

### Exam questions OPTI 517

Only a calculator and a single sheet of paper, 8"X11", with formulas will be allowed during the exam.

- 1) A single optical spherical surface does not contribute spherical aberration. Explain the situations when this can happen.
- 2) There is one wave of defocus at a wavelength of 0.0005 mm for a lens that is focusing light from an object point at infinity. The lens has a focal length of 100 mm and the aperture stop is at the lens and is 10 mm in diameter. Determine the longitudinal change of focus.
- 3) Determine the radius of the Petzval surface in a landscape lens ( $f=100$  mm,  $n_d = 1.5$ ). Explain how in the landscape lens the effects of field curvature are mitigated.
- 4) Provide the fourth order aspheric coefficient for the correcting plate of a Schmidt camera where the primary mirror works at  $F/4$  and the diameter is 200 mm.
- 5) A thin lens made out of BK7 glass and with a focal length of 100 mm is working at  $F/10$  and is placed in an optical system. This lens does not contribute chromatic aberrations. Explain where this lens is located in the optical system.
- 6) A system of two thin optical wedges in contact produces a beam deviation  $D$  and contributes no primary spectrum (dispersion) and no secondary spectrum. Provide the wedge angles (i.e. formulas) and glass characteristics for this system of wedges.
- 7) Draw the wave fans, on axis and full field, for a system that has one wave of spherical aberration and minus one wave of field curvature.
- 8) Design a singlet lens at  $f/10$  with a focal length of 100 mm that is free of coma and astigmatism. Provide the radii of curvature of the surfaces assuming the index of refraction  $n_d = 1.5$ , and provide the stop location and diameter. The object is at infinity. Provide a neat drawing.
- 9) A diffractive optical element is designed for  $\lambda=634$  nm, for a focal length of  $f=100$  mm, and an  $f$ -number of 4. What is the optical power of the lens if it is used at a wavelength of 317 nm? Estimate the minimum zone width of this lens. What is the  $V$ -number associated with this lens if the nominal wavelength at which it is used is  $\lambda_1= 1200$  nm, and the bandwidth limiting wavelengths are  $\lambda_3= 1400$  nm and  $\lambda_2= 1000$  nm.
- 10) Describe how a buried surface works and what it does.
- 11) What are the odd and even aberrations in the aberration function to fourth-order?
- 12) Write the monochromatic Seidel aberration coefficients for a single surface and determine two conditions for the absence of spherical aberration coma and astigmatism.

- 13) Draw the wave fans, on axis and full field, for a system that has one wave of spherical aberration and minus one wave of field curvature.
- 14) A system has one wave of spherical aberration (one wave is 0.0005 mm). The image height is 0.03 mm for a field of view of one arc-minute. Write the relationship between the wave aberration and the transverse ray aberration. Then determine the transverse ray aberration for the marginal ray. Give your answer in millimeters.
- 15) Consider a concave parabolic mirror with a vertex radius of 1000 mm and a diameter of 200 mm. How much spherical aberration (as a wavefront deformation) does it contribute when the object is at the center of curvature?
- 16) Consider a spherical mirror with a radius of 1000 mm. Add an aspheric plate ( $n=1.5$ ) to correct for spherical aberration when the object is at infinity. Where would you place the aspherical plate so that the system is aplanatic? How much astigmatism the system has? What is the Petzval radius? Provide the fourth-order coefficient of asphericity for the plate surface. Sketch the system.
- 17) Describe how in the Schupmann medial telescope the chromatic change of focus  $\partial_{\lambda} W_{020}$  and the chromatic change of magnification  $\partial_{\lambda} W_{111}$  are corrected. Sketch the system and the chief and marginal rays.
- 18) Describe the four classical ways to correct field curvature and include neat drawings.
- 19) Design a singlet lens at  $f/10$  with a focal length of 100 mm that is free of coma and astigmatism. Provide the radii of curvature of the surfaces assuming the index of refraction  $n_d = 1.5$ , and provide the stop location and diameter. The object is at infinity. What is the image height for a semi-field of view of 10 degrees? Provide a neat drawing.
- 20) A diffractive optical element is designed for  $\lambda=634$  nm, for a focal length of  $f=100$  mm, and an f-number of 4. What is the optical power of the lens if it is used at a wavelength of 317 nm? Estimate the minimum zone width of this lens. What is the V-number associated with this lens if the nominal wavelength at which it is used is  $\lambda_1=1200$  nm, and the bandwidth limiting wavelengths are  $\lambda_3=1400$  nm and  $\lambda_2=1000$  nm.
- 21) Write down the Coddington equations and explain what entities they relate. Write down the Sine condition and explain what it means. Include drawings and mention any essential assumptions.
- 22) An  $f/10$  optical system has 1 wave of defocus, what is the longitudinal change in image location? Derive a relationship between the defocus wavefront deformation and the longitudinal defocus. Assume the wavelength to be 0.0005 mm.

