HW 11 Solutions

Conceptual Questions:

37.5. **(a)** Yes, they are simultaneous in Peggy's reference frame because she and the firecrackers are at rest relative to one another and she is halfway between them and saw the explosions at the same time.
(b) No, the left one occurred first because it had a farther distance for its light to reach Peggy since she was moving toward the right one.

37.6. **(a)** No. During the time the flashes of light are traveling, the rocket is moving to the right. So the flash from the right lightning strike has less distance to travel to get to the rocket and therefore reaches the rocket pilot first.
(b) No. Two events which are simultaneous in reference frame S are not simultaneous in any reference frame moving relative to S. The student sees the tree on the left hit first. He is moving to the left relative to the frame of the rocket where the strikes were simultaneous. So he moves toward the wave front on the left and away from the one on the right.

37.7. **(a)** Event 1 is your friend leaving Los Angeles; event 2 is your friend arriving in New York.
(b) Your friend.
(c) Your friend.

37.10. Classically they are equal, but using the formula for relativistic momentum gives

$$\frac{p_A}{p_B} = \frac{\gamma_{pA}\left(\frac{1}{2}m_B\right)(2u_B)}{\gamma_{pB}m_Bu_B} = \frac{\gamma_{pA}}{\gamma_{pB}} > 1 \text{ so } p_A > p_B$$

37.11. **(a)** Yes. $\Delta x = 900$ m; $\Delta t = 4\ \mu s$; $v = \frac{\Delta x}{\Delta t} = \frac{900\text{ m}}{4\ \mu s} = 225\text{ m}/\mu s < c$

(b) No. $\Delta x = 2100$ m; $\Delta t = 6\ \mu s$; $v = \frac{\Delta x}{\Delta t} = \frac{2100\text{ m}}{6\ \mu s} = 350\text{ m}/\mu s > c$

38.7. Scientists at the time could not imagine the extremely high density of the tiny nucleus. They also had no idea what would hold protons together in a nucleus when there was a known repulsive force between protons.

38.8. Alpha particles scattered through large angles because they had near collisions with very massive and highly charged particles. Only small deflections were expected for an alpha particle passing through a Thomson atom.

38.9. **(a)** $^{6}Li^{+}$

(b) $^{13}C^{-}$

39.2. **(a)** When $\Delta V > 0$, all the emitted electrons are attracted to and collected by the anode. This means a further increase in the voltage cannot change the number of electrons arriving per second and thus cannot increase the current.

(b) The work function E_0 is the *minimum* energy an electron needs to escape from the metal. Some electrons, such as those a bit further from the surface, need more than E_0 to escape. There is a *range* of escape energies, so the escaped electrons have a range of kinetic energies and not a single kinetic energy.

(c) If the anode potential is V, an electron leaving the cathode with kinetic energy K arrives at the anode with kinetic energy $K' = K + eV$. A negative V causes a decrease in kinetic energy. K' *cannot* become negative, so for $eV \leq -K$ the electron is repelled by the anode and turned back toward the cathode. The emitted electrons have a maximum kinetic energy K_{max}. When $eV = -K_{max}$, *all* electrons are turned back and the current drops to zero. If the current reaches zero at $V = -V_{stop}$, then $V_{stop} = K_{max}/e$. The stopping voltage measures the maximum kinetic energy by causing the most energetic electrons, those with $K = K_{max}$, to be turned back from the anode.

mv $\quad \sqrt{\;} \; m$ $\quad m\sqrt{\frac{2K}{m}} \quad \sqrt{2Km}$

mass has the larger wavelength.

39.11. **(a)** $|E_1| = 4$ eV

(b) $E_{photon} = 3$ eV because it had to go from state $n = 1$ to state $n = 3$ to then emit the 1240 nm photon.

(c) $E_{elec} = 3$ eV for the same reasons.

