Task 1

1. **Answer any four parts:**
   a) Consider a wave represented as \( y(x, t) = 2 \sin \left(10 \frac{\pi x}{40} + \frac{\pi}{4}\right) \) Plot the space profile at \( t = \frac{T}{4} \) and time profile at \( x = \frac{\lambda}{8} \).
   b) Describe polarization of light by double refraction. Draw o- and e- wave surfaces for calcite and quartz.
   c) Explain the concept of population inversion on the basis of Einstein’s A & B coefficients. Discuss its significance for developing a LASER.
   d) What is a zone plate? Show that it acts as a multi-foci converging lens.
   e) Discuss the concept of missing orders with particular reference to double slit diffraction pattern.

2. **a)** An oil (\( \mu_0 = 1.45 \)) film of thickness 280 nm floats on water (\( \mu_w = 1.33 \)). It is illuminated by white light at normal incidence. Which colour in the visible spectrum will be most strongly (i) reflected, and (ii) transmitted?
   **b)** Obtain the expression for shift in fringes when a thin transparent sheet is introduced in the path of one of the waves in a double slit interference experiment.

3. State salient features of single slit Fraunhofer diffraction pattern. The slit is vertical and illuminated by a point source. Also, obtain an expression for intensity distribution and plot it.

4. **a)** Discuss Rayleigh’s criterion for resolving power of an optical instrument. Obtain an expression for the resolving power of a microscope.
   **b)** A He-Ne laser emits a beam of diameter \( 2 \cdot 10^{-3} \text{ m} \) and wavelength 630 nm. It is directed towards an aeroplane flying at a height of 11 km. Calculate the diameter of the light patch produced on the surface of the aeroplane.

5. **a)** Discuss three important practical applications of lasers.
   **b)** Calculate the ratio of stimulated emission and spontaneous emission at an operating temperature of 1100 K, if the wavelength of emitted light is 550 nm. Do these conditions correspond to a laser?
   **c)** State the characteristics of different types of optical fibres. Depict their refractive index profiles and propagation of light through them.

Task 2

1. Light from the hydrogen-alpha lines is passed through a diffraction grating having 4500 lines/cm. The hydrogen lines have a nominal wavelength \( \lambda = 656.282 \text{ nm} \) and a separation \( \delta \lambda = 0.01360 \text{ nm} \). Determine the resolving power needed to separate the doublet. How many diffraction grating lines are needed to just resolve the doublet in second order?

2. For the grating and wavelength in problem (1) determine the angular dispersion in the second order. Would the doublet be spread more in the first or the second order?
3. A thick lens consists of a front surface of radius \( r_1 = +28.0 \text{ cm} \) and a second surface of radius \( r_2 = -46 \text{ cm} \). The lens has an index of \( n = 1.62 \) and is in air. The two surfaces are separated by \( L = 8.00 \text{ cm} \). Sketch the shape of the lens.

4. Write the three matrices, using the numbers of the lens that are needed to describe the lens. Show clearly the order of the matrix multiplication. Is the lens converging or diverging? (Note, multiplication of the matrix is not necessary!)

5. A carbon dioxide laser emits a line with a wavelength \( = 10.6 \text{ micro meters} \). The cavity length is \( L = 4.4122 \text{ m} \). Calculate the mode number (nearest integer) and the mode spacing for the laser.

6. A laser cavity is \( L = 0.486 \text{ m} \) long. The cavity mirrors have radii of \( r_1 = 0.600 \text{ m} \) and \( r_2 = 0.750 \text{ m} \). Calculate the \( g \)-parameters for each mirror. Is the cavity stable, marginally stable, or unstable based on your \( g \)-parameters? Explain.

7. Sketch an energy diagram for a laser transition and use it to describe what is meant by stimulated emission.