Diagnostic Exam requirements for Optical Systems and Devices thrust area

The diagnostic exam problems will address the material covered in the following chapters of "Optics" book by E. Hecht (5th edition, Pearson Education, 2016):

Chapter 2 "Wave Motion,"
Chapter 3 "EM Theory, Photons, and Light,"
Chapter 4 "The Propagation of Light,"
Chapter 5 "Geometrical Optics,"
Chapter 8 "Polarization,"
Chapter 9 "Interference,"
Chapter 13.1 "Lasers and Laserlight," – the topic about Gaussian beam propagation.

In order to prepare for the exam, the students may either study the book independently or take course EE5380 "Principles of Photonics and Optical Engineering" that covers this material (offered once a year in the Fall).

For examples of prior years' exam questions, see the following pages. Note that the next exam's questions may not necessarily be on the same topics as these, but will be certainly within the material of the Chapters listed above.

Fall 2023

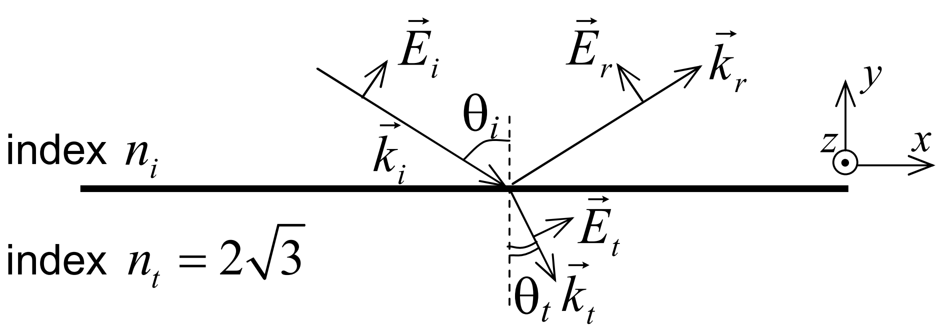
EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic plane wave falls at the plane interface between two dielectric media with refractive indices n_i and n_t (see Figure below; z-axis in the Figure points toward the reader). The magnitude of the vector of the incident electric field is

$$E_i = (12\,\text{V/m}) \times \cos\left[(6\sqrt{3}\times 10^6\,\text{m}^{-1})\,x - (6\times 10^6\,\text{m}^{-1})\,y - (1.8\times 10^{15}\,\text{s}^{-1})\,t\right].$$

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of the refractive index n_i ?
   e. What are the magnitude and orientation of incident magnetic field vector $\vec{B}_i$?
   f. What are the values of incidence angle θ_i and transmission angle θ_t ?
   g. Write the wavevector $\vec{k}_t$ of the transmitted field.
   h. What is the magnitude of the reflected electric field E_r ?



2. A collimated Gaussian beam with wavelength λ = 1550 nm is sent from Earth to probe the surface of the Moon (Earth to Moon distance is 380,000 km).

   a. How large should be its 1/e intensity radius a_0 on Earth if we would like to obtain 1/e intensity radius a_0' = 100 m on the Moon? You can assume that the Rayleigh range of the collimated beam is much shorter than the Earth-to-Moon distance.
   b. Under the conditions of problem "a" above, at what distance from Earth does the beam intensity radius increase by a factor of $\sqrt{2}$?

(continued on next page)

3. A Fabry-Perot etalon made of glass (refractive index n = 1.5) has two identical mirrors with reflectances R = 97% spaced by distance d = 0.5 cm and is used to study light of a laser with wavelength $\lambda_0 \approx$ 660 nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.

   a. What is the value of the minimum transmittance $T_{\min}$ of the interferometer?

   b. How large is the free spectral range $\Delta\nu_{FSR}$ of the Fabry-Perot interferometer?

   c. What is the value of the finesse of the etalon?

   d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?

   e. The resonance frequency of the etalon is gradually tuned by increasing the temperature (which slightly increases the refractive index by $\Delta n << n$). The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the refractive index is changed. How many of such maxima will the optical power meter detect while Δn is changing from 0 to 0.006?

Spring 2023

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated Gaussian beam with wavelength λ = 600 nm and $1/e$ intensity radius a_0' = 1 mm is being focused by a thin lens with focal distance f = 10 cm. Let us assume that the Rayleigh range of the focused beam is much shorter than the focal distance f.
   a. What is the beam waist size ($1/e$ intensity radius) a_0 at the focal point of the lens?
   b. At what distance from the focal point does the beam intensity radius increase by a factor of $\sqrt{2}$?

2. A free-space (refractive index n = 1) Fabry-Perot interferometer with two identical mirrors with reflectances R = 96% spaced by distance d = 2 cm is used to study light of a laser with wavelength λ_0 = 700 nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.
   a. What is the value of the minimum transmittance T_{min} of the interferometer?
   b. How large is the free spectral range of the Fabry-Perot interferometer?
   c. What is the value of the finesse of the interferometer?
   d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of its resonance?
   e. A voltage applied to a piezoelectric transducer is used to gradually move one of the mirrors by small distance $\Delta d \ll d$. The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the distance is changed. How many of such maxima will the optical power meter detect while Δd is changing from 0 to 14 micrometers?

3. A combination of two lenses with focal distances f_1 = +30 cm and f_2 = +50 cm, separated by distance d = 40 cm, is used to create an image of a real object located at a distance 45 cm from the first lens (i.e. from the lens with focal distance f_1).
   a. Find the location of the image created by this 2-lens combination.
   b. Is this final image real or virtual?
   c. Is the final image erect or inverted (with respect to the original object)?
   d. Is the final image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.
   e. Subsequently, the setup is changed by relocating the second lens (i.e., positive lens with focal distance f_2) to a new position, so that the final image created by the 2-lens combination is now located at the infinity. What is the new distance d between the two lenses?

   Drawing ray diagram is not required, but might be helpful in solving the problem.

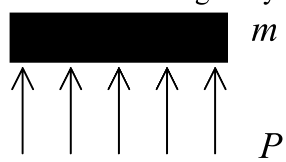
Fall 2022

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A laser beam of power P = 300 Watt is pointed vertically up to illuminate an object of mass m (see the figure below). Assuming that the beam is completely absorbed by the object, estimate the maximum mass of the object that the laser light pressure can keep from falling down on Earth. Acceleration due to gravity is $g = 9.8$ m/s^2.



2. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (g) below, the second polarizer has been rotated so that its transmission axis now forms a $\alpha = +66^{\circ}$ angle with that of the first polarizer. ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

    a. What is the intensity of light at the output of the second polarizer?

    b. A combination consisting of an ideal quarter-wave plate (QWP) followed by an ideal half-wave plate (HWP) is inserted between the polarizers. The optical axis of the QWP is parallel to the transmission axis of the first polarizer. The optical axis of the HWP is parallel to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

    c. What will be the intensity at the output of the second polarizer in problem 2b after the HWP is rotated so that its optical axis now forms a +28° angle with the transmission axis of the first polarizer?

    d. In the setup of problem 2b, would it possible to obtain ***zero*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.

    e. In the setup of problem 2b, would it possible to obtain ***100%*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.

    f. In the setup of problem 2b, the HWP is subsequently removed, and the QWP is rotated so that its axis is now at +45° angle with respect to the transmission axis of the first polarizer. What is the intensity of light after the second polarizer?

    g. A second QWP, identical to the first QWP, is added between the first QWP and the second polarizer in the setup of problem 2f. Is it possible to obtain ***zero*** transmission through the second polarizer by rotating the two QWPs (not necessarily by the same angle)? If this is possible, then indicate the orientations of the optical axes of the two QWPs with respect to the transmission axis of the first polarizer. If not, then explain why this is not possible.

3. Two non-collinear co-polarized plane waves of the same frequency interfere with each other and produce interference pattern (fringes) with maximum intensity I_{max} and minimum intensity I_{min}. Assuming that the ratio of the magnitudes of the two waves is $|E_1| / |E_2| = 3$, find the interference (fringe-pattern) contrast $V = (I_{max} - I_{min}) / (I_{max} + I_{min})$. (*Hint:* remember that at the maxima the fields are added in phase, and in the minima they are added 180º out of phase.)

Spring 2022
EE5380 Principles of Photonics and Optical Engineering
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. (*Note: some angles in the Figure 1 below are intentionally distorted.*) A beam of light travels through a right-triangular prism made of a solid dielectric with refractive index $n_d = 3$, surrounded by a gel of refractive index $n_g = \sqrt{3}$. The beam has zero reflection at the two prism-gel interfaces A and B.

   a. Plane of incidence is the plane containing the wavevector $\vec{k}$ and the vector normal to the interface (i.e., it is the plane of the problem sheet). What is the orientation of the electric field vector in this problem: is it parallel or perpendicular to the plane of incidence?

   b. What is the angle of incidence β onto the first prism-air interface A?

   c. What is the angle of incidence γ onto the second prism-air interface B?

   d. What is the value of prism angle α?

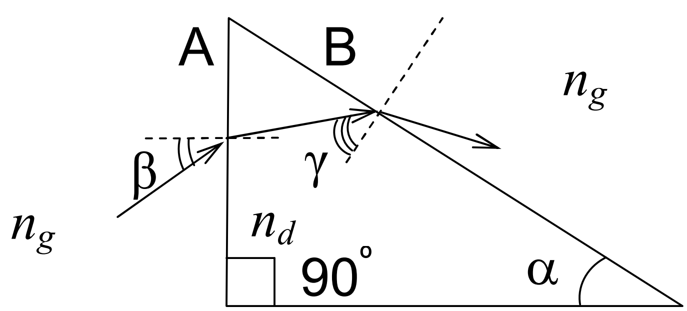


Figure 1.

2. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (g) below, the second polarizer has been set so that its transmission axis forms a +120º angle with that of the first polarizer ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

   a. What is the intensity of light at the output of the second polarizer?

   b. A combination of an ideal quarter-wave plate (QWP) followed by an ideal half-wave plate (HWP) is inserted between the two polarizers (note that the QWP occurs before the HWP in the beam path). The optical axis of the QWP is parallel to the transmission axis of the first polarizer; the optical axis of the HWP is at +50º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

c. What will be the intensity at the output of the second polarizer in problem 2b if the HWP is set so that its optical axis is at +20º with respect to the transmission axis of the first polarizer?

d. What will be the intensity at the output of the second polarizer in problem 2b if the HWP is removed from the setup while QWP is left in place?

e. In the setup of problem 2b, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the HWP if we want to obtain light intensity 0.5 I_0 at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)

f. What will be the intensity at the output of the second polarizer in problem 2b if the QWP is set so that its optical axis is at +45º with respect to the transmission axis of the first polarizer?

g. In the setup of problem 2f (<u>not 2b</u>), would it be possible to obtain ***<u>zero</u>*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.