Problems and Exercises

37.24. Model: S′ is the muon's frame and S is the ground's frame. S′ moves relative to S with a speed of 0.9997*c*.
Solve: For an experimenter in the ground's frame, a distance of 60 km (or *L*) is always there for measurements. That is, L is the atmosphere's proper length ℓ. The muon measures the thickness of the atmosphere to be length contracted to

$$L' = \sqrt{1-\beta^2}\,\ell = \sqrt{1-(0.9997)^2}\,(60\text{ km}) = 1.47\text{ km}$$

37.30. Model: S is the ground's frame and S′ is the rocket's frame. S′ moves with velocity $v = 0.5c$ relative to S.

Solve: (a) We have $\gamma = \left[1-(v/c)^2\right]^{-\frac{1}{2}} = \left[1-(0.50)^2\right]^{-\frac{1}{2}} = 1.155$. Applying the Lorentz transformations to the lightning strike at $x = 0$ m and $t = 10\ \mu$s,

$$x' = \gamma(x - vt) = (1.155)\left[0\text{ m} - (0.5)(3.0\times10^8\text{ m/s})(1\times10^{-5}\text{ s})\right] = -1732\text{ m} \approx -1700\text{ m}$$

$$t' = \gamma\left(t - \frac{vx}{c^2}\right)(1.155)(1\times10^{-5}\text{ s} - 0\text{ s}) = 11.55\ \mu\text{s} \approx 12\ \mu\text{s}$$

For the lightning strike at $x = 30$ km and $t = 10\ \mu$s,

$$x' = (1.155)\left[3.0\times10^4\text{ m} - (0.50)(3.0\times10^8\text{ m/s})(1\times10^{-5}\text{ s})\right] = 32.91\text{ m} \approx 33\text{ m}$$

$$t' = (1.155)\left[1\times10^{-5}\text{ s} - \frac{(0.50)(3.0\times10^8\text{ m/s})(3.0\times10^4\text{ m})}{(3.0\times10^8\text{ m/s})^2}\right] = -46.2\ \mu\text{s} \approx -46\ \mu\text{s}$$

(b) The events in the rocket's frame are not simultaneous. The lightning is observed to strike the pole before the tree by $46 + 12 = 58\ \mu$s.

38.24. Model: Assume the metal sphere is a blackbody (so the emissivity $e = 1$).
Visualize: First use Wein's law (Equation 38.9) to find the temperature, then use Stefan's law (Equation 38.8) to determine the power radiated. We are given $R = 1.0$ cm and $\lambda_{peak} = 2000$ nm.
Solve:

$$T = \frac{2.90\times10^6\text{ nm}\cdot\text{K}}{2000\text{ nm}} = 1450\text{ K}$$

$$\frac{Q}{\Delta t} = e\sigma AT^4 = (1)(5.67\times10^{-8}\text{ W/m}^2\cdot\text{K}^4)[4\pi(1.0\text{ cm})^2](1450\text{ K})^4 = 315\text{ W}$$

Assess: The sphere radiates more than 3100W light bulbs, but it has a larger surface area than the filaments, so the answer is reasonable.

38.25. Model: Assume the ceramic cube is a blackbody (so the emissivity $e = 1$).

Visualize: First use Stefan's law (Equation 38.8), $\frac{Q}{\Delta t} = e\sigma AT^4$, to find the temperature, then use Wein's law (Equation 38.9) to get the peak wavelength. We are given $A = 6(3.0 \text{ cm} \times 3.0 \text{ cm}) = 0.0054 \text{ m}^2$ and $Q/\Delta t = 630$ W.

Solve: Solve Stefan's law for T.

$$T = \sqrt[4]{\frac{Q/\Delta t}{e\sigma A}} = \sqrt[4]{\frac{630 \text{ W}}{(1)(5.67\times10^{-8} \text{ W/m}^2\cdot\text{K}^4)(0.0054 \text{ m}^2)}} = 1198 \text{ K}$$

Now plug this temperature into Wein's law.

$$\lambda_{\text{peak}} = \frac{2.90\times10^6 \text{ nm}\cdot\text{K}}{T} = \frac{2.90\times10^6 \text{ nm}\cdot\text{K}}{1198 \text{ K}} = 2420 \text{ nm} = 2.42\ \mu\text{m}$$

39.18. Model: The energy of a confined particle in a one-dimensional box is quantized. Model a nucleus as a one-dimensional box of length $L = 10 \text{ fm} = 1.0 \times 10^{-14}$ m.

Solve: Protons and neutrons are particles of mass m confined in a box. From Equation 39.14, the allowed energies of the protons are

$$E_n = n^2\frac{h^2}{8mL^2} = n^2\frac{\left(6.63\times10^{-34} \text{ J s}\right)^2}{8\left(1.67\times10^{-27} \text{ kg}\right)\left(1.0\times10^{-14} \text{ m}\right)^2} = n^2\left(3.29\times10^{-13} \text{ J}\right) = n^2\left(2.06 \text{ MeV}\right)$$

The first three energy levels are to two significant figures $E_1 = 2.1$ MeV, $E_2 = 4E_1 = 8.2$ MeV, and $E_3 = 9E_1 = 19$ MeV.

