

## REVIEW QUESTIONS

### IMPORTANT NOTES

- The following questions are based on actual examination papers.
- Most of them are examples of *one* type of question that will appear on your examination paper: quantitative questions involving assessment of a given situation, selection of appropriate relations (formulas), explanations and arithmetic.
- Some questions are more qualitative. A presentation of memorised slabs of the notes is invariably an unsatisfactory answer to such questions.
- Note that *both* styles of questions, *in roughly equal number*, will appear on your exam paper.
- Explanations of answers in terms of concepts and principles of physics are always required.

1 a) For each of the following three light sources

- i) a heated-filament light globe,
- ii) a low-pressure-discharge tube and
- iii) a helium-neon laser,

sketch the spectral distribution of intensity of the emitted light.

b) Define and explain what is meant by coherent and incoherent light sources.

**[7 minutes]**

2 Light with a wavelength of 639 nm in vacuum passes from air to water which has a refractive index of 1.30.

- i) What is the wavelength of the light in water?
- ii) What is the speed of the light in water?
- iii) What is the frequency of the light in water?

**[6 minutes]**

3 a) A small source is emitting light at a rate of 100 watts. Calculate the irradiance at a distance of 7.0 m from the source. Assume that the source radiates uniformly in all directions.

b) Describe what is meant by the terms -

- i) line spectrum,
- ii) continuous spectrum.

Sketch examples of graphs of irradiance against wavelength for these two cases.

**[8 minutes]**

4 The range of wavelengths for visible light is 400 nm to 700 nm.

- a) Calculate the range of frequencies.
- b) Name the colour corresponding to 700 nm.

**[6 minutes]**

5 Calculate the critical angle for light passing from glass of refractive index 1.45 to air.

**[4 minutes]**

6 Draw a labelled diagram showing the arrangement of the principal components of a compound microscope. There is no need to include the system used to illuminate the specimen. Add a cross-sectional sketch of an eye which is viewing the final image and a set of rays going from a point on the specimen to the corresponding final image point on the retina of the eye.

**[12 minutes]**

7 A converging lens has a focal length of 0.30 m. The refractive index of the glass of the lens is 1.42. A small object is placed on the principal axis of the lens, a distance 0.50 m from the lens.

- a) Calculate the position of the image.
- b) Draw a standard ray-tracing diagram to roughly confirm this position.
- c) Is the image real or virtual? Is it upright or inverted?
- d) Calculate the magnification of the image.

**[10 minutes]**

- 
- 8** Consider the following argument: "the quality of the image formed by an optical instrument is limited at large apertures by aberration effects and at small aperture by diffraction effects."  
Is the statement true or false? Explain and discuss.  
**[7 minutes]**
- 
- 9** a) A monochromatic light-source produces light of frequency  $5.00 \times 10^{14}$  Hz. Light from this source enters glass of refractive index 1.52.  
Determine the speed, the wavelength and the frequency of the light in the glass.  
b) Sketch a diagram showing a beam of light from the source crossing the glass surface from air. The angle of incidence of the light is about  $45^\circ$ .  
c) Indicate by a diagram how it is possible to trap a beam of light in a curved glass fibre so that it does not emerge from the sides of the fibre.  
d) Explain how the critical angle of the glass is important in this trapping process.  
**[8 minutes]**
- 
- 10** a) Light of wavelength 550 nm from a distant point source is focussed by a lens of diameter 80 mm and focal length 200 mm. Calculate the diameter of the central part of the diffraction pattern formed in the focal plane of the lens.  
b) Describe how this diffraction (or spreading) of light sets a limit to the amount of detail that can be seen in an image.  
c) What is the implication of this in respect of the useful magnification of microscopes?  
**[8 minutes]**
- 
- 11** An oil drop floats on a water surface. The refractive index of the oil is 1.20 and that of the water is 1.33. The oil is observed from above by reflected light.  
a) Will a bright or a dark region be observed at the outer (thinnest) parts of the drop? Explain.  
b) Suppose that the reflected light is monochromatic with wavelength 450 nm. Approximately how thick is the oil film at the place where the observer notes the third bright region from the edge of the drop?  
c) Suppose that the incident light is white light. Why do the colours gradually disappear as the thickness of the oil becomes larger?  
**[8 minutes]**
- 
- 12** A camera has an achromatic doublet lens consisting of two thin lenses, one converging and the other diverging, cemented together. The focal length of the combination is 120 mm; the focal length of the converging component is 45 mm.  
a) What is the purpose of such a doublet?  
b) The camera is accurately focussed on an object 1.25 m from the doublet lens. What is the distance from the lens to the film?  
c) Calculate the focal length of the diverging component.  
**[8 minutes]**
- 
- 13** a) Sketch a ray of light travelling from air to glass at any angle of incidence other than zero.  
b) Sketch a ray of light travelling from glass to air at an angle of incidence other than zero but less than the critical angle.  
c) If the refractive index of glass is equal to 1.5, calculate the value of the critical angle.  
**(6 minutes)**
- 
- 14** a) What is the power of a diverging lens of focal length 200 mm?  
If this lens is placed adjacent to a converging lens of focal length 100 mm, what is the focal length of the combination?  
b) An illuminated object 5.0 mm in length gives a real image 50.00 mm in length on a screen placed 200 mm from a lens. Calculate the focal length of the lens.  
**(12 minutes)**
- 
- 15** A glass converging lens has a focal length of 0.25 m. The refractive index of the glass is 1.40. A small object is located on the axis of the lens 0.40 m from the lens.  
a) Use the lens formula to calculate the position of the image.  
b) Is the image virtual or real? Justify your answer.  
c) Calculate the magnification of the image.  
**(8 minutes)**
-