3. A Fabry-Perot etalon made of diamond (refractive index n = 2.4) has two identical mirrors with reflectances R = 99% spaced by distance d = 0.5 cm and is used to study light of a laser with wavelength λ_0 = 480 nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.

a. What is the value of the minimum transmittance $T_{\min}$ of the interferometer?

b. How large is the free spectral range of the Fabry-Perot interferometer?

c. What is the value of the finesse of the etalon?

d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?

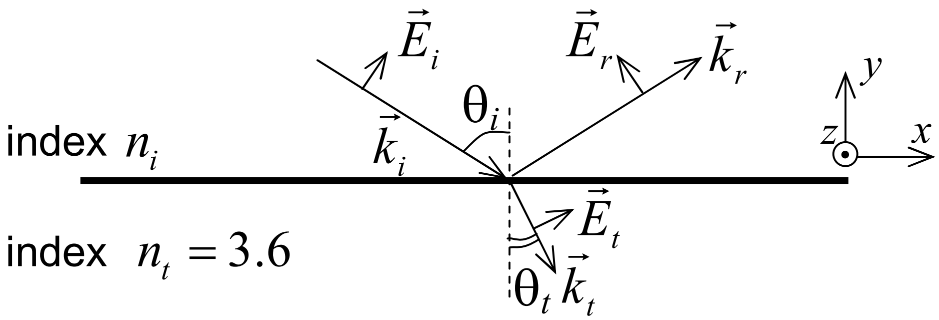
e. The resonance frequency of the etalon is gradually tuned by increasing the temperature (which slightly increases the refractive index by $\Delta n \ll n$). The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the refractive index is changed. How many of such maxima will the optical power meter detect while Δn is changing from 0 to 0.0048?

Fall 2021
EE5380 Principles of Photonics and Optical Engineering
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic plane wave falls at the plane interface between two dielectric media with refractive indices n_i and n_t (see Figure below; z-axis in the Figure points toward the reader). The magnitude of the vector of the incident electric field is

$$E_i = (6\,\mathrm{V/m})\times\cos\left[(9\times10^6\,\mathrm{m}^{-1})\,x-(3\sqrt{3}\times10^6\,\mathrm{m}^{-1})\,y-(1.5\times10^{15}\,\mathrm{s}^{-1})\,t\right].$$

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of the refractive index n_i ?
   e. What are the magnitude and orientation of the incident magnetic field vector $\vec{B}_i$?
   f. What are the values of the angles of incidence (θ_i) and transmission (θ_t) ?
   g. Write the wavevector $\vec{k}_t$ of the transmitted field.
   h. What is the magnitude of the reflected electric field E_r ?



2. A collimated Gaussian beam with wavelength λ = 800 nm and $1/e$ intensity radius a_0' = 2 mm is being focused by a thin lens with focal distance f = 16 cm. Let us assume that the Rayleigh range of the focused beam is much shorter than the focal distance f.
   a. What is the beam waist size ($1/e$ intensity radius) a_0 at the focal point of the lens?
   b. At what distance from the focal point does the beam intensity radius increase by a factor of $\sqrt{2}$?

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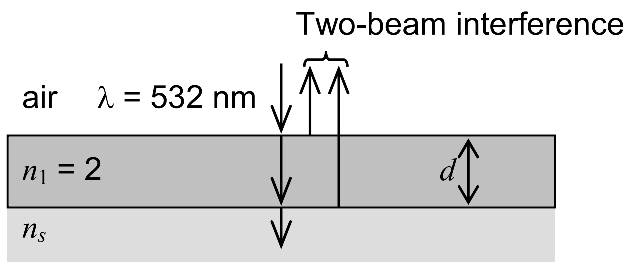
3. A monochromatic plane wave with wavelength λ = 532 nm propagates at normal incidence from air (refractive index 1) into a dielectric with refractive index n_s, separated from the air by a dielectric slab with refractive index $n_1 = 2$ and thickness d (see figure below). The reflected-wave power can be minimized by exploiting two-beam interference from the reflecting surfaces. What are the values of the thickness d that minimize the reflected power for the cases of

   a. $n_s > n_1$;

   b. $n_s < n_1$?

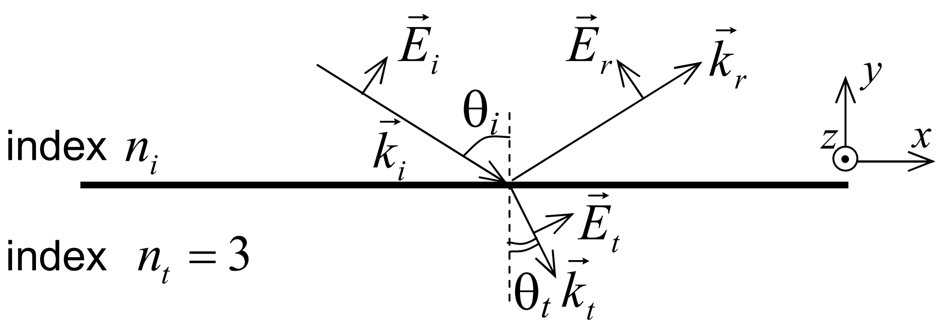


Spring 2021
EE5380 Principles of Photonics and Optical Engineering
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic plane wave falls at the plane interface between two dielectric media with refractive indices n_i and n_t (see Figure below; z-axis in the Figure points toward the reader). The magnitude of the vector of the incident electric field is

$$E_i = (5\,\mathrm{V/m}) \times \cos\left[(6\times 10^6\,\mathrm{m}^{-1})\,x - (2\sqrt{3}\times 10^6\,\mathrm{m}^{-1})\,y - (1.2\times 10^{15}\,\mathrm{s}^{-1})\,t \right].$$

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of the refractive index n_i ?
   e. What are the magnitude and orientation of incident magnetic field vector $\vec{B}_i$?
   f. What are the values of incidence angle θ_i and transmission angle θ_t ?
   g. Write the wavevector $\vec{k}_t$ of the transmitted field.
   h. What is the magnitude of the reflected electric field E_r ?



2. A collimated Gaussian beam with wavelength λ = 600 nm and $1/e$ intensity radius a_0' = 1 mm is being focused by a thin lens with focal distance f = 10 cm. Let us assume that the Rayleigh range of the focused beam is much shorter than the focal distance f.
   a. What is the beam waist size ($1/e$ intensity radius) a_0 at the focal point of the lens?
   b. At what distance from the focal point does the beam intensity radius increase by a factor of $\sqrt{2}$?

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3. A Fabry-Perot etalon made of glass (refractive index n = 1.5) has two identical mirrors with reflectances R = 99% spaced by distance d = 2 cm and is used to study light of a laser with wavelength $\lambda_0 \approx 600$ nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.

   a. What is the value of the minimum transmittance T_{min} of the interferometer?

   b. How large is the free spectral range $\Delta\nu_{\text{FSR}}$ of the Fabry-Perot interferometer?

   c. What is the value of the finesse of the etalon?

   d. How large is the full width at half-maximum $\Delta\nu_{\text{FWHM}}$ of the etalon's resonance?

   e. The resonance frequency of the etalon is gradually tuned by increasing the temperature (which slightly increases the refractive index by $\Delta n \ll n$). The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the refractive index is changed. How many of such maxima will the optical power meter detect while Δn is changing from 0 to 0.003?

Fall 2020
EE5380 Principles of Photonics and Optical Engineering
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated laser beam of power P = 2 Watt illuminates a 100%-reflecting micromirror of mass $m = 5\times10^{-10}$ kg at an angle of incidence $\theta = 30°$ for duration of τ = 15 milliseconds. Prior to laser illumination, the mirror is at rest. What is the velocity of the mirror after the laser illumination? (*Hint:* Use the conservation of momentum.)

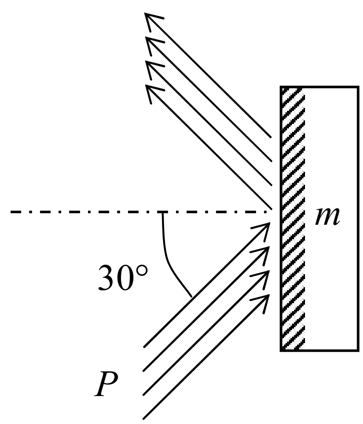


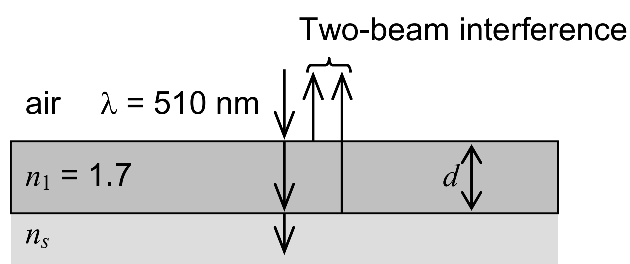
Figure 1.

2. A monochromatic plane wave with wavelength λ = 510 nm propagates at normal incidence from air (refractive index 1) into a dielectric with refractive index n_s, separated from the air by a dielectric slab with refractive index n_1 = 1.7 and thickness d (see Fig. 2 below). The reflected-wave power can be minimized by exploiting two-beam interference from the reflecting surfaces. What are the values of the thickness d that minimize the reflected power for the cases of

   a. $n_s > n_1$;

   b. $n_s < n_1$?

Figure 2.



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3. (*Note: some angles in the Figure 3 below are intentionally distorted.*) A beam of light travels through a right-triangular prism made of a solid dielectric with refractive index $n_d = \sqrt{6}$, surrounded by a gel of refractive index $n_g = \sqrt{2}$. The beam has zero reflection at the two prism-gel interfaces A and B.

   a. Plane of incidence is the plane containing the wavevector $\vec{k}$ and the vector normal to the interface (i.e., it is the plane of the problem sheet). What is the orientation of the electric field vector in this problem: is it parallel or perpendicular to the plane of incidence?

   b. What is the angle of incidence β onto the first prism-air interface A?

   c. What is the angle of incidence γ onto the second prism-air interface B?

   d. What is the value of prism angle α?

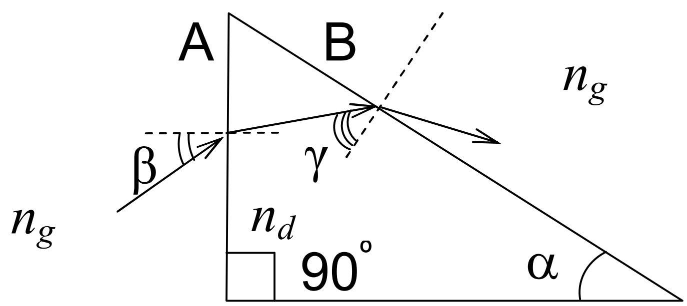


Figure 3.