39.40. Solve: (a) The stopping potential is

$$V_{\text{stop}} = \frac{h}{e}f - \frac{h}{e}f_0$$

A graph of V_{stop} versus frequency f should be linear with x-intercept f_0 and slope h/e. Since the x-intercept is $f_0 = 1.0 \times 10^{15}$ Hz, the work function is

$$E_0 = hf_0 = (4.14 \times 10^{-15} \text{ eV s})(1.0 \times 10^{15} \text{ Hz}) = 4.14 \text{ eV}$$

(b) The slope of the graph is

$$\frac{\Delta V_{\text{stop}}}{\Delta f} = \frac{8.0 \text{ V} - 0 \text{ V}}{3.0\times10^{15} \text{ Hz} - 1.0\times10^{15} \text{ Hz}} = 4.0\times10^{-15} \text{ V s}$$

Because the slope of the V_{stop} versus f graph is h/e, an experimental value of Planck's constant is

$$h = e\left(4.0\times10^{-15} \text{ V s}\right) = \left(1.6\times10^{-19} \text{ C}\right)\left(4.0\times10^{-15} \text{ V s}\right) = 6.4\times10^{-34} \text{ J s}$$

Assess: This value of the Planck's constant is about 3.5% lower than the accepted value.

39.43. Model: Photons have both particle-like and wave-like properties.

Solve: **(a)** Because $E_0 = mc^2 = 0$ J for a photon,

$$E^2 - p^2c^2 = 0 \Rightarrow p = \frac{E}{c}$$

(b) Using $E = hf$ in the momentum equation in part (a),

$$p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda} \Rightarrow \lambda = \frac{h}{p}$$

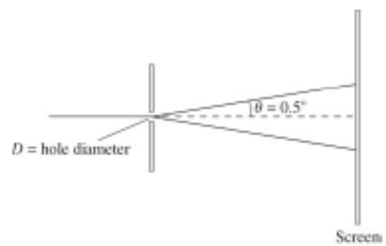
(c) Classically $p = mv$, so

$$\lambda = \frac{h}{mv}$$

This is the expression for de Broglie wavelength.

39.46. Model: Electrons have both particle-like and wave-like particles.

Visualize:



Solve: The kinetic energy of the electrons is

$$K_f = \tfrac{1}{2}mv^2 = K_i + e\Delta V = 0\text{ J} + e(250\text{ V}) = (1.60\times10^{-19}\text{ C})(250\text{ V}) = 4.00\times10^{-17}\text{ J}$$

$$\Rightarrow v = \sqrt{\frac{2(4.00\times10^{-17}\text{ J})}{9.11\times10^{-31}\text{ kg}}} = 9.37\times10^{6}\text{ m/s}$$

The de Broglie wavelength at this speed is

$$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}\text{ J s}}{(9.11\times10^{-31}\text{ kg})(9.37\times10^{6}\text{ m/s})} = 7.77\times10^{-11}\text{ m}$$

Circular-aperture diffraction produces the first minimum, defining the edge of the central maximum, at $\theta = 1.22\lambda/D$ for small angles, as is the case here. The diameter of the opening is

$$D = \frac{1.22\,\lambda}{\theta} = \frac{1.22(7.77\times10^{-11}\text{ m})}{(0.5°/180°)\pi\text{ rad}} = 1.09\times10^{-8}\text{ m}$$

Assess: The diameter of the hole that diffracts the electron beam is small indeed, and understandably so.

39.51. Model: Photons are emitted when an atom undergoes a quantum jump from a higher energy level to a lower energy level. On the other hand, photons are absorbed in a quantum jump from a lower energy level to a higher energy level. Because most of the atoms are in the $n = 1$ ground state, the only quantum jumps in the absorption spectrum start from the $n = 1$ state.

Solve: **(a)** The ionization energy is $|E_1| = 6.5$ eV.

(b) The absorption spectrum consists of the transitions $1 \rightarrow 2$ and $1 \rightarrow 3$ from the ground state to excited states. According to the Bohr model, the required photon frequency and wavelength are

$$f = \frac{\Delta E}{h} \Rightarrow \lambda = \frac{c}{f} = \frac{hc}{\Delta E}$$

where $\Delta E = E_f - E_i$ is the energy change of the atom. Using the energies given in the figure, we calculated the values in the table below.

