

**Part I.** Review of trigonometric properties and right triangles.

1. Find  $\tan 40^\circ$  to three decimal places.
2. Find  $\sin 40^\circ$  to three decimal places.
3. Find  $\tan 80^\circ$  to four decimal places.
4. Find  $m\angle C$  to the nearest degree given  $\sin C = 0.5784$ .
5. Find  $m\angle A$  to the nearest degree given  $\tan A = 3.2452$ .
6. Find  $\angle A$  to the nearest tenth of a degree if  $\cos A = 0.906$ .
7. Find  $\angle P$  to the nearest tenth of a degree of  $\sin A = 0.457$ .
8. Find  $\angle \phi$  to the nearest degree given  $\sin \phi = 0.423$ .
9. Find  $\angle \theta$  to the nearest degree given  $\tan \theta = 9.094$ .
10. Find  $m\angle \beta$  to the nearest degree given  $\sin \beta = \frac{4}{7}$ .
11. Find  $\angle \beta$  to the nearest degree given  $\tan \beta = \frac{\sqrt{5}}{3}$ .

**Part II.** Refraction of light problems.

12. What is the speed of light in flint glass?
13. Light travels from air into ruby. What is the speed of light in ruby?
14. How long will it take light to travel through a piece of fused quartz 1.35 m thick?
15. How many times faster does light travel in glycerin than in zircon?
16. What is the index of refraction of a liquid in which the speed of light is  $2.50 \times 10^8$  m/s?
17. What is the speed of light in sodium chloride?
18. Zircon is often used as an imitation diamond in costume jewelry. Calculate how much the speed of light decreases when it passes from air into zircon.
19. What is the wavelength of blue light in ruby if it travels from a vacuum where its wavelength is  $\lambda = 455$  nm?
20. Someone claims to have invented a material with an index of refraction of  $n = 0.85$ . What is the speed of light in that material? What argument can you provide against such a material existing?
21. A piece of fused quartz of a length 25 cm is placed next to a 55 cm piece of zircon (there is no gap between the two). How long will it take light to travel through both materials? Be careful with the units.
22. How does the frequency of a radio wave,  $\lambda = 2.8$  m, traveling through air compare to the frequency of the radio wave after entering water? What is the wavelength and frequency of this radio wave in the water?
23. Light travels from air into flint glass. a) What is the speed of light in flint glass? b) If the incident angle is  $25^\circ$ , what is the angle of refraction?
24. Light is traveling from an unknown medium into diamond. The angle of incidence is  $42^\circ$  and the angle of refraction is  $28^\circ$ . What is the index of refraction of the unknown medium?
25. Light travels from Plexiglass into ruby. What is the angle of incidence if the angle of refraction is measured to be  $16.8^\circ$ ?
26. Light passes from air into diamond with an angle of incidence of  $60.0^\circ$ . What will be the angle of refraction?
27. A transparent substance has a refractive index of  $n = 1.30$ . What is the angle of incidence in air when the angle of refraction in the substance is  $45^\circ$ ?

28. What is the index of refraction of a material if the angle of incidence in air is  $50.0^\circ$  and the angle of refraction in the material is  $40.0^\circ$ ?
30. A ray of light in air strikes diamond and another strikes a piece of fused quartz, in each case at an angle of incidence of  $40.0^\circ$ . What is the difference between the angles of refraction?
32. The speed of light in a certain material is  $9.68 \times 10^7$  m/s. If light enters that material from crown glass with an angle of incidence of  $33.5^\circ$ , what will be the angle of refraction?
34. Light is traveling from water into crown glass. What is the largest possible angle of refraction?
36. A ray of light travels from diamond into Plexiglas. What is the critical angle in the diamond?
38. For each of the following light travels into water. Calculate the critical angle for (a) zircon (b) sodium chloride, and (c) ethyl alcohol.
40. What is the difference between the critical angle light traveling from ruby-to-air and the critical angle for light traveling from water-to-air?
42. In a certain medium, light will travel 1.75 m in 11.0 ns. What is the critical angle of the substance if light is traveling from that substance into air?
29. A ray of light passes from water into carbon disulphide,  $n_{CS_2} = 1.63$ , with an angle of incidence of  $30.0^\circ$ . What is the angle of refraction in the carbon disulfide?
31. Light travels from water into an unknown material. If the angle of incidence is  $35.5^\circ$  and the measured angle of refraction is  $17.4^\circ$ , what is the speed of light in the unknown material?
33. Light is traveling from air into glycerin. What is the largest possible angle of refraction?
35. What is the critical angle in crystal glass if light travels from it into air?
37. What is the critical angle in flint glass when light passes from flint glass into air?
39. The critical angle for a medium is  $40.5^\circ$ . What is the index of refraction for that medium if the light travels into air?
41. In a certain substance, light travels 3.15 m in 16.5 ns. What is the critical angle of the substance if light travels from that substance into ethyl alcohol?