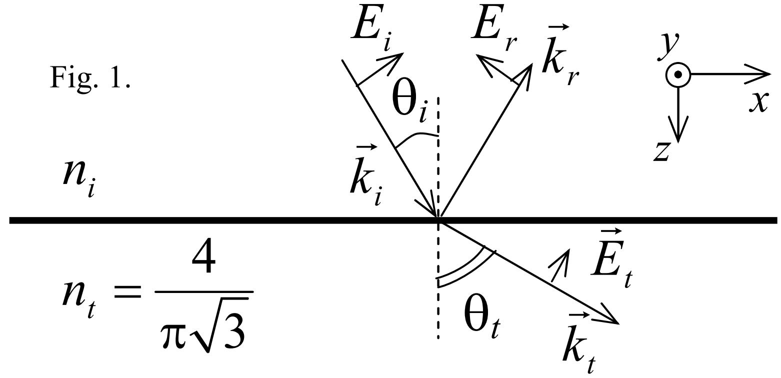
Spring 2019
EE5380 Principles of Photonics and Optical Engineering
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A real object is located at position A. Its real image is constructed at position B by a thin lens with focal distance f. The distance between A and B equals $L = 120$ cm (and $L > 4f$). There are two possible positions of the lens, such that when the lens is placed at either of them it can produce image of A at B; let us call these lens positions C and D (C is closer to the object, D is closer to the image), and the distance between C and D is $d = 40$ cm.
   a. Find lens' focal distance f.
   b. If we place the lens at position C and add another lens, with focal distance f, at position D, where will the final image produced by the two-lens combination be located?
   c. Is the final image built by the two-lens combination erect or inverted (with respect to the original object)? Drawing ray diagram is not required, but might be helpful in solving the problem.
   d. Is the final image built by the two-lens combination real or virtual? Drawing ray diagram is not required, but might be helpful in solving the problem.
   e. Is the final image built by the two-lens combination magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.
2. Monochromatic plane wave falls at the plane interface between two dielectric media with refractive indices n_i and n_t (see Fig. 1 below; y-axis in the Figure points toward the reader). The magnitude of the vector of the incident electric field is

$$E_i = (24\,\text{V/m}) \times \sin[(4\times10^6\,\text{m}^{-1})x + (\sqrt{48}\times10^6\,\text{m}^{-1})z - 2\pi(3\times10^{14}\,\text{s}^{-1})t]\ .$$

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of the refractive index n_i ?
   e. What are the magnitude and orientation of incident magnetic field vector $\vec{B}_i$?
   f. What are the values of incidence angle θ_i and transmission angle θ_t ?
   g. Write the wavevector $\vec{k}_t$ of the transmitted field.
   h. What is the magnitude of the reflected electric field E_r ?

Fig. 1.



3. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (g) below, the second polarizer has been set so that its transmission axis forms a +130º angle with that of the first polarizer ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

    a. What is the intensity of light at the output of the second polarizer?

    b. A combination of an ideal quarter-wave plate (QWP) followed by an ideal half-wave plate (HWP) is inserted between the two polarizers (note that the QWP occurs before the HWP in the beam path). The optical axis of the QWP is parallel to the transmission axis of the first polarizer; the optical axis of the HWP is at +85º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

    c. What will be the intensity at the output of the second polarizer in problem 3b if the HWP is set so that its optical axis is at +10º with respect to the transmission axis of the first polarizer?

    d. What will be the intensity at the output of the second polarizer in problem 3b if the HWP is removed from the setup while QWP is left in place?

    e. In the setup of problem 3b, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the HWP if we want to obtain light intensity 0.75 I_0 at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)

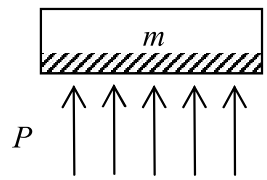
    f. What will be the intensity at the output of the second polarizer in problem 3b if the QWP is set so that its optical axis is at +45º with respect to the transmission axis of the first polarizer?

    g. In the setup of problem 3f (<u>not 3b</u>), would it be possible to obtain ***<u>zero</u>*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.

Fall 2018
EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A laser beam of power P is pointed vertically up to illuminate an object of mass m = 4×10^{-6} kg (see the figure below). Assuming that the beam is 100% reflected by the object, estimate the power of the laser that is required in order to provide sufficient light pressure to keep the object from falling down on Earth. Acceleration due to gravity is g = 9.8 m/s^2.



2. A free-space (refractive index n = 1) Fabry-Perot interferometer with two identical mirrors with reflectances R = 98% spaced by distance d = 1.5 cm is used to study light of a laser with wavelength λ_0 = 800 nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.
   a. What is the value of the minimum transmittance $T_{\min}$ of the interferometer?
   b. How large is the free spectral range of the Fabry-Perot interferometer?
   c. What is the value of the finesse of the interferometer?
   d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of its resonance?
   e. A voltage applied to a piezoelectric transducer is used to gradually move one of the mirrors by small distance $\Delta d \ll d$. The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the distance is changed. How many of such maxima will the optical power meter detect while Δd is changing from 0 to 4 micrometers?

3. A combination of two lenses with focal distances f_1 = +40 cm and f_2 = +50 cm, separated by distance d = 70 cm, is used to create an image of a real object located at a distance 60 cm from the first lens (i.e. from the lens with focal distance f_1).
   a. Find the location of the image created by this 2-lens combination.
   b. Is this final image real or virtual?
   c. Is the final image erect or inverted (with respect to the original object)?
   d. Is the final image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.
   e. Subsequently, the setup is changed by relocating the second lens (i.e., positive lens with focal distance f_2) to a new position, so that the final image created by the 2-lens combination is now located at the infinity. What is the new distance d between the two lenses?

   Drawing ray diagram is not required, but might be helpful in solving the problem.

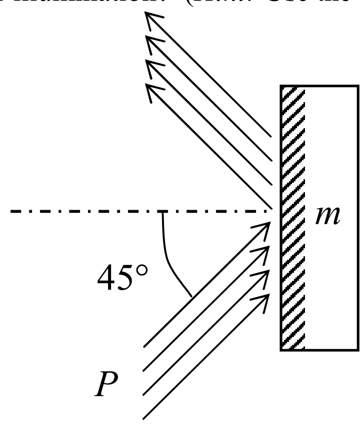
Spring 2018 EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated laser beam of power $P = 50$ Watt illuminates a 100%-reflecting micromirror of mass $m = 2$ micrograms at an angle of incidence $\theta = 45°$ for duration of $\tau = 20$ milliseconds (Fig. 1). Prior to laser illumination, the mirror is at rest. What is the velocity of the mirror after the laser illumination? (*Hint:* Use the conservation of momentum.)

Fig. 1.

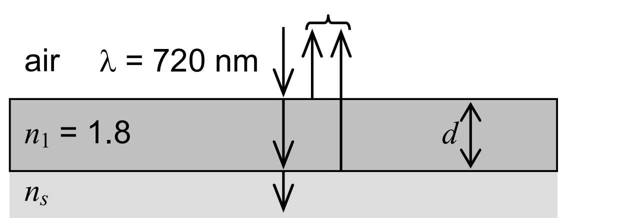


2. A monochromatic plane wave with wavelength $\lambda = 720$ nm propagates at normal incidence from air (refractive index 1) into a dielectric with refractive index n_s, separated from the air by a dielectric slab with refractive index $n_1 = 1.8$ and thickness d (see Fig. 2 below). The reflected-wave power can be minimized by exploiting two-beam interference from the reflecting surfaces. What are the values of the thickness d that minimize the reflected power for the cases of

   a. $n_s > n_1$;

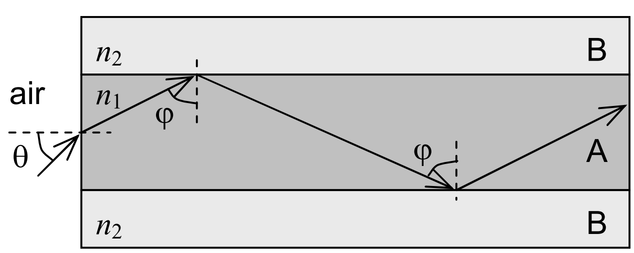
   b. $n_s < n_1$?

Fig. 2.



3. A numerical aperture NA of a dielectric waveguide (or optical fiber) is defined as the maximum value of $\sin\theta$ (with θ being the angle of incidence at the input face of the waveguide, see Fig. 3 below) for which the incident beam can propagate in the waveguide under the condition of total internal reflection (i.e., under condition that angle φ in Fig. 3 is greater than the critical angle of the total internal reflection). Assuming that the core A of the waveguide has a refractive index $n_1 = 1.9$ and the cladding B has a refractive index $n_2 = 1.5$, find the numerical aperture $\text{NA} = \sin\theta_{max}$ of the waveguide.

Fig. 3.



Fall 2017

EE5380 Principles of Photonics and Optical Engineering

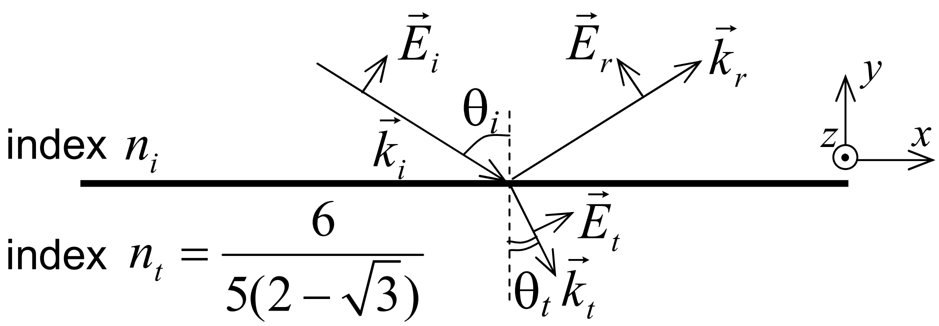
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic plane wave falls at the plane interface between two dielectric media with refractive indices n_i and n_t (see Figure below; z-axis in the Figure points toward the reader). The magnitude of the vector of the incident electric field is

$$E_i = (15\,\mathrm{V/m}) \times \sin\left[(3\sqrt{2+\sqrt{3}} \times 10^6\,\mathrm{m}^{-1})\,x - (3\sqrt{2-\sqrt{3}} \times 10^6\,\mathrm{m}^{-1})\,y - (1.5 \times 10^{15}\,\mathrm{s}^{-1})\,t \right].$$

.

