UNIT 10

Refraction of Light

INTRODUCTION

When a ray of light travels from one medium to another, it undergoes a change in its direction. When a ray of light goes from an optically less dense medium to a more dense medium, it bends towards the normal. On the other hand, a ray of light going from an optically more dense medium to a less dense medium, will bend away from the normal.

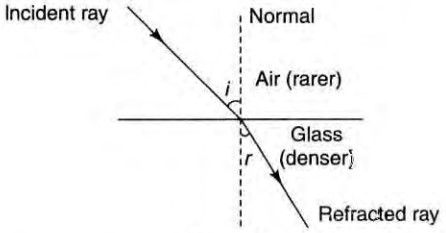


Fig. 10.1

The bending of a ray of light on passing from one medium to another is called refraction.

The rays of light while going from air (rarer) to glass (denser) will bend towards the normal. The rays of light while going from denser to rarer, say from glass or water to air, will bend away from the normal.

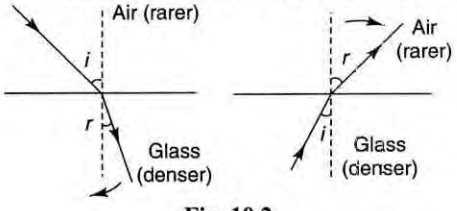


Fig. 10.2

There are two laws of refraction:

(i) The ratio of the sine of the angle of incidence to the sine of the angle of refraction for a given pair of media is constant i.e.

$$\frac{\sin i}{\sin r} = \text{constant}$$

where i and r stand for angle of incidence and angle of refraction respectively. This constant is called the refractive index of the medium and is denoted by μ.

$\therefore \quad \mu = \dfrac{\sin i}{\sin r}$ and this relation is called Snell's law.

(ii) The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.

It must be kept in mind that the angle of reflection is not same as the angle of refraction.

(i) Whereas angle of incidence is always equal to angle of reflection, the angle of incidence is not equal to angle of refraction. The graph between angle of incidence (i) and angle of reflection (r) is a straight line passing through the origin.

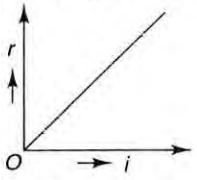


Fig. 10.3

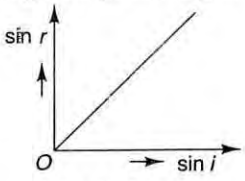


Fig. 10.4

(ii) Taking Snell's law into account, a graph between sin i and sin r is also a straight line, where i and r are angles of incidence and refraction respectively.

Total Internal Reflection

It is not a regular reflection. When a ray of light is proceeding from a denser to a rarer medium at an angle of incidence greater than the critical angle (c), it does not get transmitted rather it gets totally internally reflected at the surface separating the two media.

$$\sin c = \frac{1}{\mu},$$

where μ is refractive index of denser medium with respect to rarer medium.

Refractive Index

A ray of light while travelling from one medium to another suffers refraction. If i is the angle of incidence in medium a and r the angle of the refraction in the medium b, then $^{a}\mu_{b} = \dfrac{\sin i}{\sin r}$

where $^{a}\mu_{b}$ is the refractive index of the medium b with respect to the medium a.

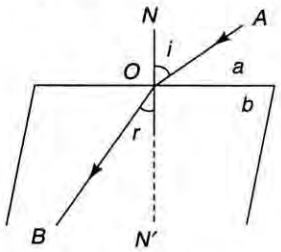


Fig. 10.5

- If c is velocity of light in air or vacuum and v that in the medium, then

$$\mu = \frac{\text{Velocity of light in vacuum or air}}{\text{Velocity of light in the medium}} = \frac{c}{v}$$

The refractive index of a medium c with respect to a medium a, when the refractive index of medium b with respect to a and that of c with respect to b are given, can be found by the following relation:

$$^{a}\mu_{c} = {}^{a}\mu_{b} \times {}^{b}\mu_{c}$$

$^{b}{}_{a}$ is the retractive index of the medium a with respect to the medium b.

When light travels from vacuum into medium, the refractive index is absolute refractive index (for air it is one).

