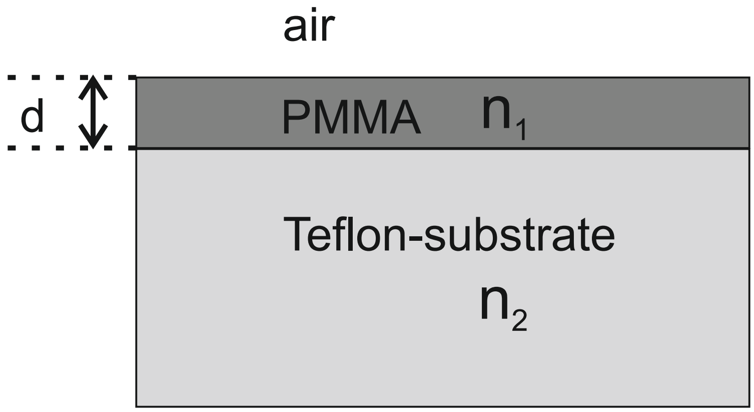
- 120 min to work on the questions
- Use **only** the sheets provided for your calcuations and answers
- Put your name on every sheet
- Use separate sheets for each question
- No calculators, no mobile phones, no electronic devices allowed
- No books, no personal notes, or other documents allowed
- Sine and Cosine function table can be found on the last page
- Generally, derive first a final equation before pluging in values.

No	Points possible	Points achieved
1	5	
2	10	
3	10	
4	10	
5	10	
Sum	**45**	

Mark:	Signature:
Final mark:	Signature:

1. **Dielectric coating** (5 points)

a) A thin layer of PMMA with a refractive index of $n_1 = 1.49$ is deposited on a Teflon-substrate with a refrative index n_2=1.34. Calculate the minimal thickness d of the PMMA-layer in order to achieve constructive interference in reflection geometry when light of wavelength λ=596 nm hits the surface at normal incidence.

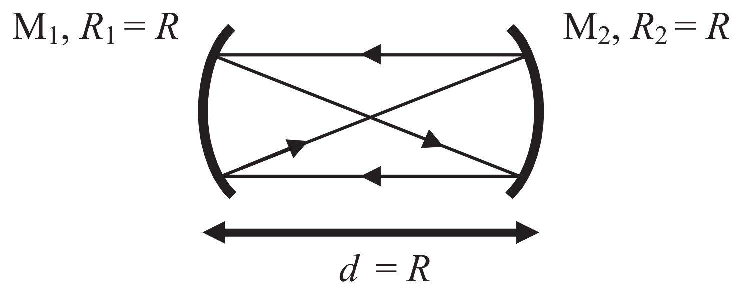


b) Now the same layer of PMMA (same thickness as calculated in a)) is deposited on a glass substrate ($n_{\text{Glass}} > n_1$). Give a short, qualitive explanation how the reflectivity changes compared to the situation in a).

2. **Spherical mirrors** (10 points)

a) Show that for a spherical mirror with curvature radius R, $2f = R$ holds (f is the focal length). Start with a sketch of the reflection of a ray parallel to the optical axis.

b) A confocal resonator consists of two identical, concave sperical mirrors M_1 and M_2 with curvature $R_1 = R_2 = R$ (see drawing). The distance d between both mirrors is as large as their curvature ($d = R$).



Using matrix optics, show that a ray moving under an arbitrary angle to the optical axis from the left mirror to the right reaches its intial state after four reflections. This means that the ray does not leave the resonator.

The matrix of a mirror in the basis $\begin{pmatrix} \mathrm{r} \\ \alpha \end{pmatrix}$ is given by $\begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix}$.

c) Metal mirrors typically have a high reflectivity in the visible spectral region. Sketch the reflectivity as function of frequency $R(\omega)$ under normal incidence for a typical metal like aluminum. Indicate the plasma frequency in your graph.

In which spectral range lies the plasma frequency ω_p for metals like aluminum?

Sketch the real part of the dielectric function $\epsilon_1(\omega)$. Why do metals become transparent for $\omega \geq \omega_p$?

3. **Fabry-Perot interferometer** (10 points)

a) Sketch the transmission spectrum $T(\nu)$ of a Fabry-Perot interferometer for a high and low finesse. Mark the spectral half-width $\Delta\nu$ and the free spectral range $\delta\nu$ in your drawing.

b) Give the definition of the finesse.

c) How can the finesse and the free spectral range of a Fabry-Perot interferometer be changed experimentally?

d) The spectral half-width and a characteristic time are related through an uncertainty relation. What is this characteristic time? How is this time related to the finesse?

4. **Grating** (10 points)

A grating is homogeneously illuminated by monochromatic light with wavelength λ. For this specific grating, one can notice that certain orders of the diffration pattern vanish. In order to explain this, please answer the following:

a) Derive a short formula (using a geometric approach) which specifies under which angles Θ_m one can find maxima in the diffraction pattern of a grating (assume δ-slits, that means slit width b$\rightarrow$ 0).

b) Derive a short formula (using a geometric approach) which specifies under which angles Θ_n one can find minima in the diffraction pattern of a **single** slit (with slit width b).

c) Now, which maxima (which order) vanish for a 1000 lines/mm grating and a slit width b=500 nm?

d) Sketch the diffraction pattern of the grating (with 1000 lines/mm and slit width b=500 nm) as function of $\sin\Theta$.

5. **Polarization** (10 points)

a) Use the relations between electric field $\vec{E}$ and Poynting vector $\vec{S}$, and dielectric displacement $\vec{D}$ and wavevektor $\vec{k}$, respectively to prove that for a birefringent material (no free charges, neutral) $\vec{S}$ and $\vec{k}$ are not parallel in general.

b) Explain the working principle of a quarter wave plate. If linearly polarized light hits the $\lambda/4$-plate at normal incidence, how does the crystal axis lie relative to the polarization axis of the incident light in order achieve circularly polarized light behind the plate?

c) On a sunny day, light scattered from the sky is partially polarized. Give a short explanation for this fact.

d) Name two other ways to achieve polarized light from an originally unpolarized beam.