**16** Consider a converging lens.

Draw ray diagrams for the formation of an image for

- i) an object distance equal to half the focal length and
- ii) an object distance equal to three times the focal length.

From the diagrams describe the nature of the image in terms of real/virtual, erect/inverted, diminished/magnified.

[12 minutes]

**17** i) In a slide projector the distance from the slide holder to the lens is 0.15 m. What is the focal length of the lens if the image is formed on a screen 5.0 m away?

ii) The lens originally fitted to the projector had a power of  $4.0 \text{ m}^{-1}$ . What is the power of a second lens placed in contact with the original lens, which will make the projector suitable for use with the screen distance of 5.0 m?

iii) If the object (slide) is 35 mm high how high is the image on the screen?

[11 minutes]

**18** A biconvex lens has a focal length of 0.40 m. The refractive index of the glass is 1.50. An object is located 0.60 m from the lens.

Determine

- i) the position of the image;
- ii) the nature (real or virtual) of that image,
- iii) the magnification.

[7 minutes]

**19** A plano-convex lens has a radius of curvature for its curved face of 20 mm. It is made of glass of refractive index 1.5.

a) Use the lens-maker's formula

$$\frac{1}{f} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

to calculate the power of the lens.

- b) Is the lens a converging or diverging lens? Justify your answer.
- c) Explain why this lens would be expected to exhibit both

- i) spherical aberration
- and ii) chromatic aberration.

[10 minutes]

**20** The refractive index of a lens material is 1.50 for red light and 1.51 for blue light.

- i) If the focal length of a convex lens made from this material is 0.100 m for red light, what is it for blue light?
- ii) What would the image of a distant white-light point source look like?

[5 minutes]

**21** A lens is to be given a thin coating of material of refractive index 1.3 in order to reduce the reflection of light with a wavelength of 600 nm.

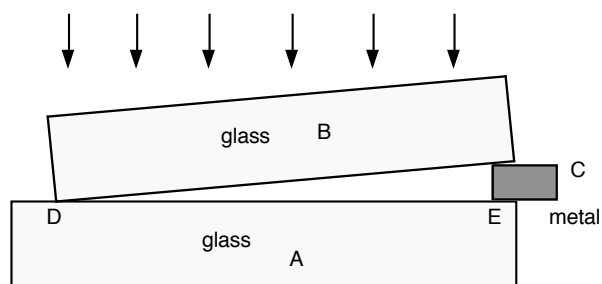
What is the minimum thickness of the coating?

[6 minutes]

**22** Explain why the lens of a good quality camera appears slightly coloured when viewed in reflected daylight.

[4 minutes]

23



As shown in the figure optically-flat slabs of glass A, B are separated at one end by a metal strip, C. When light with a wavelength of 400 nm is shone perpendicularly on the slabs, 150 bright interference fringes appear between the points D and E shown in the figure.