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of the refractive index n_i ?
   e. What are the magnitude and orientation of incident magnetic field vector $\vec{B}_i$?
   f. What are the values of incidence angle θ_i and transmission angle θ_t ?
   g. Write the wavevector $\vec{k}_t$ of the transmitted field.
   h. What is the magnitude of the reflected electric field E_r ?



2. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (g) below, the second polarizer has been set so that its transmission axis forms a +110º angle with that of the first polarizer ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

   a. What is the intensity of light at the output of the second polarizer?
   b. A combination of an ideal quarter-wave plate (QWP) followed by an ideal half-wave plate (HWP) is inserted between the two polarizers (note that the QWP occurs before the HWP in the beam path). The optical axis of the QWP is parallel to the transmission axis of the first polarizer; the optical axis of the HWP is at +40º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

c. What will be the intensity at the output of the second polarizer in problem 2b if the HWP is set so that its optical axis is at +10º with respect to the transmission axis of the first polarizer?

d. What will be the intensity at the output of the second polarizer in problem 2b if the HWP is removed from the setup while QWP is left in place?

e. In the setup of problem 2b, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the HWP if we want to obtain light intensity 0.5 I_0 at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)

f. What will be the intensity at the output of the second polarizer in problem 2b if the QWP is set so that its optical axis is at +45º with respect to the transmission axis of the first polarizer?

g. In the setup of problem 2f (not 2b), would it be possible to obtain ***zero*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.

3. A Fabry-Perot etalon made of glass (refractive index n = 1.5) has two identical mirrors with reflectances R = 98% spaced by distance d = 1 cm and is used to study light of a laser with wavelength λ_0 = 500 nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.

a. What is the value of the minimum transmittance $T_{\min}$ of the interferometer?

b. How large is the free spectral range of the Fabry-Perot interferometer?

c. What is the value of the finesse of the etalon?

d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?

e. The resonance frequency of the etalon is gradually tuned by increasing the temperature (which slightly increases the refractive index by $\Delta n \ll n$). The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the refractive index is changed. How many of such maxima will the optical power meter detect while Δn is changing from 0 to 0.001?

Spring 2017

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (f) below, the second polarizer has been set so that its transmission axis forms a +50º angle with that of the first polarizer ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).
    a. What is the intensity of light at the output of the second polarizer?
    b. A combination of an ideal quarter-wave plate followed by an ideal half-wave plate is inserted between the two polarizers (note that the quarter-wave plate occurs before the half-wave plate in the beam path). The optical axis of the quarter-wave plate is parallel to the transmission axis of the first polarizer; the optical axis of the half-wave plate is at +40º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?
    c. What will be the intensity at the output of the second polarizer in problem 1b if the half-wave plate is set so that its optical axis is at +80º with respect to the transmission axis of the first polarizer?
    d. What will be the intensity at the output of the second polarizer in problem 1b if the half-wave plate is removed from the setup while quarter-wave plate is left in place?
    e. What will be the intensity at the output of the second polarizer in problem 1b if the quarter-wave plate is set so that its optical axis is at +45º with respect to the transmission axis of the first polarizer?
    f. In the setup of problem 1b, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the half-wave plate if we want to obtain light intensity 0.25 I_0 at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)

(problems continue on the next page)

2. A real object is located at position A. Its real image is constructed at position B by a thin lens with focal distance f. The distance between A and B equals L = 80 cm (and $L > 4f$). There are two possible positions of the lens, such that when the lens is placed at either of them it can produce image of A at B; let us call these lens positions C and D (C is closer to the object, D is closer to the image), and the distance between C and D is d = 40 cm.

    a. Find lens' focal distance f.

    b. If we place the lens at position C and add another lens, with focal distance f, at position D, where will the final image produced by the two-lens combination be located?

    c. Is the final image built by the two-lens combination erect or inverted (with respect to the original object)? Drawing ray diagram is not required, but might be helpful in solving the problem.

    d. Is the final image built by the two-lens combination real or virtual? Drawing ray diagram is not required, but might be helpful in solving the problem.

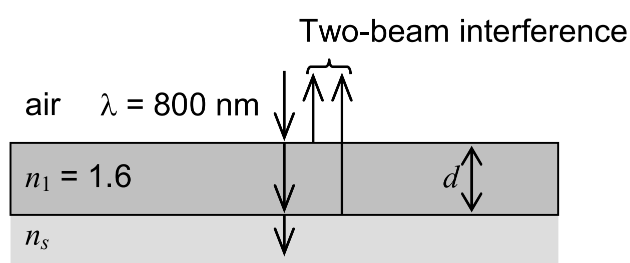
    e. Is the final image built by the two-lens combination magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

3. A monochromatic plane wave with wavelength λ = 800 nm propagates at normal incidence from air (refractive index 1) into a dielectric with refractive index n_s, separated from the air by a dielectric slab with refractive index n_1 = 1.6 and thickness d (see Fig. 1 below). The reflected-wave power can be minimized by exploiting two-beam interference from the reflecting surfaces. What are the values of the thickness d that minimize the reflected power for the cases of

    a. $n_s > n_1$;

    b. $n_s < n_1$?

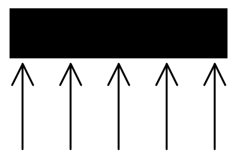
Fig. 1.



Fall 2016
EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A laser beam of power P is pointed vertically up to illuminate an object of mass $m = 3\times10^{-6}$ kg (see the figure below). Assuming that the beam is completely absorbed by the object, estimate the power of the laser that is required in order to provide sufficient light pressure to keep the object from falling down on Earth. Acceleration due to gravity is $g = 9.8$ m/s^2.



2. A free-space (refractive index $n = 1$) Fabry-Perot interferometer with two identical mirrors with reflectances $R = 99\%$ spaced by distance $d = 2$ cm is used to study light of a laser with wavelength $\lambda_0 = 750$ nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.
   a. What is the value of the minimum transmittance T_{min} of the interferometer?
   b. How large is the free spectral range of the Fabry-Perot interferometer?
   c. What is the value of the finesse of the etalon?
   d. How large is the full width at half-maximum $\Delta\nu_{\text{FWHM}}$ of the etalon's resonance?
   e. A voltage applied to a piezoelectric transducer is used to gradually move one of the mirrors by small distance $\Delta d \ll d$. The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the distance is changed. How many of such maxima will the optical power meter detect while Δd is changing from 0 to 9 micrometers?

3. A combination of two lenses with focal distances $f_1 = +60$ cm and $f_2 = +100$ cm, separated by distance $d = 30$ cm, is used to create an image of a real object located at a distance 90 cm from the first lens (i.e. from the lens with focal distance f_1).
   a. Find the location of the image created by this 2-lens combination.
   b. Is this final image real or virtual?
   c. Is the final image erect or inverted (with respect to the original object)?
   d. Is the final image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.
   e. Subsequently, the setup is changed by relocating the second lens (i.e., positive lens with focal distance f_2) to a new position, so that the final image created by the 2-lens combination is now located at the infinity. What is the new distance d between the two lenses?

   Drawing ray diagram is not required, but might be helpful in solving the problem.

Spring 2016

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (g) below, the second polarizer has been rotated so that its transmission axis now forms a $\alpha = +80^o$ angle with that of the first polarizer. ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).
    a. What is the intensity of light at the output of the second polarizer?
    b. A combination consisting of an ideal half-wave plate (HWP) followed by an ideal quarter-wave plate (QWP) is inserted between the polarizers. The optical axis of the HWP is parallel to the transmission axis of the first polarizer. The optical axis of the QWP is parallel to the transmission axis of the second polarizer. What is the intensity at the output of the second polarizer?
    c. What will be the intensity at the output of the second polarizer in problem 3b after the HWP is rotated so that its optical axis now forms a +25° angle with the transmission axis of the first polarizer?
    d. In the setup of problem 3b, would it possible to obtain ***zero*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.
    e. In the setup of problem 3b, would it possible to obtain ***100%*** transmission through the second polarizer by rotating the HWP only? If this is possible, then what should be the angle γ of the optical axis of the HWP with respect to the transmission axis of the first polarizer? If this is not possible, then explain why.
    f. In the setup of problem 3b, the HWP is subsequently removed, and the QWP is rotated so that its axis is now at +45° angle with respect to the transmission axis of the first polarizer. What is the intensity of light after the second polarizer?
    g. A second ideal QWP is added between the first QWP and the second polarizer in the setup of problem 3f. Is it possible to obtain ***zero*** transmission through the second polarizer by rotating the two QWPs (not necessarily by the same angle)? If this is possible, then indicate the orientations of the optical axes of the two QWPs with respect to the transmission axis of the first polarizer. If not, then explain why this is not possible.

2. Two non-collinear co-polarized plane waves of the same frequency interfere with each other and produce interference pattern (fringes) with maximum intensity I_{max} and minimum intensity I_{min}. Assuming that the ratio of the magnitudes of the two waves is $|E_1| / |E_2| = 2$, find the interference (fringe-pattern) contrast $V = (I_{max} - I_{min}) / (I_{max} + I_{min})$. (*Hint:* remember that at the maxima the fields are added in phase, and in the minima they are added 180º out of phase.)

(problems continue on the next page)

3. (*Note: some angles in the Figure 1 below are intentionally distorted.*) A beam of light travels through a right-triangular prism made of a dielectric with refractive index $n = 1/(2-\sqrt{3})$. The beam has zero reflection at the two prism-air interfaces A and B.

   a. Plane of incidence is the plane containing the wavevector $\vec{k}$ and the vector normal to the interface (i.e., it is the plane of the problem sheet). What is the orientation of the electric field vector in this problem: is it parallel or perpendicular to the plane of incidence?

   b. What is the angle of incidence β onto the first prism-air interface A?

   c. What is the angle of incidence γ onto the second prism-air interface B?

   d. What is the value of prism angle α?

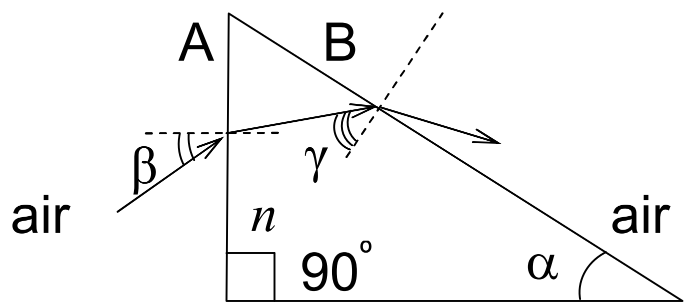


Figure 1.