Principle of Reversibility

$$^{a}\mu_{\omega} = \frac{1}{{}^{\omega}\mu_{a}}$$

and $$^{g}\mu_{\omega} = \frac{^{a}\mu_{\omega}}{^{a}\mu_{g}}$$

Critical Angle (c)

It is the angle of incidence in a denser medium corresponding to which the refracted ray just grazes the surface of separation (angle of refraction is 90°).

$$^{\text{denser}}\mu_{\text{rarer}} = \frac{\sin c}{\sin \pi/2} = \sin c \quad \text{or} \quad \mu = \frac{1}{\sin c}$$

- Apparent depth of the bottom of a water-filled bucket is given by,

$$\text{Refractive index of water} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

- A lens is a piece of transparent glass which is bounded by two spherical surfaces. A convex lens is thick at the centre but thinner at the edges.
- The lens formula or lens equation is given by

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

where the symbols have their usual meanings. It must be noted that the mirror formula is

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

- The power of a lens may be defined as the reciprocal of its focal length in metres.

Power of a lens

$$(P) = \frac{1}{\text{focal length of the lens}\,(f)\text{ in metres}}$$

or $$P = \frac{1}{f} = \frac{100}{f \text{ in cm}}$$

The power of a lens is inversely proportional to its focal length, hence the lens of short focal length has more power and the lens of long focal length has less power.

- The SI unit of power of a lens is dioptre. It is denoted by D. One dioptre is the power of a lens whose focal length is 1 metre. A convex lens has a

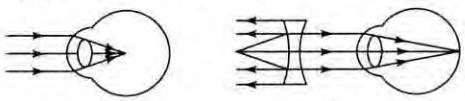
positive focal length, hence its power is also positive ($+D$). A concave lens has a negative focal length, hence its power is also negative ($-D$).

- The phenomenon of the splitting of white light into seven constitutent colours is known as dispersion of white light. The band of seven colours obtained on a screen due to the dispersion of white light is known as the spectrum of white light. These seven colours seen on the screen are violet, indigo, blue, green, yellow, orange and red. It can be remembered as VIBGYOR.

MULTIPLE CHOICE QUESTIONS

Tick (✓) the correct choice amongst the following:

1. During the 19th century, light was considered to be a stream of particles called
   (a) atoms (b) electrons
   (c) corpuscles (d) quantas
2. Who amongst the following used corpuscular theory to explain reflection and refraction of light?
   (a) Newton (b) Maxwell
   (c) Young (d) Hertz
3. Who amongst the following used corpuscular theory to explain the radiations emitted by hot objects?
   (a) Max Planck (b) Newton
   (c) Young (d) Einstein
4. The wave-like character was experimentally proved for light by
   (a) Newton (b) Young
   (c) Maxwell (d) none of these
5. Albert Einstein used corpuscular theory to explain
   (a) $E = mc^2$
   (b) photoelectric effect
   (c) quantisation of charge
   (d) none of these
6. Who first proposed that light was wave-like in character?
   (a) Huygens (b) Newton
   (c) Young (d) Maxwell
7. Light is a form of _____ that we can detect with our _____.
   (a) energy, ears (b) corpuscles, eyes
   (c) energy, eyes (d) sensation, skin
8. The unit of power of a lens is
   (a) metre (b) dyne
   (c) dioptre (d) none of these
9. The least distance of distinct vision for a normal person is about
   (a) 1 m (b) 0.5 m
   (c) 0.25 m (d) none of these
10. The focal length of a lens is 50 cm. Its power would be
    (a) 50 dioptres (b) 2 dioptres
    (c) 20 dioptres (d) none of these
11. The unit of refractive index is
    (a) metre (b) degree
    (c) dioptre (d) it has no units
12. A simple magnifying glass consists of a
    (a) concave lens
    (b) convex lens of large focal length
    (c) convex lens of small focal length
    (d) plane mirror only
13. How should people wearing spectacles work with a microscope?
    (a) they should keep on wearing their spectacles.
    (b) they should never use the microscope.
    (c) they should take off their spectacles.
    (d) they may either put on their spectacles or they may take off their spectacles.
14. Figures 10.6 (a), (b), (c), and (d) respectively correspond to
    (a) the short-sighted eye, the correction of long-sight, the long-sighted eye and the correction of short-sight
    (b) the short-sighted eye, the correction of short-sight, the long-sighted eye and the correction of long-sight
    (c) the long-sighted eye, correction of short-sight, the short-sighted eye and the correction of long-sight
    (d) none of these