What is the thickness of the metal strip?

[4 minutes]

24 A 100 nm thick film of oil (refractive index 1.43) on water (refractive index 1.33) is illuminated with white light in the direction perpendicular to the film.

What visible wavelengths will be strongly reflected?

[5 minutes]

25 Interference fringes are observed on a screen 3.0 m away from two parallel slit sources which are separated by a distance of  $6.0 \times 10^{-5}$  m. Calculate the distance between adjacent maxima on the screen if the slits are illuminated with light of wavelength 500 nm.

[5 minutes]

26 a) What is the necessary condition on the path length difference between two waves from two coherent in-phase sources that interfere

i) to give a maximum in intensity,

and ii) to give a minimum in intensity?

b) The slits in a Young's twin slit apparatus are illuminated with monochromatic light. The third dark band in the interference pattern on the screen is 9.5 mm from the central maximum. The two slits are 0.15 mm apart and the screen is 0.90 m away from the slits.

Calculate the wavelength of the light used.

[7 minutes]

27 A wire frame is dipped into soapy water, taken out and held vertically. The soap film in this position is viewed by the reflection of white light from it. Colours are observed in the film. As the water drains away from the top of the film, the colours there disappear.

Explain

i) the origin of the colours and

ii) the reason they disappeared at the top of the film.

[7 minutes]

28 i) What is a diffraction grating?

ii) Explain, using a diagram, how such a device produces a spectrum.

iii) How can a diffraction grating be used to measure the wavelength of a spectral line?

iv) What advantages does a grating have over a prism?

[10 minutes]

29 The surface of an opal consists of rows of reflectors that act as a reflection grating. The rows are  $8 \mu\text{m}$  apart and are illuminated normally (perpendicularly) with white light.

i) At what angle will red light be seen?

ii) At what angle will blue light be seen?

[6 minutes]

30 a) Sketch a graph of light irradiance as a function of position on a screen illuminated by coherent light from two very narrow slits.

b) Sketch a similar graph for the situation where the slits are wider (about one-quarter the spacing between the slits).

c) The very narrow slits are 0.40 mm apart, the distance of the slits from the screen is 1.5 m and the wavelength of the light used is 500 nm. What is the distance on the screen between adjacent fringes?

[9 minutes]

- 31 a) Write down an expression for the distance between *adjacent* bright fringes in a *two-slit* interference pattern displayed on a screen. Define the symbols you use.
- b) How does the pattern change if
- the slits are illuminated first by a monochromatic red light source, and then by a monochromatic blue light source,
  - the slits are brought closer together?
- c) Describe the effect of widening the slits.

---

[8 minutes]

- 32 The distance between the centres of two small red warning lights on a machine is 10.0 mm. Assume that the lights are point sources and that the resolution is limited by diffraction only.

Determine the maximum distance an operator can be from the machine and resolve these lights.

---

[6 minutes]

- 33 The headlights of a truck are 1.5 m apart. At approximately what maximum distance will the human eye just distinguish the two lights. Take the diameter of the eye pupil to be  $4.0 \times 10^{-3}$  m.

---

[6 minutes]

- 34 a) What is the difference between the electric field of a plane polarised light wave and that of a circularly polarised light wave?
- b) Suppose that you were given a sheet of transparent plastic, which is said to be a piece of Polaroid. Describe a simple test to discover whether it is a plane polariser.
- c) Suppose that you were given three light sources, one of which is circularly polarised, one plane polarised and the third unpolarised, but you do not know which is which.

Could you use a Polaroid sheet alone to distinguish each of the sources? Explain.

---

[8 minutes]

- 35 a) Describe the change in the width of the central maximum of a single-slit diffraction pattern as the width of the slit is made smaller.
- b) State and explain the Rayleigh criterion for the resolution of two point sources.
- c) A radar installation operates at a frequency of 9 GHz and uses an antenna with a diameter of 15 m. Two objects are 150 m apart.

At what distance from the antenna would they be at the limit of resolution.

---

[10 minutes]

- 36 a) What is an electromagnetic wave?
- b) What is a plane polarised electromagnetic wave?
- c) What is a circularly polarised electromagnetic wave?
- d) What is a birefringent material?
- e) A piece of material acts as a quarter-wave plate when polarised light of wavelength 600 nm falls normally on it. In this situation the refractive indices for the ordinary and the extraordinary waves are 1.443 and 1.458 respectively.