Transition	E_f (eV)	E_i (eV)	ΔE (eV)	λ (nm)
$1 \rightarrow 2$	−3.0	−6.5	3.5	355
$1 \rightarrow 3$	−2.0	−6.5	4.5	276

(c) Both wavelengths are ultraviolet ($\lambda < 400$ nm).

(d) A photon with wavelength $\lambda = 1240$ nm has an energy $E_{photon} = hf = hc/\lambda = 1.0$ eV. Because E_{photon} must exactly match ΔE of the atom, a 1240 nm photon can be emitted only in a $3 \rightarrow 2$ transition. So, after the collision the atom was in the $n = 3$ state. Before the collision, the atom was in its ground state ($n = 1$). Thus, an electron with $v_i = 1.4 \times 10^6$ m/s collided with the atom in the $n = 1$ state. The atom gained 4.5 eV in the collision as it is was excited from the $n = 1$ to $n = 3$, so the electron lost 4.5 eV $= 7.20 \times 10^{-19}$ J of kinetic energy. Initially, the kinetic energy of the electron was

$$K_i = \tfrac{1}{2} m_{elec} v_i^2 = \tfrac{1}{2}(9.11 \times 10^{-31} \text{ kg})(1.40 \times 10^6 \text{ m/s})^2 = 8.93 \times 10^{-19} \text{ J}$$

After losing 7.20×10^{-19} J in the collision, the kinetic energy is

$$K_f = K_i - 7.20 \times 10^{-19} \text{ J} = 1.73 \times 10^{-19} \text{ J} = \tfrac{1}{2} m_{elec} v_f^2 \Rightarrow v_f = \sqrt{\frac{2K_f}{m_{elec}}} = \sqrt{\frac{2(1.73 \times 10^{-19} \text{ J})}{9.11 \times 10^{-31} \text{ kg}}} = 6.16 \times 10^5 \text{ m/s}$$

HW # 12 Solutions

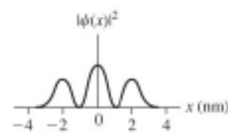
37.8. **(a)** No, you measured the left end first.
(b) Yes, experimenters in S' are at rest relative to the meter stick so they are measuring the proper length and the proper time.

37.9. Yes, the experimenters on the ground will measure the train as length contracted, and if it is going fast enough $L < 80$ m.

40.1. **(a)** At $x \approx 1$ because the probability density graph is higher there.
(b) From Equation 40.14 we see that $\text{Prob}(\text{in } \delta x \text{ at } x) = P(x)\delta x$. If 1,000,000 photons are detected then the number expected in a 1-mm-wide interval is $1{,}000{,}000 P(x)\delta x$ where $\delta x = 1.0$ mm. For $x = 0.25$ m, $P(x) = 0.5\ \text{m}^{-1}$ and the number expected is $1{,}000{,}000(0.5\ \text{m}^{-1})(0.0001\ \text{m}) = 500$. For $x = 0.75$ m, $P(x) = 1.5\ \text{m}^{-1}$ and the number expected is $1{,}000{,}000(1.5\ \text{m}^{-1}) \cdot (0.0001\ \text{m}) = 1500$.

40.2. The relationship between probability and probability density is similar to the relationship between mass m and mass density ρ. Regions of higher mass density tell us where mass is concentrated. The mass itself is a more tangible quantity that depends both on the mass density and on the size of a specific piece of material. Similarly, probability density tells us regions in which a particle is more likely, or less likely, to be found. The probability is a definite number between 0 and 1. Probability depends both on the probability density and on the

40.3. The probability of finding a particle at position x is determined by $|\psi(x)|^2$.



The electron is most likely to be found at the point or points where $|\psi(x)|^2$ is a maximum. The graph given in the problem shows ψ(x). The figure here shows $|\psi(x)|^2$. Notice that $|\psi(x = 0\ \text{nm})|^2 > |\psi(x = \pm 2\ \text{nm})|^2$, even though ψ (x = 0 nm) < 0 in the original graph. So, the electron is most likely to be found at x = 0 nm. The electron is least likely to be found where $|\psi(x)|^2$ is a minimum. From the figure, $|\psi(x)|^2 = 0$ at x = ±1 nm. Thus, the electron is *least* likely to be found at x = ±1 nm.

40.4. **(a)** The probability density is maximum at $x \pm 2$ mm.
(b) We cannot tell where the wave function is most positive; it could be at either $x = 2$ mm or $x = -2$ mm. It will be positive at one and negative at the other.