Fall 2015 Diagnostic Exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (f) below, the second polarizer has been rotated so that its transmission axis now forms a +90º angle with that of the first polarizer. ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

   a. What is the intensity of light at the output of the second polarizer?

   b. A combination of two identical ideal quarter-wave plates (QWPs) is inserted between the two polarizers; the optical axes of the QWPs are parallel to each other and also parallel to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

   c. What will be the intensity at the output of the second polarizer in problem 3b after the second (the one that is closer to the second polarizer) of the two QWPs is rotated so that its optical axis now forms a +45° angle with the first polarizer?

   d. In the setup of problem 3c, would it possible to obtain ***<u>zero</u>*** transmission through the second polarizer by rotating the first QWP, while leaving the second QWP at +45° angle with respect to the first polarizer? If this is possible, then what should be the angle of the optical axis of the first QWP with respect to the first polarizer? If this is not possible, then explain why.

   e. In the setup of problem 3c, would it possible to obtain ***<u>100%</u>*** transmission through the second polarizer by rotating the first QWP, while leaving the second QWP at +45° angle with respect to the first polarizer? If this is possible, then what should be the angle of the optical axis of the first QWP with respect to the first polarizer? If this is not possible, then explain why.

   f. In the setup of problem 3c, the first QWP is subsequently removed, while the second QWP remains at +45° angle with respect to the first polarizer. You are given two identical ideal half-wave plates (HWPs) and told that you can put either (or both) of them anywhere between the two polarizers of the setup (e.g., between the first polarizer and the QWP, between the QWP and the second polarizer, or putting one of the HWPs before the QWP, and the other – after it, etc.). Is it possible to obtain ***<u>zero</u>*** transmission through the second polarizer with one of such arrangements of the two HWPs? If this is possible, then indicate the locations of the HWPs and the orientations of their optical axes. If not, then explain why this is not possible. (Note: you are not allowed to place any HWPs before the first polarizer.)

2. A free-space (refractive index $n = 1$) Fabry-Perot interferometer with two identical mirrors spaced by distance $d = 1$ cm is used to study light of a laser with wavelength $\lambda_0 = 600$ nm at normal incidence. An optical power meter measures the power transmitted through the interferometer. Initially, the laser light experiences minimum transmission through the interferometer.

   a. How large is the free spectral range of the Fabry-Perot interferometer?

   b. A voltage applied to a piezoelectric transducer is used to gradually move one of the mirrors by small distance $\Delta d \ll d$. The optical power meter shows that the transmitted power goes through a sequence of maxima and minima as the distance is changed. How many of such maxima will the optical power meter detect while Δd is changing from 0 to 12 micrometers?

3. A combination of two lenses with focal distances $f_1 = 20$ cm and $f_2 = -30$ cm, separated by distance $d = 30$ cm, is used to create an image of a real object located at a distance 40 cm from the first lens (i.e. from the lens with focal distance f_1).

   a. Find the location of the image created by this 2-lens combination.

   b. Is this final image real or virtual?

   c. Is the final image erect or inverted (with respect to the original object)?

   d. Is the final image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

   e. Subsequently, the setup is changed by relocating the second lens (i.e., negative lens with focal distance f_2) to a new position, so that the final image created by the 2-lens combination is now located at the infinity. What is the new distance d between the two lenses?

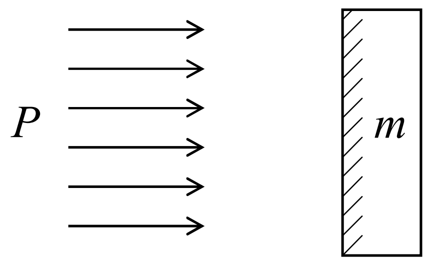
   Drawing ray diagram is not required, but might be helpful in solving the problem.

Spring 2015 Diagnostic exam

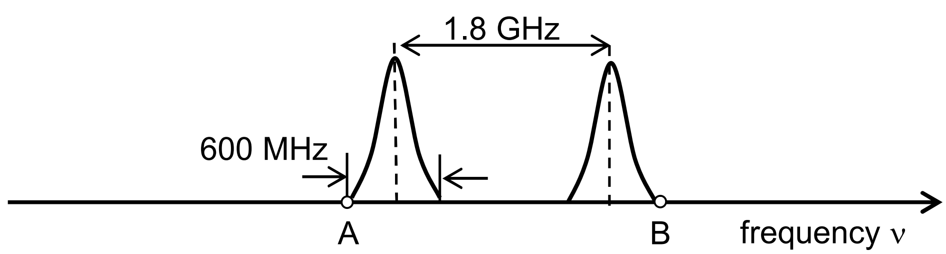
EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated laser beam of power $P = 10^5$ Watt illuminates a 100%-absorbing micromirror at normal incidence for duration $\tau = 0.03$ seconds. Prior to laser illumination, the mirror is at rest. What velocity does the mirror acquire after the laser illumination if the mass of the mirror is $m = 0.001$ gram? (*Hint:* Use the conservation of momentum.)



2. Yellow flame color of a birthday-cake candle originates from the D_2 fluorescence line of sodium, which consists of two spectral components centered at wavelength $\lambda_0 = 589$ nm and separated in frequency by 1.8 GHz ("hyperfine splitting"), as shown in the Figure below. Each of the two spectral components has a width of 600 MHz ("Doppler broadening"). A free-space (refractive index $n = 1$) Fabry-Perot etalon with two identical mirrors with reflectances $R = 98\%$ is used at normal incidence as a high-resolution spectrometer to study such sodium fluorescence light: the etalon's resonance is tuned from frequency A to frequency B of the D_2 line spectrum by slightly changing the distance between the mirrors d. From measurements of the power transmitted through the etalon for each value of d and the knowledge of how etalon's resonance frequency changes as a function of d, the optical spectrum of D_2 line can be obtained.



   a. What is the maximum spacing between the mirrors of the Fabry-Perot etalon, which would still allow it to be used to measure D_2 line spectrum? (*Hint*: this application demands that only one resonance of the etalon is located within the spectrum to be measured, i.e., between frequencies A and B.)

   b. What is the spacing d between the etalon mirrors if the free spectral range of the etalon is 3 GHz?

   c. What is the finesse of the etalon in problem "b"?

   d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance in problem "b"?

e. If the etalon has the free spectral range of problem "b" above, and one of its resonances is initially at frequency A, then by what minimum distance Δd should we move one of the etalon's mirrors in order to tune this resonance to frequency B (i.e., tune it all the way across the D_2 line spectrum)?

3. A real object is located at position A. Its real image is constructed at position B by a thin lens with focal distance f. The distance between A and B equals $L = 100$ cm. There are two possible positions of the lens, such that when the lens is placed at either of them it can produce image of A at B; let us call these lens positions C and D (C is closer to the object, D is closer to the image), and the distance between C and D is $d = 60$ cm.

   a. Find lens' focal distance f.

   b. If we place the lens at position C and add another lens, with focal distance f, at position D, where will the final image produced by the two-lens combination be located?

   c. Is the final image built by the two-lens combination erect or inverted (with respect to the original object)? Drawing ray diagram is not required, but might be helpful in solving the problem.

   d. Is the final image built by the two-lens combination real or virtual? Drawing ray diagram is not required, but might be helpful in solving the problem.

   e. Is the final image built by the two-lens combination magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

Fall 2014 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

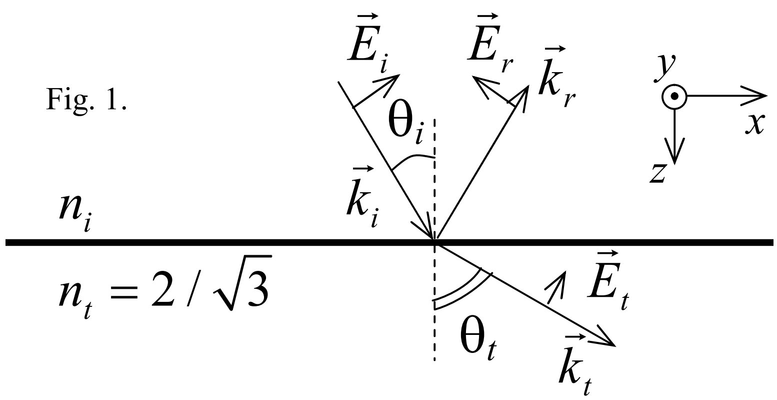
Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Monochromatic plane wave falls at the plane interface between two dielectric media with refractive indices n_i and n_t (see Fig. 1 below; y-axis in the Figure points toward the reader). The magnitude of the vector of the incident electric field is

$$E_i = (18\,\text{V/m}) \times \sin[(5\times10^6\,\text{m}^{-1})x + (\sqrt{75}\times10^6\,\text{m}^{-1})z - (1.5\times10^{15}\,\text{s}^{-1})t] \ .$$

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of the refractive index n_i ?
   e. What are the magnitude and orientation of incident magnetic field vector $\vec{B}_i$?
   f. What are the values of incidence angle θ_i and transmission angle θ_t ?
   g. Write the wavevector $\vec{k}_t$ of the transmitted field.
   h. What is the magnitude of the reflected electric field E_r ?

Fig. 1.



2. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (f) below, the second polarizer has been set so that its transmission axis forms a +120º angle with that of the first polarizer ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

   a. What is the intensity of light at the output of the second polarizer?
   b. A combination of an ideal quarter-wave plate followed by an ideal half-wave plate is inserted between the two polarizers (note that the quarter-wave plate occurs before the half-wave plate in the beam path). The optical axis of the quarter-wave plate is parallel to the transmission axis of the first polarizer; the optical axis of the half-wave plate is at +45º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

c. What will be the intensity at the output of the second polarizer in problem 2b if the half-wave plate is set so that its optical axis is at +60º with respect to the transmission axis of the first polarizer?

d. What will be the intensity at the output of the second polarizer in problem 2b if the half-wave plate is removed from the setup while quarter-wave plate is left in place?

e. What will be the intensity at the output of the second polarizer in problem 2b if the quarter-wave plate is set so that its optical axis is at +45º with respect to the transmission axis of the first polarizer?

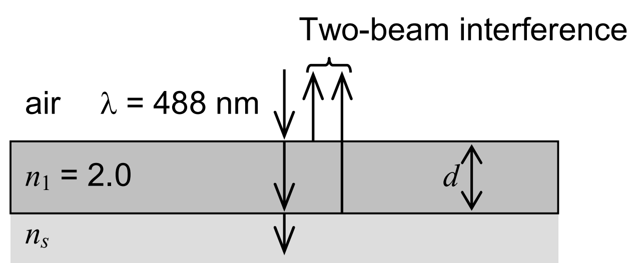
f. In the setup of problem 2b, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the half-wave plate if we want to obtain light intensity 0.5 I_0 at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)

3. A monochromatic plane wave with wavelength λ = 488 nm propagates at normal incidence from air (refractive index 1) into a dielectric with refractive index n_s, separated from the air by a dielectric slab with refractive index n_1 = 2.0 and thickness d (see Fig. 2 below). The reflected-wave power can be minimized by exploiting two-beam interference from the reflecting surfaces. What are the values of the thickness d that minimize the reflected power for the cases of

   a. $n_s > n_1$;

   b. $n_s < n_1$?