What is the thickness of this quarter-wave plate?

---

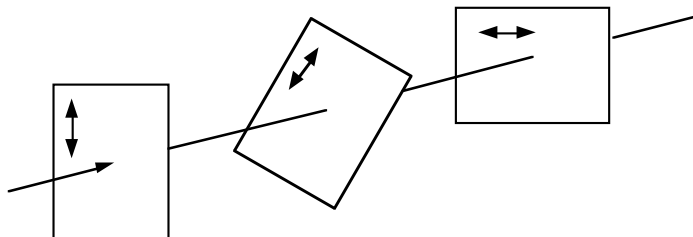
[12 minutes]

- 37 Explain how
- dichroic materials and
  - birefringent materials
- affect the transmission of light as far as the polarisation of the light is concerned.

---

[7 minutes]

38



Unpolarised light of irradiance  $I_0$  is passed through three consecutive plane polarisers whose polarising axes are vertical,  $45^\circ$  to the vertical and horizontal respectively.

What are

- the plane of polarisation of the emergent light and
- its irradiance?

[6 minutes]

39 a) If a piece of transparent sticky tape is placed between two crossed polarisers, the taped area will transmit more light than the non-taped area of the crossed polarisers. Explain.

- Light is reflected from smooth ice (refractive index 1.31) and the reflected ray is completely polarized. What was the angle of incidence of the light?

[6 minutes]

40 Suppose you are given two light sources, one of which is said to be plane polarised, and two similar sheets of transparent plastic, one of which is said to be a piece of Polaroid.

- Describe how you would identify which lamp is polarised, and which sheet is the Polaroid.
- How could you test the plastic sheets without the lamps?

[8 minutes]

41 Illustrate, using a diagram, how the sun's light becomes partly polarized on reflection from the surface of a lake.

What should be the orientation of a Polaroid material in order to protect the eye from the glare of the reflected light? Explain your answer.

[4 minutes]

42 A beam of circularly polarised light of irradiance  $I_0$  passes through a sheet of Polaroid. What are the changes in

- the irradiance,
- the polarisation of the transmitted beam?

[4 minutes]

43 a) Sketch the diffraction pattern obtained when monochromatic light passes through a very small circular aperture and falls on a screen.

- Suppose the wavelength of the light is 500 nm and the diameter of the aperture is 0.05 mm.

Calculate the diameter of the central maximum on a screen placed 2.0 m away from the aperture.

[6 minutes]

44 a) A camera lens is set to  $f/16$ . What does that mean?

- Given that the amount of light falling on a film inside a camera is proportional to the area of the lens aperture, calculate the ratio, new image brightness to original image brightness, for a change in the camera setting from  $f/16$  to  $f/4$ .

[6 minutes]

45 a) Explain the term: *resolving power* of an optical component.

- Calculate the diameter of the central part of the diffraction pattern formed on the retina of the eye when viewing a distant point source of light of wavelength 500 nm.

Focal length of the eye = 20 mm.

Pupil diameter = 5 mm.

[7 minutes]