40.5. The area under the probability density curve must be one. That is, $\int_{-\infty}^{\infty} P(x)dx = 1$. For that to be true for Figure Q40.4, a must be $2\ \text{mm}^{-1}$, because the area of a triangle is half the base times the height.

40.6. Particle 1 because it has a less definite Δx and therefore a more definite $\Delta p = \Delta mv$.

37.39. Model: The hamburger is a classical particle whose rest energy is $E_0 = mc^2$.
Solve: (a) We have

$$E_0 = mc^2 = (200\times10^{-3}\text{ kg})(3.0\times10^8\text{ m/s})^2 = 1.8\times10^{16}\text{ J}$$

(b) The ratio of the energy equivalent to the food energy is

$$\frac{1.8\times10^{16}\text{ J}}{2\times10^6\text{ J}} = 9.0\times10^9$$

37.71. Model: Mass and energy are equivalent and given by Equation 37.43.
Solve: (a) The power plant running at full capacity for 80% of the year runs for

$$(0.80)(365\times24\times3600)\text{ s} = 2.52\times10^7\text{ s}$$

The amount of thermal energy generated per year is

$$3\times(1000\times10^6\text{ J/s})\times(2.52\times10^7\text{ s}) = 7.56\times10^{16}\text{ J} \approx 7.6\times10^{16}\text{ J}$$

(b) Since $E_0 = mc^2$, the mass of uranium transformed into thermal energy is

$$m = \frac{E_0}{c^2} = \frac{7.56\times10^{16}\text{ J}}{(3.0\times10^8\text{ m/s})^2} = 0.84\text{ kg}$$

37.72. Model: Mass and energy are equivalent and given by Equation 37.43.
Solve: (a) The sun radiates energy for 3.154×10^7 s per year. The amount of energy radiated per year is

$$(3.8\times10^{26}\text{ J/s})(3.154\times10^7\text{ s}) = 1.198\times10^{34}\text{ J/y}$$

Since $E_0 = mc^2$, the amount of mass lost is

$$m = \frac{E_0}{c^2} = \frac{1.198\times10^{34}\text{ J}}{(3.0\times10^8\text{ m/s})^2} = 1.33\times10^{17}\text{ kg} \approx 1.3\times10^{17}\text{ kg}$$

(b) Since the mass of the sun is 2.0×10^{30} kg, the sun loses 6.7×10^{-12} % of its mass every year.
(c) The lifetime of the sun can be estimated to be

$$T = \frac{2.0\times10^{30}\text{ kg}}{1.33\times10^{17}\text{ kg/y}} = 1.5\times10^{13}\text{ years}$$

The sun will not really last this long in its current state because fusion only takes place in the core and it will become a red giant when the core hydrogen is all fused.

40.10. Solve: $|\psi(x)|^2 \delta x$ is a probability, which is dimensionless. The units of δx are m, so the units of $|\psi(x)|^2$ are m^{-1} and thus the units of ψ are $\mathrm{m}^{-1/2}$.

40.6. Model: The probability density of finding a photon is directly proportional to the square of the light-wave amplitude $|A(x)|^2$.

Solve: The probability of finding a photon within a narrow region of width δx at position x is

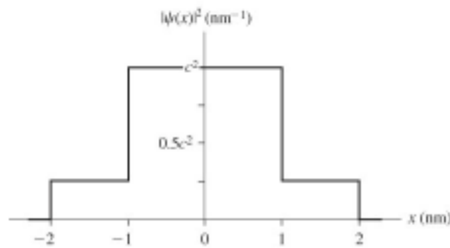
$$\text{Prob(in } \delta x \text{ at } x) \propto |A(x)|^2 \delta x \Rightarrow \frac{\text{Prob}(\text{in } \delta x_1 \text{ at } x_1)}{\text{Prob}(\text{in } \delta x_2 \text{ at } x_2)} = \frac{|A(x_1)^2|\delta x}{|A(x_2)^2|\delta x}$$

Let N be the total number of photons and N_2 the number of photons detected at x_2 in a width δx. The above equation simplifies to

$$\frac{2000/\mathrm{N}}{N_2/N} = \frac{(10\ \mathrm{V/m})^2(0.10\ \mathrm{mm})}{(30\ \mathrm{V/m})^2(0.10\ \mathrm{mm})} \Rightarrow N_2 = \frac{(2000)(30\ \mathrm{V/m})^2}{(10\ \mathrm{V/m})^2} = 18{,}000$$

40.16. Model: The probability of finding the particle is determined by the probability density $P(x) = |\psi(x)|^2$.

Solve: **(a)** According to Equation 40.18, $\int_{-\infty}^{\infty} |\psi(x)|^2 dx = 1$. We calculate this integral by drawing the graph of $|\psi(x)|^2$ and finding the area under the curve.