(a) (b)

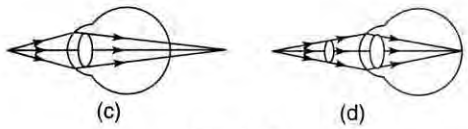


Fig. 10.6

15. The screen behind the eye lens is called the
    (a) iris (b) ciliary muscle
    (c) retina (d) pupil
16. Cornea is a transparent spherical structure which
    (a) reflects light (b) scatters light
    (c) refracts light (d) none of these
17. The image on the retina remains for
    (a) 20 s (b) 10 s
    (c) $\frac{1}{10}$ s (d) $\frac{1}{16}$ s
18. The middle vascular coat that darkens the eye chamber and prevents refraction by absorbing the light rays is
    (a) choroid (b) sclera
    (c) retina (d) cornea
19. The amount of light entering the eye is controlled by the
    (a) iris (b) cornea
    (c) pupil (d) crystalline lens
20. Figures 10.7 (a), (b), and (c) respectively, indicate the point of focus in case of

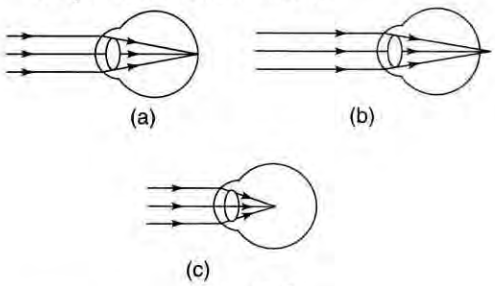


Fig. 10.7

    (a) the normal eye, the hypermetropic eye and myopic eye
    (b) the hypermetropic eye, the myopic eye and the normal eye
    (c) the normal eye, the myopic eye and the hypermetropic eye
    (d) the myopic eye, the normal eye and the hypermetropic eye
21. The eye lens is a
    (a) transparent double-convex lens
    (b) transparent double-concave lens
    (c) transparent concavo-convex lens
    (d) none of these
22. The eye lens contains a watery liquid called the
    (a) aqueous humour (b) peroxide
    (c) vitreous humour (d) none of these
23. Long-sightedness is caused by the eyeball being too short. It can be corrected by the use of a
    (a) convergent lens (b) plane mirror
    (c) divergent lens (d) none of these
24. Astigmatism occurs when the cornea does not have a truly spherical shape. This defect can be cured by the use of a
    (a) concave lens (b) cylindrical lens
    (c) convex lens (d) plano-convex lens
25. The power of a lens being + 4 dioptres suggests that it is a
    (a) convex lens (b) plano-convex lens
    (c) concave lens (d) none of these
26. When an object moves towards a convex lens, the size of the image
    (a) decreases
    (b) increases
    (c) first decreases then increases
    (d) remains the same
27. When an object approaches a convex lens from infinity, the image formed by it shifts
    (a) away from the lens
    (b) towards the lens
    (c) first away and then towards the lens
    (d) none of these
28. The amount of light entering in the eye is controlled by the
    (a) pupil (b) iris
    (c) cornea (d) eye lens
29. If the power of a lens is 0.1 D, its focal length is
    (a) 1 m (b) 10 m
    (c) 100 m (d) –10 m
30. The refraction of light is commonly known as
    (a) bending (b) scattering
    (c) reflection (d) interference

31. When a ray of light passes from an optically less dense medium to a more dense medium, it
    (a) goes undeviated
    (b) bends towards the normal
    (c) bends away from the normal
    (d) none of these
32. When a ray of light passes from an optically more dense medium to a less dense medium, it
    (a) goes undeviated
    (b) bends towards the normal
    (c) bends away from the normal
    (d) none of these
33. Which of the following shows the bending of light from rarer (R) into denser (D) medium?