Fig. 2.



Spring 2014 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A 3-cm-long Fabry-Perot etalon made of material with refractive index n_f has two identical mirrors with reflectances R = 96% and a free spectral range of 5 GHz.
    a. What is the value of the refractive index n_f of the Fabry-Perot etalon?
    b. What is the value of the finesse of the etalon?
    c. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?
    d. A signal from a laser with wavelength λ = 532 nm is initially at resonance with the etalon, resulting in 100% transmission through the etalon. Subsequently, the resonance frequency of the etalon is gradually tuned by increasing the distance d between the mirrors. As a result, transmission through the etalon at first decreases to a minimum value $T_{\min}$, and then increases to reach 100% transmission again (i.e., laser frequency now coincides with the next resonance of the etalon). By how much has the distance d between the mirrors changed between the two 100% transmission cases?
    e. What was the minimum transmission value $T_{\min}$ in problem d?
2. Monochromatic light is linearly polarized, with electric field oriented at an angle α = +60° with respect to the vertical direction ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation). We would like to convert it to a linearly polarized light with vertically (i.e., 0° or 180°) oriented electric field. We have one half-wave plate and two identical quarter-wave plates in our optical tools inventory. Describe at least two different combinations (each consisting of one or more waveplates) of the optical tools from our inventory that can achieve this task. For each combination, specify the orientation of each waveplate.
3. A combination of two lenses with focal distances f_1 = +30 cm and f_2 = +60 cm, separated by distance d = 30 cm, is used to create an image of a real object located at a distance 45 cm from the first lens (i.e. from the lens with focal distance f_1).
    a. Find the location of the image created by this 2-lens combination.
    b. Is the final image built by the two-lens combination erect or inverted (with respect to the original object)? Drawing ray diagram is not required, but might be helpful in solving the problem.
    c. Is the final image built by the two-lens combination real or virtual? Drawing ray diagram is not required, but might be helpful in solving the problem.
    d. Is the final image built by the two-lens combination magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.
    e. Subsequently, the setup is changed by relocating the second lens (i.e., positive lens with focal distance f_2) to a new position, so that the final image created by the 2-lens combination is now located at the infinity. What is the new distance d between the two lenses? (*Hint: d* has increased.)

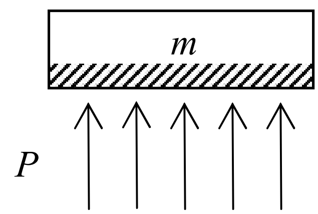
Fall 2013 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A laser beam of power P = 100 Watt is pointed vertically up to illuminate an object of mass m (see the figure below). Assuming that the beam is 100% reflected by the object, estimate the maximum mass of the object that the laser light pressure can keep from falling down on Earth. Acceleration due to gravity is $g = 9.8$ m/s^2.



2. Monochromatic light is linearly polarized, with electric field oriented at an angle α = +30° with respect to the vertical direction ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation). We would like to convert it to a linearly polarized light with horizontally (i.e., +90° or –90°) oriented electric field. We have one half-wave plate and two identical quarter-wave plates in our optical tools inventory. Describe at least two different combinations (each consisting of one or more waveplates) of the optical tools from our inventory that can achieve this task. For each combination, specify the orientation of each waveplate.

3. A real object is located at position A. Its real image is constructed at position B by a thin lens with focal distance f. The distance between A and B equals L = 100 cm. There are two possible positions of the lens, such that when the lens is placed at either of them it can produce image of A at B; let us call these lens positions C and D (C is closer to the object, D is closer to the image), and the distance between C and D is d = 40 cm.

    a. Find lens' focal distance f.

    b. If we place the lens at position C and add another lens, with focal distance $-f$, at position D, where will the final image produced by the two-lens combination be located?

    c. Is the final image built by the two-lens combination erect or inverted (with respect to the original object)? Drawing ray diagram is not required, but might be helpful in solving the problem.

    d. Is the final image built by the two-lens combination real or virtual? Drawing ray diagram is not required, but might be helpful in solving the problem.

    e. Is the final image built by the two-lens combination magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

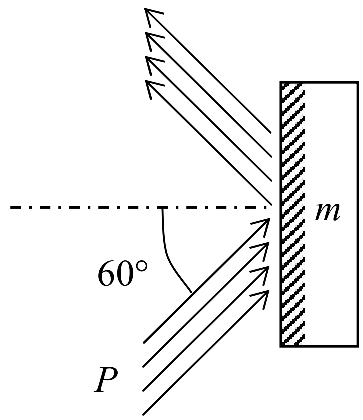
Spring 2013 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated laser beam of power P = 3 Watt illuminates a 100%-reflecting micromirror of mass m = 1 microgram at an angle of incidence $\theta = 60°$ for duration of τ = 10 milliseconds. Prior to laser illumination, the mirror is at rest. What is the velocity of the mirror after the laser illumination? (*Hint:* Use the conservation of momentum.)



2. Monochromatic light is sent through a sequence of two ideal linear polarizers. The transmission axis of the second (i.e., output) polarizer is at an angle $\alpha = +70°$ with respect to the transmission axis of the first (i.e., input) polarizer ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation). A combination consisting of a half-wave plate (HWP) followed by a quarter-wave plate (QWP) is inserted between the polarizers (note that the HWP occurs before the QWP in the beam path). The optical axis of the QWP is parallel to the transmission axis of the second polarizer.

    a. What should be the angle γ of the HWP's optical axis with respect to the transmission axis of the first polarizer, if we want to achieve zero transmission after the second polarizer? (Note that there are several solutions; it is sufficient for you to provide one.)

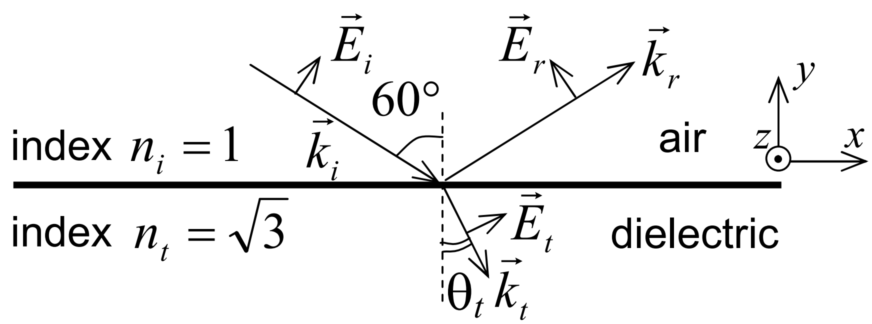
    b. What should be the angle γ of the HWP's optical axis with respect to the transmission axis of the first polarizer, if we want to achieve maximum transmission after the second polarizer? (Note that there are several solutions; it is sufficient for you to provide one.)

(*continued on the next page*)

3. Monochromatic plane wave falls from the air (refractive index $n_i = 1$) onto a flat interface with a dielectric medium of refractive index $n_t = \sqrt{3}$ at an angle of incidence $\theta_i = 60°$ (see the figure below; z-axis in the figure points from the plane of the problem sheet toward the reader). The incident electric field vector is in the plane of incidence (i.e., in plane of the problem sheet), and its magnitude is given by

$$E_i = (600\,\text{V/m}) \times \cos[\vec{k}_i\,\vec{r} - (3\times10^{15}\,\text{rad/s})\,t]\ .$$

   a. What are the values of radian frequency ω (in rad/s) and frequency ν (in Hz) of the incident wave?
   b. Find the magnitude of the incident wavevector k_i .
   c. Write the wavevector $\vec{k}_i$.
   d. What are the magnitude and orientation of the incident magnetic field vector $\vec{B}_i$?
   e. What is the value of the transmission angle θ_t ?
   f. Write the wavevector $\vec{k}_t$ of the transmitted field.
   g. What is the magnitude of the reflected electric field E_r ?



Fall 2012 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A 2-cm-long Fabry-Perot etalon made of material with refractive index n_f has two identical mirrors with reflectances R = 98% and a free spectral range of 3.75 GHz.
   a. What is the value of the refractive index n_f of the Fabry-Perot etalon?
   b. What is the value of the finesse of the etalon?
   c. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?
   d. A signal from a laser with wavelength λ = 600 nm is initially at resonance with the etalon, resulting in 100% transmission through the etalon. Subsequently, the resonance frequency of the etalon is gradually tuned by increasing the temperature (which slightly increases the refractive index n_f). As a result, transmission through the etalon at first decreases to a minimum value $T_{\min}$, and then increases to reach 100% transmission again (i.e., laser frequency now coincides with the next resonance of the etalon). By how much has the refractive index n_f changed between the two 100% transmission cases?
   e. What was the minimum transmission value $T_{\min}$ in problem d?

2. (*Note: some angles in the Figure 1 below are intentionally distorted.*) A beam of light travels through a right-triangular prism made of a dielectric with refractive index $n > 1$. The beam has zero reflection at the two prism-air interfaces A and B.
   a. Plane of incidence is the plane containing the wavevector $\vec{k}$ and the vector normal to the interface (i.e., it is the plane of the problem sheet). What is the orientation of the electric field vector in this problem: is it parallel or perpendicular to the plane of incidence?
   b. What is the angle of incidence γ onto the second prism-air interface B?
   c. What is the angle of incidence β onto the first prism-air interface A?
   d. What is the value of refractive index n?

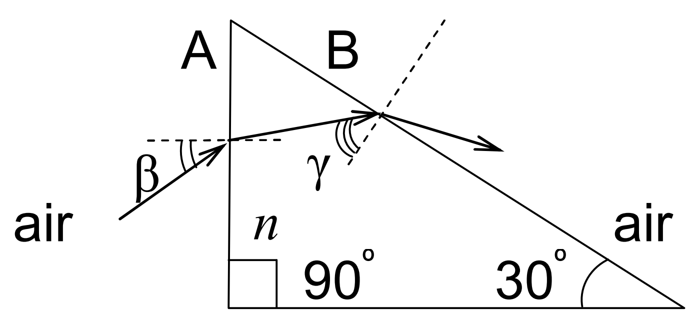


Figure 1.

