Allowed material: writing implements and a graphical calculator. You are not allowed to use any other material. There are some formulas and constant tabulated in last page of the exam. In your answers, justify the formulas you use and introduce the meaning of the symbols within these formulas. Solve each problem in separate page.

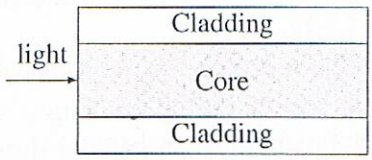
It is important that you at least try every question. Good luck!

1. Define the following terms using at most about 30 words. Answering using only formulas is, however, not sufficient. a) Diffraction b) Huygens principle c) Dė Broglie wave d) F-number e) Accommodation f) Heisenberg uncertainty principle

2. Anwer the following questions shortly, but precisely. Use figures and diagrams to support your answer as necessary. Answering using only figures will not, however, yield full credit.
   (a) A beam of light propagates in air before striking a glass surface. Is total internal reflection possible? Justify.
   (b) You are observing a distant object using a system of lenses. The diameter of the system is D and you are detecting light at wavelength λ. You then realize that the optical resolution of the system is not satisfying. Which of the following can be used to improve the resolution: i) decreasing the lens diameter, ii) decreasing the wavelength of the light, or iii) decreasing the frequency of the light? Justify.

3. The first Bragg interference maximum of X rays ($m_X = 1$) is found at the angle 35.8°. At which angle will the first intensity maximum ($m_e = 1$) of electron scattering be found? The kinetic energy of the electrons is 4.50 keV.

4. We want to couple a well-collimated (=parallel) laser beam ($\lambda = 1.064\,\mu$m, diameter 4 mm) with as small as possible losses into an optical fiber. The diameter of the fiber is very small compared to the diameter of the laser beam. Refractive index of the fiber core is 1.30 and 1.28 for the cladding surrounding the core.



Problem 4

   (a) What kind of a lens (focal length and distance from the fiber end) is needed for the coupling?
   (b) We also want to maximise the light power exiting the fiber. This can be accomplished by coating the fiber end with, for example, magnesium fluoride. How thick a MgF_2-coating is needed at the exit end of the fiber? The refractive index of magnesium fluoride is 1.38. You may assume that the light exits the fiber at normal incidence.

5. A diffraction grating has 300 grooves/mm. The grating is illuminated at 30° incidence angle with a light source that contains wavelengths between 400 nm and 700 nm. *Hint: The Huygens principle will be your friend here.*
   (a) (4p) By requiring that a plane wave incident on the grating diffracts as a plane wave, show that for incidence angle θ_i the diffraction condition is given by $a(\sin\theta_m - \sin\theta_m) = m\lambda$, where θ_m is the direction of the diffracted beam. All angles are expressed relative to surface normal of the grating.
   (b) (2p) Determine the separation of first order diffracted beams at the ends of the spectrum. Can the first and second order diffraction be distinguished throughout the spectral range?

Write CLEARLY in each paper your name, student number, degree programme, the code of the study module, and the date of the exam. Please solve each problem in separate page.