- 
- 46** A camera lens has a focal length of 50 mm and a maximum useable diameter of 18 mm.
- Express the aperture in the conventional manner.
  - If the aperture is reduced how does the brightness of the image change? Why?
- [6 minutes]**
- 
- 47** Draw a carefully labelled diagram to illustrate image formation in a compound microscope.
- Your diagram should include the lenses, the specimen, the paths of rays from one off-axis point on the specimen, and the location of the image produced by the microscope.
- [8 minutes]**
- 
- 48** The designer of a camera decides to use a single objective whose focal length is 50 mm. How far must this lens be able to move in its mounting if the camera is to focus selectively on objects whose distance from the lens range from 150 mm to infinity?
- [8 minutes]**
- 
- 49** The camera and the eye have different methods of focussing on an object. Describe both methods.
- [6 minutes]**
- 
- 50** A camera has an achromatic doublet lens consisting of two thin lenses, one converging and one diverging, cemented together. The focal length of the combination is 100.0 mm.
- Given that the focal length of the converging component of the doublet is 43.0 mm, calculate the focal length of the other component.
  - Calculate the diameter of the stop when the aperture (for the doublet) is set at  $f/8$ .
  - The camera is accurately focussed on an object 1.10 m from the doublet lens. What is the distance from the lens to the film?
- [10 minutes]**
- 
- 51**
- Show, by reference to a suitable diagram, how a simple magnifier functions.
  - Determine the focal length of such a magnifier labelled ' $\times 5$ '. Take the least distance of distinct vision to be 0.25 m.
  - Calculate where you would place the object relative to this simple magnifier to obtain a magnification of  $6\times$ .
- [10 minutes]**
- 
- 52** Deleted.
- 
- 53**
- Draw a diagram showing the viewing, with relaxed eye, of an object through a simple magnifier.
  - What is the angular size of an object 4 mm high held at a distance 0.25 m from the eye?
  - What is the apparent angular size of the same object viewed through a simple magnifier of focal length 0.050 m? The object is placed in the focal plane of the lens.
- [8 minutes]**
- 
- 54**
- Draw a ray diagram showing a relaxed eye viewing an image through a simple magnifier.
  - What is the apparent angular size of a 2.0 mm high object when it is so viewed through a  $8\times$  magnifier?
- [8 minutes]**
- 
- 55** Draw a diagram showing the viewing with relaxed eye of an image through a simple magnifier.
- What is the apparent angular size of a 5 mm object when it is so viewed through a simple magnifier whose focal length is 20 mm?
- [8 minutes]**
- 
- 56**
- Draw a diagram showing the viewing with relaxed eye of an object through a simple magnifier.
  - The desired overall magnification of a compound microscope is  $140\times$ . The objective alone produces a lateral magnification of  $12\times$ . Determine the required focal length for the eyepiece lens. (Assume that the final image is viewed with relaxed eye.)
- [8 minutes]**
- 
- 57**
- Explain with the aid of a diagram how the eyepiece of a compound microscope is used to magnify the image produced by the objective lens.
  - The lateral magnification produced by the objective lens in a compound microscope is 15. A simple eyepiece of focal length 50 mm is used.
    - What is the angular magnification of the eyepiece?
    - What is the total angular magnification of the microscope?
- [8 minutes]**
-

- 58** Suppose that a beam of light is passed through a sheet of Polaroid.
- The incident light is *circularly* polarised. Describe how the irradiance (intensity) and the polarisation of the emerging beam depend on the orientation of the sheet.
  - Describe how the irradiance (intensity) and the polarisation of the emerging beam depend on the orientation of the sheet if the incident beam is *plane* polarised.

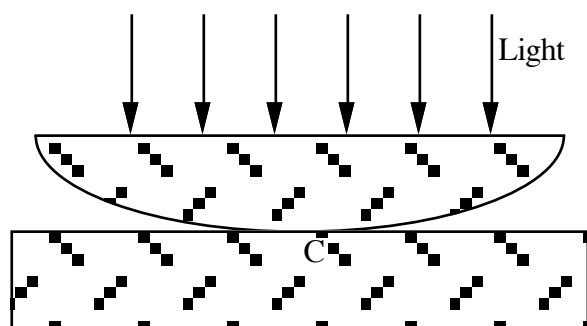
(8 minutes)

- 59 a)** A monochromatic light-source produces light of wavelength 525 nm in vacuum. Light from this source enters glass of refractive index 1.54.
- Determine the speed, the wavelength and the frequency of light in the glass.
  - Sketch a diagram showing a ray of light from the source crossing the glass surface from air. The angle of incidence of the light is about  $15^\circ$ .
- b)** Indicate by a diagram how it is possible to trap a beam of light in a solid, curved, glass rod so that it does not emerge from the sides of the rod.

[Speed of light :  $3.0 \times 10^8 \text{ m.s}^{-1}$ .]

(8 minutes)

- 60 a)** A very thin soap film appears uniformly black when illuminated with white light. Explain briefly.
- b)** Reflections from thin oil films are brightly coloured while reflections from thick films are not. Explain briefly.
- c)** A glass lens rests on a flat plate of glass and is illuminated from above. The point of contact between the two pieces of glass is marked C in the diagram.



When looking from above does one observe a bright or dark spot at C? Explain briefly.

- d)** Some lenses used in cameras appear slightly purple when illuminated by white light. Explain briefly.

(8 minutes)