3. A combination of two lenses with focal distances $f_1 = +30$ cm and $f_2 = -20$ cm, separated by distance $d = 40$ cm, is used to create an image of a real object located at a distance 75 cm from the first lens (i.e. from the lens with focal distance f_1).

   a. Find the location of the image created by this 2-lens combination.

   b. Is this final image real or virtual?

   c. Is the final image erect or inverted (with respect to the original object)?

   d. Is the final image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

   e. Subsequently, the setup is changed by relocating the second lens (i.e., negative lens with focal distance f_2) to a new position, so that the final image created by the 2-lens combination is now located at the infinity. What is the new distance d between the two lenses?

Spring 2012 Diagnostic exam

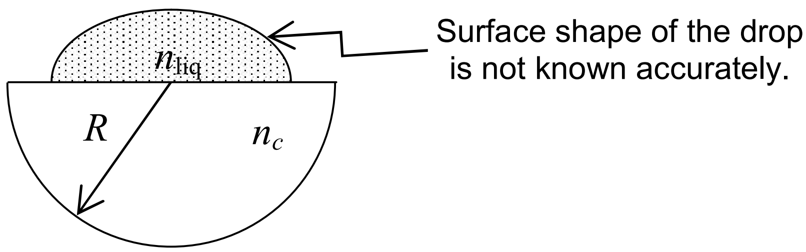
EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. You are given the half-cylinder with radius R, shown in Fig. 1 below and made of a transparent dielectric material with refractive index $n_c = 1.90$. A drop of liquid is placed on its surface as shown. It is known that the liquid has refractive index n_{liq} somewhere in the range 1.33–1.65 (this is the range from water to oil). You are also given a polarized HeNe laser with wavelength of 633 nm that you can orient at will and a device to measure angles. Describe two good methods to find n_{liq} using this gear.

Fig. 1.

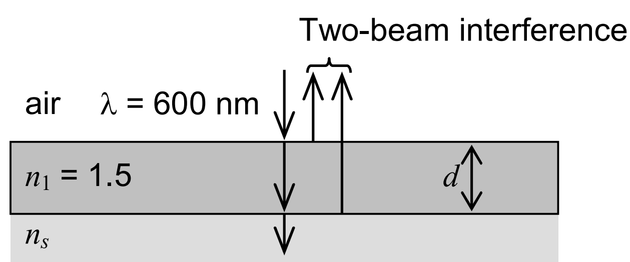


2. A monochromatic plane wave with wavelength $\lambda = 600$ nm propagates at normal incidence from air (refractive index 1) into a dielectric with refractive index n_s, separated from the air by a dielectric slab with refractive index $n_1 = 1.5$ and thickness d (see Fig. 2 below). The reflected-wave power can be minimized by exploiting two-beam interference from the reflecting surfaces. What are the values of the thickness d that minimize the reflected power for the cases of

    a. $n_s > n_1$;

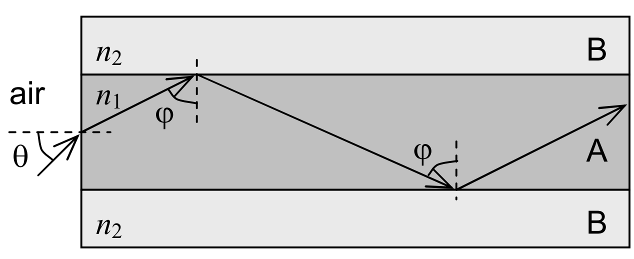
    b. $n_s < n_1$?

Fig. 2.



3. A numerical aperture NA of a dielectric waveguide (e.g., optical fiber) is defined as the maximum value of $\sin\theta$ (with θ being the angle of incidence at the input face of the waveguide, see Fig. 3 below) for which the incident beam can propagate in the waveguide under the condition of total internal reflection (i.e., under condition that angle φ in Fig. 3 is greater than the critical angle of the total internal reflection). Assuming that the core A of the waveguide has a refractive index $n_1 = 1.51$ and the cladding B has a refractive index $n_2 = 1.49$, find the numerical aperture NA = $\sin \theta_{max}$ of the waveguide.

Fig. 3.



Fall 2011 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions

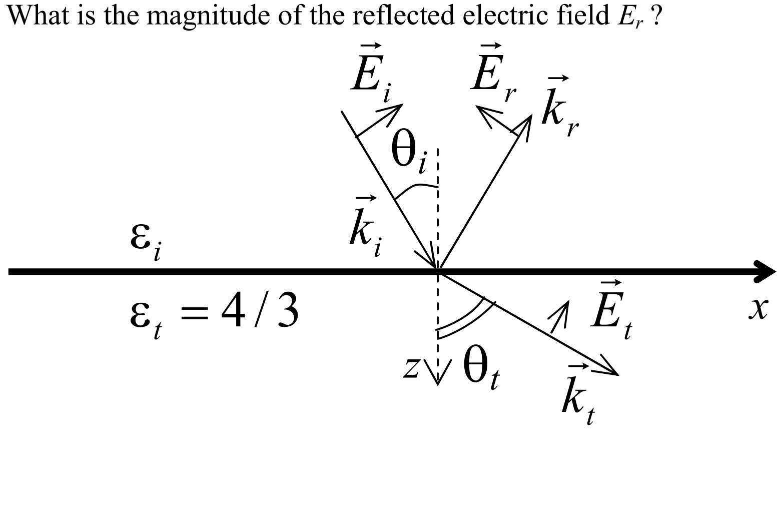
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. Yellow flame color of a birthday-cake candle originates from the D_2 fluorescence line of sodium, which consists of two spectral components centered at wavelength $\lambda_0 = 589$ nm and separated in frequency by 1.8 GHz ("hyperfine splitting"). A free-space (refractive index $n = 1$) Fabry-Perot etalon with two identical mirrors with reflectances $R = 99\%$ is used to study such sodium fluorescence light at normal incidence. The measurements show that, initially, the two spectral components of the D_2 line coincide with two consecutive etalon resonances.
   a. How large is the free spectral range of the Fabry-Perot etalon?
   b. What is the spacing d between the etalon mirrors?
   c. By what minimum distance should we move one of the etalon's mirrors in order to minimize the transmission of the fluorescence through the Fabry-Perot etalon?
   d. What is the ratio of the fluorescence power transmitted through the etalon initially to that transmitted after the adjustment of the mirror in part c?
   e. What is the finesse of the etalon?
   f. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?

2. Monochromatic plane wave falls at the plane interface between two dielectric media with permittivities ε_i and ε_t (see figure below). The magnitude of the vector of the incident electric field is

$$E_i = (6\,\text{V/m}) \times \cos[(10^7\ \text{m}^{-1})x + (\sqrt{300} \times 10^6\ \text{m}^{-1})z - (3\times 10^{15}\ \text{s}^{-1})t]\ .$$

   a. Write the magnitude of the incident wavevector k_i .
   b. Write the wavevector $\vec{k}_i$.
   c. What are the values of frequency ν (in Hz) and radian frequency ω (in rad/s) of the incident wave?
   d. What is the value of dielectric permittivity ε_i ?
   e. What are the magnitude and orientation of incident magnetic field vector $\vec{B}_i$?
   f. What are the values of incidence angle θ_i and transmission angle θ_t ?
   g. What is the magnitude of the reflected electric field E_r ?



3. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (e) below, the second polarizer has been set so that its transmission axis forms a +270º angle with that of the first polarizer. ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

   a. What is the intensity of light at the output of the second polarizer?

   b. A combination of two ideal quarter-wave plates is inserted between the two polarizers; the optical axes of the quarter-wave plates are parallel to each other and also parallel to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

   c. What will be the intensity at the output of the second polarizer in problem 3b after the two quarter-wave plates are rotated together so that their optical axes are still parallel to each other, but now form a +45° angle with the first polarizer?

   d. What will be the intensity at the output of the second polarizer in problem 3c if only the first quarter-wave plate is rotated so that its optical axis is at +45º with respect to the transmission axis of the first polarizer, whereas the second quarter-wave plate's optical axis remains parallel to the transmission axis of the first polarizer?

   e. In the setup of problem 3d, what would be the intensity at the output of the second polarizer if the first quarter-wave plate is rotated by additional +45º so that its optical axis is at +90º with respect to the transmission axis of the first polarizer, whereas the second quarter-wave plate's orientation remains parallel to the transmission axis of the first polarizer?

Spring 2011 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

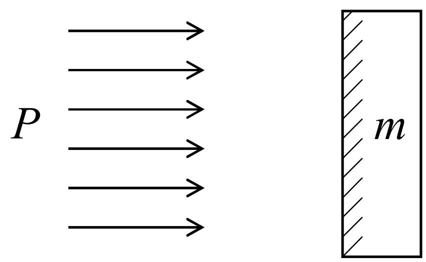
1. The D_2 absorption line of sodium vapor, commonly used in spectroscopy, consists of two spectral components centered at the wavelength $\lambda_0 = 589$ nm and separated in frequency by 1.8 GHz ("hyperfine splitting"). A free-space (refractive index $n = 1$) Fabry-Perot etalon with distance $d = 2$ cm between the etalon's mirrors is used to study the absorption spectrum of the sodium vapor. Initially, one of the two spectral components of the D_2 line coincides with one of the etalon's resonances.
    a. How large is the free spectral range of the Fabry-Perot etalon?
    b. By what minimum distance should we move one of the etalon's mirrors in order to tune the Fabry-Perot resonance so that it coincides with the other spectral component of the D_2 line instead?
2. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (e) below, the second polarizer has been set so that its transmission axis forms a +30º angle with that of the first polarizer. ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).
    a. What is the intensity of light at the output of the second polarizer?
    b. A combination of an ideal quarter-wave plate followed by an ideal half-wave plate is inserted between the two polarizers; the optical axis of the quarter-wave plate is parallel to the transmission axis of the first polarizer; the optical axis of the half-wave plate is at +60º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?
    c. What will be the intensity at the output of the second polarizer in problem 3b if the half-wave plate is removed from the setup while quarter-wave plate is left in place?
    d. What will be the intensity at the output of the second polarizer in problem 3b if the quarter-wave plate is set so that its optical axis is at +45º with respect to the transmission axis of the first polarizer?
    e. In the setup of problem 3b, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the half-wave plate if we want to obtain light intensity 0.25 I_0 at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)
3. A reconnaissance plane carries a 1920×1080 pixel camera looking straight down at the Earth from the cruising altitude of 12 km. The camera's detector array consists of 50×50 μm^2 square pixels completely filling the detector's sensitive area (i.e. there are no gaps between the neighboring pixels). The camera's objective is a single lens with focal length of 1 m.
    a. What is the total size of the area on the ground observed by the camera?
    b. What is the size of the area on the ground imaged onto a single pixel of the camera?

