PHYSICS 232 - Solution Key to the Sample Final

1. $T = 10/6 = 1.67\ s$, so

$$y = A \sin \frac{2\pi}{T}(t - x/v) = 3.4 \sin \frac{2\pi}{1.67}(0.42 - 1.14/20) = 3.33 \text{ cm}$$

2a. $n_a = 1$, $n_b = 1.5$, $s = 31\ cm$, $s' = 35\ cm$, $y = 4\ mm$, so

$$R = \frac{n_b - n_a}{n_a/s + n_b/s'} = 6.66\ cm$$

2b. $y' = \frac{n_a s'}{n_b s}\ y = 3\ mm.$

3. $d \sin\theta = m\lambda$, where $m = 2$, $\lambda = 632.8\ nm$, $\theta = 43.2^o$. So

$$d = \frac{m\lambda}{\sin\theta} = 1849 \text{ nm}$$

For $\theta = 53.4^o$, we obtain

$$\lambda = \frac{d \sin\theta}{m} = 742 \text{ nm}$$

4a. $m_e v = h/\lambda$, so $v = \frac{h}{m_e \lambda}$, so

$$E = \frac{1}{2} m_e v^2 = \frac{h^2}{2 m_e \lambda^2} = 5.66 \times 10^{-15} J$$

4b.

$$E = \frac{h^2}{2 m_n \lambda^2} = 3.08 \times 10^{-18} J$$

4c.

$$E = \frac{hc}{\lambda} = 3.05 \times 10^{-14} J$$

5a. It represents binding energy. We need to do work to extract an electron. E.g. $13.6\ eV$ is the ionization energy, so the electron in the ground state has energy $-13.6\ eV$.

5b. Turn on a magnetic field. The electrons get extra energy $U = -m_\ell \mu_B B$, so spectral lines split.

5c. Shoot the electrons through the aperture and place a screen in front of them. They'll form a diffraction pattern on he screen. The spread of the central maximum is proportional to the uncertainty in the transverse momentum. The size of the aperture is the uncertainty of transverse position. As we narrow the aperture, the central maximum gets broader, and vice-versa.

5d. Scattering of photons by electrons. The wavelength of the photons changes by

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\phi)$$

Since

$$\frac{h}{mc} = 2.4 \times 10^{-12} m$$

this change is not significant in visible light which has $\lambda \sim 500\ nm = 5 \times 10^{-7} m$, so this effect is not observable with visible light.

6a. Electrons in an atom are completely described by a set of numbers called quantum numbers $(n, \ell, m_\ell, s, m_s)$. The energy of the electrons is also specified by these numbers. The exclusion principle states that no two electrons can have the same set of quantum numbers. This is why they arrange themselves in shells and subshells with different energies.

6b. $Na : 1s^2 2s^2 2p^6 3s$ and $K : 1s^2 2s^2 2p^6 3s^2 3p^6 4s$. They have similar chemical properties because they both have one valence electron.

6c. When atoms come together to form solids, the energy levels of their electrons change a bit. If you have about 10^{20} atoms, then the new energy levels form a continuum of energy levels, called energy band.

In a conductor, the energy band corresponding to the valence electrons is not full, so electrons can easily move within it. This happens when you apply an electric field.

In an insulator, this energy band is full, so electrons have to jump to the next (conduction) band for a current to form. This is not so easy. It can happen if the electric field is strong.

6d. Semiconductors conduct electricity when they contained impurities. If the impurity consists of atoms with one more electron than the atoms of the semiconductor, then we have an n-type semiconductor. In this case, the current consists of these extra electrons.

If the impurity consists of atoms with one less electron than the atoms of the semiconductor, then we have a p-type semiconductor. In this case, the current consists of (positively charged) holes.