Solutions - PHY3054 - Final - Fall 1994

1. Add the forces due to Q_2 and Q_3. Make sure to add the forces as vectors.

$$\begin{aligned} F_x \text{ on } Q_1 \text{ due to } Q_2 &= 0 \\ F_x \text{ on } Q_1 \text{ due to } Q_3 &= +k\frac{|2C||2C|}{(2\sqrt{2}m)^2}\cos(45) \\ F_x \text{ net} &= \frac{1}{2\sqrt{2}}\, k\, C^2\, m^{-2} \end{aligned}$$

$$\begin{aligned} F_y \text{ on } Q_1 \text{ due to } Q_2 &= -k\frac{|2C||-2C|}{(2m)^2} \\ F_y \text{ on } Q_1 \text{ due to } Q_3 &= +k\frac{|2C||2C|}{(2\sqrt{2}m)^2}\sin(45) \\ F_y \text{ net} &= \left(-1+\frac{1}{2\sqrt{2}}\right) k\, C^2\, m^{-2} \end{aligned}$$

The magnitude of the net force is

$$|F| = \sqrt{(F_x)^2 + (F_y)^2} = 6.6\times 10^9 N \approx \mathbf{6.5\times 10^9 N}.$$

2. The direction of the net force is determined by

$$\theta = \arctan(F_y/F_x) = -61^o \approx \mathbf{-60^o}.$$

3. The electric field inside the outer shell must be zero. Using Gauss's Law with a Gaussian surface drawn inside the outer shell,

$$\begin{aligned} 0 &= \text{charge on sphere} \\ &+ \text{charge on inner shell} \\ &+ \text{charge on inside surface of outer shell.} \end{aligned}$$

Since the charge on the sphere is 1 C and the charge on the inner shell is -2 C, the charge on the inside surface of the outer shell is **1 C**.

4. The electric field is zero because the charges on opposite corners produce opposing fields. The electrical potential, V, is not zero because there are not equal numbers of positive and negative charges:

$$V = 4\frac{kQ}{R} - 2\frac{kQ}{R} \neq 0.$$

V is not zero, and E is zero.

5. Add the three contributions to the potential energy:

$$\begin{aligned} U &= k\frac{Q_1Q_2}{2m} + k\frac{Q_2Q_3}{2m} + k\frac{Q_1Q_3}{2\sqrt{2}m} \\ &= \left(-2 - 2 + \sqrt{2}\right) k\, C^2/m \\ &= \mathbf{-2.3 \times 10^{10} J}. \end{aligned}$$

6. Use conservation of energy:

$$\begin{aligned} E = K_i + U_i &= K_f + U_f \\ 0 + k\,\frac{(-|e|)(10^{-15}C)}{10^{-3}m} &= \frac{1}{2}mv^2 + k\,\frac{(-|e|)(10^{-15}C)}{R} \\ k\,\frac{(-|e|)(10^{-15}C)}{R} &= (-1.44 - 4.56) \times 10^{-21} J \\ R &= \mathbf{0.24mm}. \end{aligned}$$

7. **Resistors do not store energy.** They dissipate energy ($P = IV$).

8. If the charge on the left most capacitor is $1\mu C$, then the voltage drop across it is 1V. This is also the net voltage drop across the other four capacitors because they are in parallel with the left most capacitor.

   The effective capacitance of the other four capacitors is 0.4 μF. $\rightarrow$ The charge on this effective capacitor is 0.4 μC. This charge is split between the two right most capacitors $\rightarrow$ $\mathbf{0.2\mu C}$.

9. **Figure 5.4** is different. All of the other circuits have two resistors in parallel. In Fig. 5.4 the resistors are in series with one of the resistors shorted out.

10. Using the point rule, the current in the upper right corner is $3A$ up. The current in the unmarked middle segment is $1A$ down. Consequently, the current labeled I is $3A - 1A =$ **2A**.

11. The two 2Ω resistors in parallel have effective resistance 1Ω. The three resistors in parallel have effective resistance 0.5Ω. Since these two groups of resistors are in series, the effective resistance of the circuit is **1.5 Ohms**.

12. For a magnetic field out of the page, an electron will go **counterclockwise**. A wire with current moving from left to right will a experience a force **towards the bottom of the page.**

13. For circular motion

$$F = \frac{mv^2}{r} = qvB \rightarrow \frac{v}{r} = \frac{qB}{m},$$

but $v/r = 2\pi/T$, where T is the period. Consequently,

$$B = 2\pi\frac{m}{qT} \approx \mathbf{3.6T}.$$

14. The top wire is attracted to the middle wire and repelled from the bottom wire. Since the middle wire is closer, the force on the **top wire** is **down**.

    The middle wire is attracted to the top wire and repelled from the bottom wire so the net force on the **middle wire** is **up**.

    The bottom wire is repelled from both wires so the net force on the **bottom wire** is **down**.

15. Using the superposition principle, add the magnetic fields due to each wire. Use the sign convention that + is into the page.

$$\begin{aligned} B &= \frac{\mu_o(2A)}{2\pi}\left(\frac{1}{1m}+\frac{1}{3m}+\frac{1}{1m}+\frac{1}{3m}\right) \\ &= \mathbf{1\times 10^{-6}T\ into\ the\ page} \end{aligned}$$

16. The flux through the loop is going out of the page, but it is decreasing. Consequently, the induced current produces a flux going out of the page (**counterclockwise**).

$$I=\frac{1}{R}vBl=\mathbf{4mA}$$

17. In **Fig. 11.1** the magnetic field is coming out of the page at the inner loop. Since this field is increasing, the induced current in the inner loop acts to produce a flux going into the page (**clockwise**).

    In **Fig. 11.2** the field at the right loop is going into the page. Since the field is decreasing, the induced current produces a a flux going into the page (**clockwise**).

18. **Sound is not an electromagnetic wave.**

19. Let the angle of incidence at the first surface be θ. Let the angle of incidence at the second surface be θ_1. In order to have total internal reflection one must have

$$\sin(\theta)=n_1\sin(\theta_1)>n_2>1,$$

    but $\sin(\theta)\leq 1$ so it is not possible for the light ray to be totally internally reflected at the second surface (**no**).

20. After the unpolarized light passes through the first polarizer, the intensity is reduced by a factor of 2. If the remaining three polarizers are oriented in the same direction, there will be no further reduction in the intensity. Thus, the maximum possible intensity is $\mathbf{I_o/2}$.

21. Since $m=-2.5=-s'/s$, $s'=2.5s$. For a concave mirror, $f=R/2=4.5cm$.

$$\frac{1}{s}+\frac{1}{2.5s}=\frac{1}{4.5cm}\rightarrow s=\mathbf{6.3cm}$$

22. **All rays are correct.**

23. **False** A converging lens produces a virtual image when the object is inside of a focal length. A diverging lens can even produce a real image if the object is on the side of the outgoing light ($s < 0$).

24. For the first lens

$$\frac{1}{2cm} + \frac{1}{s'} = \frac{1}{1cm} \rightarrow s' = 2cm.$$

For the second lens

$$\frac{1}{(10-2)cm} + \frac{1}{s'} = \frac{1}{9cm} \rightarrow s' = -72cm.$$

With this coordinate system, this also corresponds to $-$**72cm**.