Fall 2010 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated laser beam of power $P = 10^6$ Watt illuminates a 100%-reflecting micromirror at normal incidence for duration of $\tau = 0.015$ seconds. Prior to laser illumination, the mirror is at rest. What is the mass of the mirror m if it acquires velocity of 1 m/s after laser illumination? (*Hint:* Use the conservation of momentum.)



2. A Fabry-Perot etalon with distance $d = 1$ cm between the etalon's mirrors is filled with air (refractive index $n = 1$). The m^{th} transmission resonance ($m >> 1$) of it corresponds to wavelength $\lambda = 800$ nm. By what fraction of the free spectral range will the frequency of the m^{th} resonance increase if the distance between the mirrors is shortened by $\Delta d = 200$ nm?

3. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes were set to be parallel, and the intensity of light after the two polarizers was measured to be I_0. Then, for the purpose of all the questions from (a) to (e) below, the second polarizer has been set so that its transmission axis currently forms a +60º angle with that of the first polarizer. ("+" sign here is just a convention for angle measured clockwise, looking in the direction of propagation).

   a. What is the intensity of light at the output of the second polarizer?

   b. A combination of an ideal quarter-wave plate followed by an ideal half-wave plate is inserted between the two polarizers; the optical axis of the quarter-wave plate is at +45° with respect to the transmission axis of the first polarizer; the optical axis of the half-wave plate is at +30º with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

   c. What will be the intensity at the output of the second polarizer in problem 3b if the half-wave plate is removed from the setup while quarter-wave plate is left in place?

   d. What will be the intensity at the output of the second polarizer in problem 3b if the quarter-wave plate is removed from the setup while half-wave plate is left in place?

   e. In the setup of problem 3d, at what angle (with respect to the transmission axis of the first polarizer) should we set the optical axis of the half-wave plate if we want to completely extinguish the light at the output of the second polarizer? (There are several possible angle values satisfying this condition; you need to give just one of them.)

SPRING 2010 Diagnostic exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. The m^{th} transmission resonance ($m >> 1$) of a Fabry-Perot etalon with free spectral range of $\Delta\nu_{FSR} = 1$ GHz is used as a tunable filter to study an optical spectrum from unknown source in the vicinity of wavelength $\lambda_0 = 500$ nm. The filter tuning is done by changing the distance d between the etalon's mirrors. Assuming that the etalon is filled with air (refractive index $n = 1$), what is the distance change Δd required to tune the filter by 100 MHz?

2. Monochromatic light is sent through two ideal linear polarizers. Initially, their transmission axes are parallel, and the intensity of light after the two polarizers is measured to be I_0. After that, the second polarizer is rotated so that its transmission axis becomes orthogonal to that of the first polarizer.

   a. What is the intensity of light at the output of the second polarizer?

   b. An ideal half-wave plate is inserted between the two polarizers; the optical axis of the half-wave plate is at 30° with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

   c. If, instead of the problem 2b, an ideal quarter-wave plate is inserted between the two polarizers; the optical axis of the quarter-wave plate is at 45° with respect to the transmission axis of the first polarizer. What is the intensity at the output of the second polarizer?

   d. What would be the intensity at the output of the second polarizer in problem 2c if the optical axis of the quarter-wave plate is set to be parallel to the transmission axis of the first polarizer?

3. A combination of two lenses, separated by the distance equal to the sum of their focal distances f_1 and f_2, is used to create a real image of a real object, and the object is located at a distance 40 cm from the first lens (i.e. from the lens with focal distance f_1). It is known that a) the object is located exactly half-way between the first lens and the intermediate image created by it; b) the final image created by this 2-lens combination is located at a distance $3f_2$ from the second lens.

   a. Find the focal distance of the first lens f_1.

   b. Find the focal distance f_2 of the second lens.

   c. Is the final image erect or inverted (with respect to the original object)?

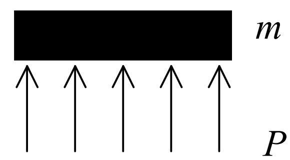
   d. Is the final image magnified or reduced (compared to the original object)? Find the transverse magnification (or reduction) factor.

FALL 2009 Diagnostic exam

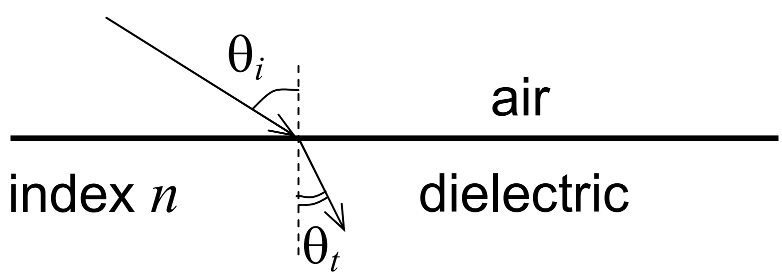
EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A laser beam of power P = 500 Watt is pointed vertically up to illuminate an object of mass m (see the figure below). Assuming that the beam is completely absorbed by the object, estimate the maximum mass of the object that the laser light pressure can keep from falling down on Earth. Acceleration due to gravity is $g = 9.8$ m/s^2.



2. Monochromatic plane wave falls from the air onto a flat interface with a dielectric medium of refractive index $n > 1$ (see the figure below). It is observed that for the case of the incidence angle θ_i equal to twice the transmission angle θ_t (i.e. $\theta_i = 2\theta_t$) the wave does not experience any reflection from the interface.
   a. What is the orientation of the incident electric field in this case? (In other words, is it in the plane of incidence or normal to the plane of incidence?)
   b. What are the values of θ_i and θ_t in this case?
   c. What is the value of the refractive index n ?



3. A combination of two identical positive lenses, each having a focal distance f = 20 cm, and separated by distance d = 110 cm from each other, is used to create an image of a real object located at a distance 25 cm in front of the first lens.
   a. Find the location of the image created by this 2-lens combination.
   b. Is the image real or virtual?
   c. Is the image erect or inverted (with respect to the original object)?
   d. Is the image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

   Drawing ray diagram is not required, but might be helpful in solving the problem.

SPRING 2009 Diagnostic Exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A Fabri-Perot etalon of length L = 0.5 cm is made of glass with refractive index n_f =1.5, and has two identical mirrors with reflectances R = 99%.
   a. How large is the free spectral range of this device?
   b. What is the ratio between maximum and minimum transmittance of the etalon (i.e. between transmittance of the resonant and non-resonant wavelengths)?
   c. What is the finesse of the etalon?
   d. How large is the full width at half-maximum $\Delta\nu_{FWHM}$ of the etalon's resonance?
2. Monochromatic light is sent through two ideal linear polarizers with transmission axes at α=60° with respect to each other. A half-wave plate is put between the polarizers. What should be the angle β between the optical axis of the plate and the transmission axis of the first polarizer in order to achieve maximum transmission through the three-piece system?
3. A combination of two lenses with focal distances f_1 = 20 cm and f_2 = –40 cm, separated by distance d = 80 cm, is used to create an image of a real object located at a distance 40 cm from the first lens (i.e. from the lens with focal distance f_1).
   a. Find the location of the image created by this 2-lens combination.
   b. Is this final image real or virtual?
   c. Is the final image erect or inverted (with respect to the original object)?
   d. Is the final image magnified or reduced (compared to the original object)? Find the magnification (or reduction) factor.

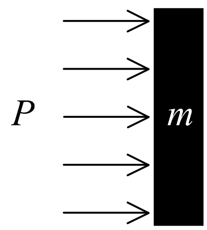
   Drawing ray diagram is not required, but might be helpful in solving the problem.

FALL 2008 Diagnostic Exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A collimated laser beam of power $P = 6\times10^{6}$ Watt illuminates a completely absorbing object of mass $m = 2\times10^{-6}$ kg for duration of $\tau = 2$ milliseconds. Prior to laser illumination, the object is at rest. Use the conservation of momentum to estimate the final velocity of the object after laser illumination.



2. Monochromatic light is sent through two ideal linear polarizers with transmission axes at α=90° with respect to each other (so-called crossed polarizers). A half-wave plate is put between the polarizers. What should be the angle β between the optical axis of the plate and the transmission axis of the first polarizer in order to achieve maximum transmission through the three-piece system?
3. A positive thin lens with focal distance of $f_1 = 4$ cm and a negative lens with focal distance of $f_2 = -12$ cm are in optical contact (i.e. there is no space between them). A real object located 3 cm away from the lenses is imaged through this 2-lens combination.
    a. Find the location of the image created by this 2-lens combination.
    b. Is the image real or virtual?
    c. Is the image erect or inverted?
    d. Is the image magnified or reduced? Find the magnification (or reduction) factor.

   Drawing ray diagram is not required, but might be helpful in solving the problem.

SPRING 2008 Diagnostic Exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have equal weight; solving 2 out of 3 constitutes 100%)

1. A positive lens with focal distance $f = 10$ cm is used to create an image of a real object located 5 cm away from it.
   a. Find the location of the image created by the lens.
   b. Is the image real or virtual?
   c. Is the image magnified or reduced? Find the magnification (or reduction) factor.

   Drawing ray diagram is not required, but might be helpful in solving the problem.

2. A Fabri-Perot etalon is made of glass with refractive index $n_f = 1.5$. It has finesse of 100 and the full width at half maximum of each resonance $\Delta\nu = 10$ MHz.
   a. How large is the free spectral range of this device?
   b. What is the length of the etalon?

3. A combination of two positive lenses with focal distances $f_1 = 10$ cm and $f_2 = 40$ cm, separated by distance $d = 100$ cm, is used to create an image of a real object located at a distance 20 cm away from the first lens (i.e. from the lens with focal distance f_1). Find the location of the image created by this 2-lens combination (ray diagram is not required).

SPRING 2007 Diagnostic Exam

EE5380 Principles of Photonics and Optical Engineering

Diagnostic exam questions
(all 3 problems have the same weight, solving 2 out of 3 constitutes 100%)

1. A negative lens with focal distance $f = -10$ cm is used to create an image of a real object located 30 cm away from it.
   a. Find the location of the image created by the lens.
   b. Is the image real or virtual?
   c. Is the image magnified or reduced?

   Drawing ray diagram is not required, but might be helpful in solving the problem.
2. A Fabri-Perot etalon of length $l = 1$ cm is made of glass with refractive index $n_f = 1.5$.
   a. How large is the free spectral range of this device?
   b. Estimate its finesse if both etalon mirrors have reflectance $R = 98\%$.
3. A positive thin lens with focal distance of $f_1 = 20$ cm and a negative lens with focal distance of $f_2 = -60$ cm are in optical contact (i.e. there is no space between them). A real object located $L_O = 45$ cm away from the lenses is imaged through this 2-lens combination (see figure below). Find the location of the image created by this 2-lens combination (ray diagram is not required).