- 23) Describe how a buried surface works and what it does.
- 24) Describe how the lens design in the Brownie camera addresses: 1) spherical aberration, 2) coma, 3) astigmatism, 4) field curvature, 5) distortion, 6) chromatic change of focus and 7) chromatic change of magnification
- 25) Describe how the Petzval portrait lens design addresses: 1) spherical aberration, 2) coma, 3) astigmatism, 4) field curvature, 5) distortion, 6) chromatic change of focus and 7) chromatic change of magnification
- 26) What is the difference between real ray tracing and first-order ray tracing?
- 27) Write down the second and fourth order terms of the aberration function including the  $W$  coefficients and field and aperture dependence. There is a total of three second-order terms and six fourth-order terms. Please include the aberration names. Do not include chromatic aberrations.
- 28) A  $f/10$  system has 10 waves of focus. What is the image displacement along the optical axis?  
One wave is 0.0005 mm.
- 29) An optical system has three waves of spherical aberration and one wave of coma at the edge of the field. Draw wave-fan plots for the wavefront deformation on-axis and at full field.
- 30) A concave spherical mirror is illuminated from a point object at infinity and its radius of curvature is 1000 mm. If the aperture diameter is 100 mm, how much spherical aberration is introduced by the mirror in the incoming light beam?
- 31) If the aperture stop is located at the center of curvature of a spherical mirror, how much coma is present in the images produced by this mirror? Make a drawing and explain why.
- 32) Mention three ways to correct for higher order spherical aberration.
- 33) What is an aplanatic system? Mention one example.
- 34) A thin lens has a focal length of 100 mm and is made out of BK7 glass ( $n=1.51$ ,  $v=64$ ). The stop is contact with the lens. If the lens works at  $f/10$  how much longitudinal and transverse chromatic aberrations are generated?
- 35) For a system of two wedges in contact, what is the condition to avoid light dispersion? Write down the relevant equation. Explain.
- 36) Write down the Seidel sum formulas for spherical aberration and coma.
- 37) Write down the surface contributions to the fourth-order wave aberrations including the chromatic aberrations.

- 38) A plano-convex lens made out of BK7 glass ( $n=1.517$  and  $V=64.2$ ) is working at  $f/10$ . The aperture stop coincides with lens and is 100 mm in diameter. The full field of view is 1 degree. What is the size of the image? Calculate the chromatic change of focus and the chromatic change of magnification.
- 39) An optical system has 2.0 waves of field curvature and -2.0 waves of spherical aberration. Draw the on-axis and full field OPD plots (tangential and sagittal fans).
- 40) A plano-convex lens made out of glass with  $n=1.5$  and with thickness of 10 mm. The radius of curvature of the convex surface is 100 mm. The object is at infinity. Where should be the stop located so that no coma or astigmatism are introduced by the lens?
- 41) The mirror of a Schmidt camera works at  $f/2$  and the focal length is 250 mm. How much spherical aberration does this mirror contribute? What is the coma contributed by the mirror at 1 degree field of view?
- 42) Explain two examples about how a field lens helps to correct aberrations.
- 43) A field lens is made out of BK7 glass and has a focal length of 25 mm. How much spherical aberration and coma does it contribute? What is its contribution to the Petzval sum?
- 44) Briefly state the sine condition. Write the equation and define the parameters involved.
- 45) Which type of Cassegrain like telescope is aplanatic?
- 46) List three calculations done in a lens design program that use paraxial ray-tracing and list three calculations using real ray-tracing. What is the difference between paraxial and real ray tracing?
- 47) Explain how a Wollaston meniscus lens works. Make a sketch showing the meniscus, the stop, the image plane, and the marginal and chief rays. Explain how the seven aberrations are controlled in this lens.
- 48) Provide an equation and a graph about the variation of spherical aberration with the lens shape factor. Explain how spherical aberration is corrected in the Maksutov camera.
- 49) There is one wave of defocus at a wavelength of 0.0005 mm for a lens that is focusing light from an object point at infinity. The lens has a focal length of 100 mm and the aperture stop is at the lens and is 10 mm in diameter. Determine the longitudinal change of focus due to the defocus and provide a graph of the wavefront deformation at the exit pupil.