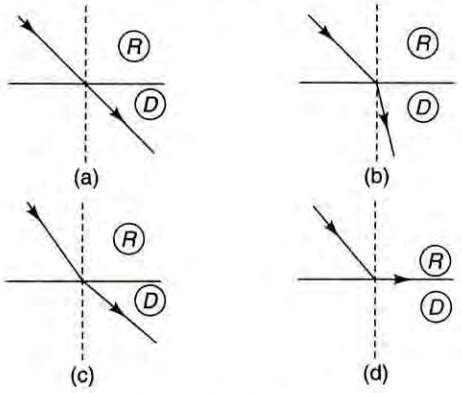


Fig. 10.8

34. Which of the following shows the bending of light from denser (D) medium into a rarer (R) medium?

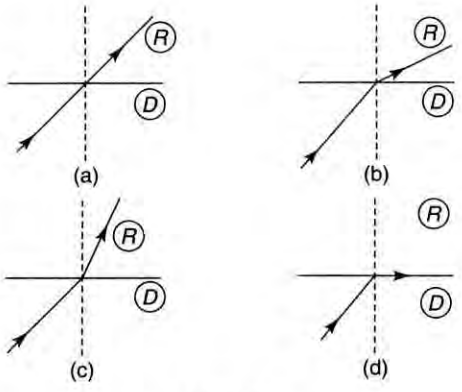


Fig. 10.9

35. The cells in the retina that are able to distinguish between different colours are
    (a) rod shaped (b) cone-shaped
    (c) cuboid shaped (d) long and flat
36. How will the image formed by a convex lens be affected if the upper half of the lens is wrapped with a black paper?

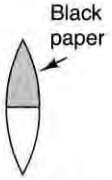


Fig. 10.10

    (a) the size of the image is reduced to one-half.
    (b) the upper half of the image will be absent.
    (c) the brightness of the image is reduced.
    (d) there will be no effect.
37. A green leaf placed in a dark room is illuminated by red light. The leaf will appear to be
    (a) green (b) red
    (c) yellow (d) black
38. An object looks red when seen through a piece of red glass. What is the actual colour of the object?
    (a) Red only (b) White only
    (c) Red or green (d) Black
39. The mirror formula is given by

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

where the symbols have their usual meanings. Then the lens formula is given by

    (a) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ (b) $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$
    (c) $\frac{1}{v}+\frac{1}{u}=-\frac{1}{f}$ (d) none of these

40. A convex lens is also called a
    (a) diverging lens (b) converging lens
    (c) cylindrical lens (d) none of these
41. A lens is called a thin lens if its overall thickness is
    (a) small (b) large
    (c) infinitely large (d) none of these

42. In optical instruments, the lenses are used to form images by
(a) reflection (b) refraction
(c) dispersion (d) scattering

43. A lens which is thicker in the middle and thinner at the edges is called a _____ lens.
(a) convex (b) concave
(c) cylindrical (d) none of these

44. A lens which is thinner at the middle and thicker at the edges is called a _____ lens.
(a) convex (b) concave
(c) cylindrical (d) none of these

45. The principal axis is also called _____ of the lens.
(a) optical axis (b) x-axis
(c) y-axis (d) axis

46. The power of a lens can't be measured in
(a) m (b) W
(c) h.p. (d) all the above

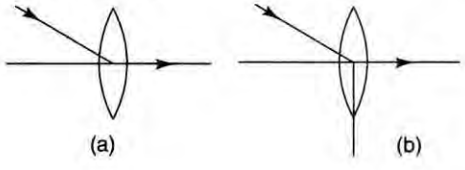
47. 1 D is equal to
(a) 1 m (b) 1 cm
(c) 1 m^{-1} (d) 1 cm^{-1}

48. If f is focal length of the lens, then the power of a lens is equal to
(a) $\frac{100}{f(\text{cm})}$ (b) $\frac{10}{f(\text{cm})}$
(c) $\frac{100}{f(\text{m})}$ (d) $\frac{1}{100f(\text{cm})}$

49. Which of the following term is not associated with a lens?
(a) aperture (b) focal length
(c) principal focus (d) efficiency

50. To construct a ray diagram, you need at least _____ whose path(s) after refraction through the lens are known.
(a) one ray (b) two rays
(c) three rays (d) none of these

