Solutions and the applicable equations are at the end.

Useful Constants

\[ e = 1.60 \times 10^{-19} \text{C}, \quad \varepsilon_0 = 8.85 \times 10^{-12} \text{C}^2/(\text{N} \cdot \text{m}^2), \quad \mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m}/\text{Amp s}, \quad k = 8.99 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 \]

\[ c = 2.9979 \times 10^8 \text{m/s}, \quad h = 6.62606891 \times 10^{-34} \text{J} \cdot \text{s}, \quad m \cdot c^2 = 931.5 \text{MeV} \]

1. (5 pts) An FM radio station generates radio waves that have a frequency of 95.5 MHz. What is the wavelength of these radio waves?

2. (5 pts) A distant space probe is programmed to emit a radio signal toward Earth at regular time intervals. One such pulse arrives on Earth 2.92 s after it is emitted from the probe. What is the approximate distance from the Earth to the probe?

3. (5 pts) The amplitude of the electric field component of an electromagnetic wave is increased from \( E \) to \( 4E \). What is the corresponding change in the intensity of the wave?

4. (5 pts) Linearly polarized light is incident on a sheet of polarizing material. The angle between the transmission axis and the incident electric field is 52°. What percentage of the incident intensity is transmitted?

5. (5 pts) A ray of light is reflected from two plane mirror surfaces as shown in the figure. What are the correct values of the angles \( \alpha \) and \( \beta \)?

6. (5 pts) The focal length of a spherical concave mirror is 20 cm. What is its radius of curvature?

7. (5 pts) A ray of light propagates in water (\( n = 1.333 \)) and strikes a sheet of crown glass (\( n = 1.523 \)). If the angle of refraction in the glass is 35.2°, measured off the normal to the interface, determine the angle of incidence, measured off the normal to the interface.

8. (5 pts) Trace some representative rays to determine the image’s location, size, and orientation. Is it real or virtual?
9. (5 pts) Say the object is +6.0 cm from the converging lens whose focal length is +1.2 cm. How far is the image from the lens?

10. (5 pts) What is the magnification?

11. (5 pts) Light of wavelength 600 nm is incident upon a single slit with width $4 \times 10^{-4}$ m. The figure shows the pattern observed on a screen positioned 2 m from the slits. Determine the distance S.

12. (5 pts) What are the two postulates of Einstein’s Special Relativity?

13. (5 pts) During a baseball game, a batter hits a ball directly back to the pitcher who catches it. An observer flying over the stadium at a speed of 0.75c, measures 0.658s as the time between the hit and the catch. What is the proper time interval between the two events?

14. (5 pts) Which one of the following statements concerning the proper length of a meter stick is true?
   a. The proper length is always one meter.
   b. The proper length depends upon the speed of the observer.
   c. The proper length depends upon the acceleration of the observer.
   d. The proper length depends upon the reference frame in which it is measured.
   e. The proper length is the length measured by an observer who is moving with respect to the meter stick.

15. (5 pts) How much energy would be released if 0.001 kg of material were completely converted into energy?

16. (5 pts) An Earth observer sees and alien ship pass overhead at 0.3c. The ion gun of the ship shoots ions straight ahead of the ship at a speed of 0.4c relative to the ship. What is the speed of the ions relative to the Earth observer?

17. (5 pts) Complete the following statement: The photon description of light is necessary to explain
   a. Polarization       c. diffraction       e. interference
   b. Photoelectric effect

18. (5 pts) Photons with what maximum wavelength are required to remove electrons from gold, whose work function is 4.8 eV?

19. (5 pts) A digital wireless telephone communicates via microwaves that have a frequency of 1930 MHz. What are the momentum and energy for the microwave photons emitted by the telephone?
20. (5 pts) Determine the de Broglie wavelength of a neutron \((m = 1.67 \times 10^{-27} \text{kg})\) with a speed of 5.0 m/s.

21. (5 pts) Electrons have been removed from a beryllium atom \((Z=4)\) until only one remains. Determine the energy of an incident photon required to cause an electron transition from the \(n = 7\) to the \(n = 9\) level in a hydrogen atom.

22. (5 pts) In which one of the following sets do the species have the same neutron number, \(N\)?
   a. \(^{16}\text{O}, {}^{14}\text{N}\)  
   b. \(^{12}\text{C}, {}^{14}\text{C}\)  
   c. \(^{16}\text{O}, {}^{23}\text{Na}\)  
   d. \(^{14}\text{N}, {}^{13}\text{C}\)  
   e. \(^{14}\text{N}, {}^{13}\text{C}\)

23. (5 pts) What interplay plays an important role in determining the \(N\) and \(Z\) numbers of stable nuclei?