- 50) Determine the radius of the Petzval surface in a landscape lens ( $f=100$  mm,  $n_d = 1.5$ ). Explain how in the Wollaston landscape lens the effects of field curvature are mitigated. Describe two methods to control field curvature.
- 51) Provide the fourth order aspheric coefficient for the correcting plate of a Schmidt camera where the camera primary mirror works at F/4 and the diameter is 200 mm.
- 52) A thin lens made out of BK7 glass and with a focal length of 100 mm is working at F/10 and is placed in an optical system. This lens does not contribute chromatic aberrations. Explain where this lens is located in the optical system.
- 53) A system of two thin optical wedges in contact produces a beam deviation  $D=5$  degrees and contributes no primary spectrum (dispersion). If the glasses are 516642 and 645365 provide the wedge angle for both wedges.
- 54) Draw the wave fans, on axis and full field, for a system that has one wave of spherical aberration and minus one wave of coma aberration.
- 55) Design a singlet lens at f/10 with a focal length of 100 mm that is free of coma and astigmatism. Provide the radii of curvature of the surfaces assuming the index of refraction  $n_d = 1.5$ , and provide the stop location and diameter. The object is at infinity. Provide a neat drawing.
- 56) In the glass P-V diagram describe how you chose the glasses for a two lens apochromatic objective and for a three lens apochromatic objective.
- 57) Describe how a buried surface works and what it does. Theoretically, how chromatic aberrations  $\partial_\lambda W_{111}$  and  $\partial_\lambda W_{020}$  are corrected in the Maksutov camera?
- 58) A lens system working in air and at F/5 has 2 waves of coma aberration where a wavelength is 0.0005 mm. Make a plot of the saggital and tangential wave fans at full field. Determine the transverse ray aberration for  $\rho = 1$  at full field. If spherical aberration and coma aberration are corrected, how such a system is often called?
- 59) Design a relay lens with a magnification of -1 that is corrected for spherical aberration, coma and astigmatism. No more than three elements are allowed and only one aspheric surface is permitted. The system must have positive optical power. Sketch carefully and in detail your design. Explain how the aberrations are corrected and provide the shape, optical power, and positions of the elements and the position of the stop.
- 60) Use the formula  $RS = \exp \left\{ - \left( \frac{2\pi}{\lambda} \sigma \right)^2 \right\}$  to determine what should be  $\sigma$  to have a Raleigh-Strehl ratio of 0.8. Explain what this formula refers to.

- 61) A singlet thin lens with a focal length of 100 mm is used to image the Moon. The stop aperture is at the lens which works at  $F/10$ . Determine the amount of distortion aberration. Determine the amount of astigmatism aberration.
- 62) Provide the fourth order aspheric coefficient for the correcting plate of a Schmidt camera where the camera primary mirror works at  $F/4$  and the diameter is 200 mm.
- 63) A thin lens made out of BK7 glass and with a focal length of 100 mm is working at  $F/10$  and is placed in an optical system. This lens does not contribute chromatic aberrations. Explain where this lens is located in the optical system.
- 64) A diffractive optical element works at  $F/10$  at a wavelength of 0.0005 mm. Determine what is the longitudinal depth of focus for 1 wave of defocus. Determine what the minimum zone spacing is. Determine what the longitudinal chromatic focal shift is for the F and C wavelengths.
- 65) Describe how each of the primary aberrations and chromatic aberrations are controlled in the Wollaston meniscus lens. Make a sketch of the lens including the aperture stop, chief and marginal rays. Arrange your answer in a list of seven bullet items one for each aberration.
- 66) A plano-convex lens made out of Bk7 glass (517642) is working at  $f/10$ . The aperture stop coincides with lens and is 100 mm in diameter. The full field of view is 1 degree. What is the size of the image? Calculate the longitudinal chromatic aberration as a longitudinal quantity and the lateral chromatic aberration.
- 67) Write down the surface contributions to the fourth-order wave aberrations including the chromatic aberrations.
- 68) An optical system has 1 wave of coma and 5 waves of spherical aberration. Draw the on-axis and full field OPD plots (tangential and sagittal fans).
- 69) A plano-convex lens made out of glass with  $n=1.5$  and with thickness of 10 mm. The radius of curvature of the convex surface is 100 mm. The object is at infinity. Where should be the stop located so that no coma or astigmatism are introduced by the lens?
- 70) The mirror of a Schmidt camera works at  $f/4$  and the focal length is 500 mm. The stop is at the center of curvature. How much spherical aberration does this mirror contribute? What is the coma contributed by the mirror at 1 degree field of view?
- 71) Explain two examples about how a field lens helps to correct aberrations.

- 72) A field lens is made out of BK7 glass and has a focal length of 25 mm. How much spherical aberration and coma does it contribute? What is its contribution to the Petzval sum?
- 73) Briefly state the sine condition. Write the equation and define the parameters involved.
- 74) What is the radius of curvature of the sagittal surface for a spherical mirror of radius  $R$  when the object is at infinite? The stop is located at the mirror. You can use the Coddington equations to answer this question.
- 75) Explain how an Offner null corrector works. Make a sketch showing the null corrector in relation to the mirror under test. What is the function of lenses in the null corrector?
- 76) How do I choose the glass types to make the secondary spectrum zero in a doublet?
- 77) Explain how the aplanatic-concentric lens works.