51. Which of the following diagrams correctly represents the ray of light passing through the optical centre?



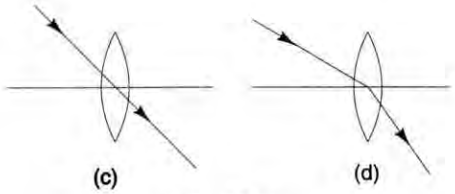


Fig. 10.11

52. A ray of light coming parallel to the principal axis after passing through a convex lens, passes through its
(a) optical centre
(b) focus
(c) centre of curvature
(d) none of these

53. The focal length can be expressed in
(a) metre (b) dioptre
(c) watt (d) horse power

54. Which of the following diagrams correctly represents the passage of a ray of light through a concave lens?

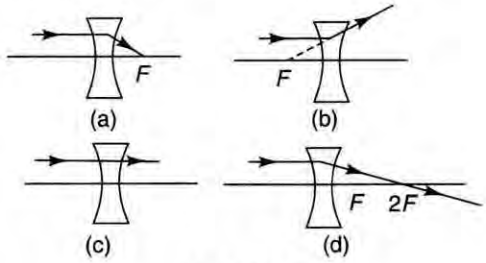


Fig. 10.12

55. Where should an object be placed so that a real and inverted image of same size is obtained using a convex lens?
(a) between the lens and its focus
(b) at the focus
(c) at twice the focal length
(d) at infinity

56. A concave lens always gives
(a) virtual image (b) erect image
(c) diminished image (d) all the above

57. The power of a lens whose focal length is one metre is _____ dioptre.
(a) one (b) ten
(c) hundred (d) none of these

58. The focal length of a lens is –0.4 m. The lens is
(a) convex (b) concave
(c) cylindrical (d) none of these
59. The power of a lens is a measure of its degree of
(a) convergence only
(b) divergence only
(c) convergence or divergence
(d) none of these
60. The focal length of a lens is 0.1 m. Then the lens must be
(a) convex (b) concave
(c) cylindrical (d) none of these
61. Hypermetropia is due to the _____ of the eye.
(a) low converging power
(b) low diverging power
(c) high converging power
(d) high diverging power
62. Long-sightedness is to hypermetropia as short-sightedness is to
(a) myopia (b) focusing
(c) astigmatism (d) accommodation
63. Which of the following lens is used to minimise hypermetropia?
(a) convex lens (b) concave lens
(c) cylindrical lens (d) none of these
64. Which of the following lens is used to minimise myopia?
(a) convex lens (b) concave lens
(c) cylindrical lens (d) none of these
65. The human eye forms the image of an object at its
(a) cornea (b) iris
(c) pupil (d) retina
66. The change in focal length of an eye-lens to focus the image of object at varying distances is done by the action of the
(a) pupil (b) ciliary muscles
(c) retina (d) blind spot
67. Figure 10.13 shows the eye suffering from
(a) hypermetropia (b) myopia
(c) astigmatism (d) none of these

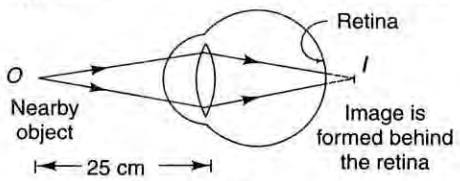


Fig. 10.13

68. Figure 10.14 shows the eye suffering from
(a) hypermetropia (b) myopia
(c) astigmatism (d) none of these

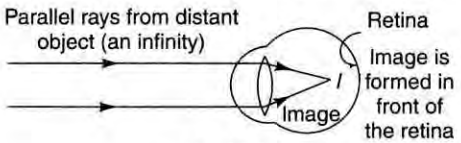


Fig. 10.14

69. When an object is placed between F and $2F$ in front of a convex lens, the image formed is
(a) real and inverted (b) beyond $2F$
(c) magnified (d) all the above
70. The magnifying power of an optical instrument is expressed in
(a) m (b) m^{-1}
(c) D (d) it has no unit
71. A magnifying glass comprises a simple
(a) convex lens (b) convex mirror
(c) concave lens (d) concave mirror
72. The least distance of distinct vision for a normal person is
(a) 1 m (b) 25 cm
(c) 25 cm (d) none of these
73. The power of a lens having a focal length of 1 cm is
(a) 1 D (b) 10 D
(c) $\frac{1}{10}D$ (d) 100 D
74. A camera is an optical instrument which makes use of a
(a) convex lens (b) concave lens
(c) cylindrical lens (d) none of these
75. The inability of a lens to bring all the rays coming from a point object to focus at one single point is called
(a) spherical aberration
(b) parallex
(c) optical illusion
(d) none of these
76. The spherical aberration can be minimised by
(a) reducing the aperture of the lens
(b) using specially made meniscus lens
(c) combination of lenses made of different glasses
(d) none of these