24. (5 pts) \(^{235}\text{U} (\text{mass} = 238.0508 \text{u})\) looses a \(^4\text{He} (\text{mass} = 4.0026 \text{u})\) chunk, commonly referred to as an alpha particle, and thus \(^{234}\text{Th} (\text{mass} = 234.0436)\) is created. How much energy is released per decay?

25. (5 pts) What isotope is produced when \(^{28}\text{Mg} \beta^-\text{-decays}\)? Note: the periodic table at the front of the room may be of some use.

26. (5 pts) The half-life of a particular isotope of iodine is 8.0 days. How much mass of an initially 10.0g sample of this isotope will remain after 28 days?

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1. \(3.14 \text{ m}, \quad c = f\lambda\)
2. \(8.76 \times 10^8 \text{ m} \quad c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 2.9979 \times 10^8 \text{ m/s} \quad \frac{\Delta x}{\Delta t}\)
3. The intensity increases by a factor of sixteen.
   \[ E = cB \]
   \[ S = \frac{\varepsilon}{2} \left( \varepsilon_0 E^2 + \frac{1}{\mu_0} B^2 \right) \]
4. \(38\% \quad S_1 = \frac{1}{2} S_o, \quad S_n = S_{n-1} \left( \cos \theta_{n-1} \right)^2 \)
5. \(\alpha = 40^\circ \quad \beta = 50^\circ \quad \theta_i = \theta_i\)
6. \(40 \text{ cm} \quad f = \frac{1}{2} R\)
7. \(41.2^\circ \quad n_i \sin \theta_1 = n_2 \sin \theta_2\)
8. \(1.5 \text{ cm} \quad \frac{1}{\pm d_o} + \frac{1}{\pm d_i} = \frac{1}{\pm f}\)
9. \(m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}\)
11. \(0.006 \text{ m}\)
\[
\sin \theta_{\text{con}} = \frac{m \lambda}{d}, \quad m = 0, 1, 2, \ldots
\]
\[
\sin \theta_{\text{de}} = (m + \frac{1}{2}) \frac{\lambda}{d}, \quad m = 0, 1, 2, \ldots
\]
\[
\sin \theta_{\text{de}} = \frac{\lambda}{W}, \quad m = 1, 2, \ldots
\]

13. \(0.435 \text{ s}\)
\[
\Delta t = \frac{\Delta t_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}
\]

14. The proper length is always one meter.
\[
L = L_0 \sqrt{1 - \left(\frac{v}{c}\right)^2}
\]

15. \(9 \times 10^{13} \text{ J}\)
\[
E = \frac{mc^2}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}
\]

16. \(0.63c\)
\[
\nu_{AB} = \frac{\nu_{AC} + \nu_{CB}}{1 + \frac{\nu_{AC} \nu_{CB}}{c^2}}
\]

17. Photoelectric effect

18. \(260 \text{ nm}\)
\[
E_{\text{ph}} = hf \quad E_{\text{ph}} = KE_{\text{max}} + W_0
\]

19. Momentum = \(4.27 \times 10^{-33} \text{ kg m/s}\), Energy = \(1.28 \times 10^{-24} \text{ J}\)

\[
hf = hf' + KE
\]

20. \(79 \text{ nm}\)
\[
\lambda = \frac{h}{k} + mv \
\lambda' = \frac{h}{mc} (1 - \cos \theta) \quad p = \frac{h}{\lambda}
\]

21. \(r_n = \frac{1}{mkZ} \left(\frac{hn}{2\pi e}\right)^2, \quad n = 1, 2, 3, \ldots\)
\[
E_n = -\frac{m}{2} \left(\frac{4\pi kZe^2}{nh}\right)^2, \quad n = 1, 2, 3, \ldots
\]
\[
E_{\text{ph}} = |E_{n,f} - E_{n,i}|
\]

22. \(A = Z + N\)

23. The balance between short range, strong attraction of the Strong Force and the long range, weaker repulsion of the Electric Force.

24. \(^{238}_{92}\text{U} \rightarrow ^{4}_{2}\text{He} + ^{234}_{90}\text{Th}\)
\[
E = -\Delta mc^2 = -\left(m_{^{234}_{90}\text{He}} + m_{^{4}_{2}\text{He}} - m_{^{238}_{92}\text{U}}\right)^2
\]
\[
E = -((234.0436u + 4.0026u) - 238.0508u)c^2 = 0.0046uc^2
\]
\[
E = 0.0046u \cdot \frac{1.6605 \times 10^{-27} \text{ kg}}{1u} \cdot \frac{1e}{1.6 \times 10^{-19} \text{Coul}} \cdot (3.00 \times 10^8 m/s)^2 = 4.3 \text{ MeV}
\]
25. $^{28}_{13}$Al $\overset{\beta^-}{\rightarrow}^{A}_{Z+1}D^0 + e + \bar{\nu}$

26. 0.88 g