**Answer List**

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|---------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------|
| 1. 0.839                                                                                                                              | 2. 0.643                                                   | 3. 5.6713                                            |
| 4. $35^\circ$                                                                                                                         | 5. $73^\circ$                                              | 6. $25.0^\circ$                                      |
| 7. $27.2^\circ$                                                                                                                       | 8. $25^\circ$                                              | 9. $83.7^\circ$                                      |
| 10. $35^\circ$                                                                                                                        | 11. $37^\circ$                                             | 12. $v = 1.82 \times 10^8 \text{ m/s}$               |
| 13. $v_{\text{ruby}} = 1.95 \times 10^8 \text{ m/s}$                                                                                  | 14. $t = 6.57 \text{ ns}$                                  | 15. $v_{\text{glycerin}} = 1.31v_{\text{zircon}}$    |
| 16. $n = 1.20$                                                                                                                        | 17. $v_{\text{s.chloride}} = 1.96 \times 10^8 \text{ m/s}$ | 18. Light decreases $1.44 \times 10^8 \text{ m/s}$ . |
| 19. $\lambda_{\text{ruby}} = 295 \text{ nm}$                                                                                          | 20. $v_{\text{material}} = 3.53 \times 10^8 \text{ m/s}$   | 21. $t = 4.74 \text{ ns}$                            |
| 22. The wavelength decreases in water. The frequency is $f = 1.1 \times 10^8 \text{ Hz}$ and $\lambda = 2.11 \text{ m}$ in the water. | 23. a) $v = 1.82 \times 10^8 \text{ m/s}$                  | 24. $n_{\text{unknown}} = 1.7$                       |
|                                                                                                                                       | b) $\theta_R = 15^\circ$                                   |                                                      |
| 25. $\theta_i = 17.1^\circ$                                                                                                           | 26. $\theta_R = 21.0^\circ$                                | 27. $\theta_i = 67^\circ$                            |
| 28. $n = 1.19$                                                                                                                        | 29. $\theta_R = 24.0^\circ$                                | 30. The difference is $11^\circ$ .                   |
| 31. $v_{\text{material}} = 1.16 \times 10^8 \text{ m/s}$                                                                              | 32. $\theta_R = 15.7^\circ$                                | 33. $42.9^\circ$                                     |
| 34. $61.0^\circ$                                                                                                                      | 35. $\theta_C = 40.5^\circ$                                | 36. $\theta_C = 38.6^\circ$                          |
| 37. $\theta_C = 37.3^\circ$                                                                                                           | 38. a) $\theta_C = 43.8^\circ$                             | 39. $n = 1.54$                                       |
|                                                                                                                                       | b) $\theta_C = 60.4^\circ$                                 |                                                      |
|                                                                                                                                       | c) $\theta_C = 77.9^\circ$                                 |                                                      |
| 40. The difference is $8.3^\circ$ .                                                                                                   | 41. $\theta_C = 59.5^\circ$                                | 42. $\theta_C = 31.9^\circ$                          |

**Catalog List**

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|---------------|---------------|---------------|---------------|
| 1. CM2 JA 85  | 2. CM2 JA 86  | 3. CM2 JA 88  | 4. CM2 JA 89  |
| 5. CM2 JA 90  | 6. CM2 JA 91  | 7. CM2 JA 92  | 8. CM2 JA 93  |
| 9. CM2 JA 94  | 10. CM2 JA 95 | 11. CM2 JA 96 | 12. 20P CC 1  |
| 13. 20P CC 2  | 14. 20P CC 5  | 15. 20P CC 6  | 16. 20P CC 9  |
| 17. 20P CC 10 | 18. 20P CC 11 | 19. 20P CC 13 | 20. 20P CC 15 |
| 21. 20P CC 16 | 22. 20P CC 17 | 23. 20P CC 19 | 24. 20P CC 20 |
| 25. 20P CC 22 | 26. 20P CC 23 | 27. 20P CC 24 | 28. 20P CC 25 |
| 29. 20P CC 27 | 30. 20P CC 29 | 31. 20P CC 30 | 32. 20P CC 33 |
| 33. 20P CC 47 | 34. 20P CC 48 | 35. 20P CC 34 | 36. 20P CC 35 |
| 37. 20P CC 38 | 38. 20P CC 39 | 39. 20P CC 40 | 40. 20P CC 42 |
| 41. 20P CC 43 | 42. 20P CC 45 |               |               |