77. Our eye makes use of the property of
(a) convex lens (b) concave lens
(c) cylindrical lens (d) none of these

78. Most of the refraction of light takes place in the
(a) iris (b) cornea
(c) pupil (d) retina

79. The central circular aperture of _____ is called _____.
(a) iris, pupil (b) pupil, iris
(c) retina, iris (d) none of these

80. When the light is very bright,
(a) the iris makes the pupil expand
(b) the iris makes the pupil contract
(c) the iris and the pupil remain as they are
(d) none of these

81. Who discovered by his experiments with glass prisms that white light consists of seven colours?
(a) Newton (b) Faraday
(c) Maxwell (d) Young

82. Which of the following figures correctly represents the passage of white light through a prism?

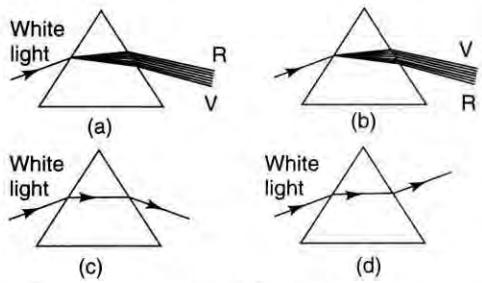


Fig. 10.15

83. Which of the following figures is correct when a monochromatic light passes through a prism?

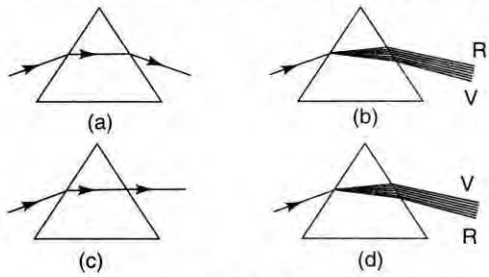


Fig. 10.16

84. The light which refracts most while passing through a prism is
(a) red (b) violet
(c) indigo (d) yellow

85. Which of the following colours of light undergoes the least deviation while passing through a glass prism?
(a) red (b) blue
(c) yellow (d) green

86. Which of the following colour of light undergoes the maximum deviation while passing through a glass prism?
(a) red (b) blue
(c) violet (d) green

87. Which of the following sources of light is different from others?
(a) sunlight (b) white light
(c) light from a bulb (d) sodium light

88. The wavelength of light is expressed in
(a) metre (b) micron
(c) light year (d) angstrom

ANSWERS

1. (c)	2. (a)	3. (a)	4. (b)	5. (b)
6. (a)	7. (c)	8. (c)	9. (c)	10. (b)
11. (d)	12. (c)	13. (c)	14. (b)	15. (c)
16. (c)	17. (d)	18. (a)	19. (c)	20. (a)
21. (a)	22. (a)	23. (a)	24. (b)	25. (a)
26. (b)	27. (a)	28. (a)	29. (b)	30. (a)
31. (b)	32. (c)	33. (b)	34. (b)	35. (b)
36. (c)	37. (d)	38. (a)	39. (b)	40. (b)
41. (a)	42. (b)	43. (a)	44. (b)	45. (a)
46. (d)	47. (c)	48. (a)	49. (d)	50. (b)
51. (c)	52. (b)	53. (a)	54. (b)	55. (c)
56. (d)	57. (a)	58. (b)	59. (c)	60. (a)
61. (a)	62. (a)	63. (a)	64. (b)	65. (d)
66. (b)	67. (a)	68. (b)	69. (d)	70. (d)
71. (a)	72. (b)	73. (d)	74. (a)	75. (a)
76. (d)	77. (a)	78. (b)	79. (a)	80. (b)
81. (a)	82. (a)	83. (a)	84. (b)	85. (a)
86. (c)	87. (d)	88. (d)		