The area of the $|\psi(x)|^2$ versus x graph is

$$\int_{-2\,\mathrm{nm}}^{-1\,\mathrm{nm}} |\psi(x)|^2 dx + \int_{-1\,\mathrm{nm}}^{1\,\mathrm{nm}} |\psi(x)|^2 dx + \int_{1\,\mathrm{nm}}^{2\,\mathrm{nm}} |\psi(x)|^2 dx = (0.25c^2)(1\ \mathrm{nm}) + (c^2)(2\ \mathrm{nm}) + (0.25c^2)(1\ \mathrm{nm}) = 2.5c^2$$

$$\Rightarrow 2.5c^2\ \mathrm{nm} = 1 \Rightarrow c = \frac{1}{\sqrt{2.5}}\ \mathrm{nm}^{-1/2} = 0.632\ \mathrm{nm}^{-1/2}$$

(b) The graph is shown in part (a).
(c) The probability is

$$\text{Prob}(-1.0\ \mathrm{nm} \le x \le 1.0\ \mathrm{nm}) = \text{area} = (c^2)(2\ \mathrm{nm}) = \left(\frac{1}{2.5}\ \mathrm{nm}^{-1}\right)(2\ \mathrm{nm}) = 0.80$$

40.25. Model: Protons are subject to the Heisenberg uncertainty principle.
Solve: We know the proton is somewhere within the nucleus, so the uncertainty in our knowledge of its position is at most $\Delta x = L = 4.0$ fm. With a finite Δx, the uncertainty Δp_x is given by the uncertainty principle:

$$\Delta p_x = m\Delta v_x = \frac{h/2}{\Delta x} \Rightarrow \Delta v_x = \frac{h}{2mL} = \frac{6.63\times10^{-34}\text{ J s}}{2(1.67\times10^{-27}\text{ kg})(4.0\times10^{-15}\text{ m})} = 5.0\times10^{7}\text{ m/s}$$

Because the average velocity is zero, the best we can say is that the proton's velocity is somewhere in the range -2.5 $\times$
10^7 m/s to 2.5×10^7 m/s. Thus the smallest range of speeds is 0 to 2.5×10^7 m/s.

40.42. Model: A pulse is a wave packet, hence it must satisfy the relation $\Delta f\,\Delta t \approx 1$.
Solve: **(a)** The wavelength of 600 nm corresponds to a center frequency of

$$f_0 = \frac{c}{\lambda_0} = \frac{3\times10^{8}\text{ m/s}}{600\times10^{-9}\text{ m}} = 5.0\times10^{14}\text{ Hz}$$

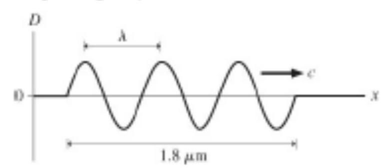
(b) The pulse duration is 6.0 fs, that is, $\Delta t = 6.0 \times 10^{-15}$ s. Because the time period of the center frequency is $T = f_0^{-1} = 2.0\times10^{-15}$ s, the number of cycles in the pulse is

$$\frac{\Delta t}{T} = \frac{6.0\times10^{-15}\text{ s}}{2.0\times10^{-15}\text{ s}} = 3$$

(c) The frequency bandwidth for a 6.0-fs-long pulse is

$$\Delta f = \frac{1}{\Delta t} = \frac{1}{6.0\times10^{-15}\text{ s}} = 1.67\times10^{14}\text{ Hz}$$

This bandwidth is centered on $f_0 = 5.00 \times 10^{14}$ Hz, so the necessary range of frequencies from $f_0 - \frac{1}{2}\Delta f$ to $f_0 + \frac{1}{2}\Delta f$ is from 4.17×10^{14} Hz to 5.83×10^{14} Hz.
(d) The pulse travels at speed c, so the length is $\Delta x = c\Delta t = (3.0 \times 10^8\text{ m/s})(6.0 \times 10^{-15}\text{ s}) = 1.8 \times 10^{-6}\text{ m} = 1.8$ μm. This is 3λ, in agreement with the finding that there are 3 cycles in the pulse.
(e) The graph has three oscillations spanning 1.8 μm $= 3\lambda$.



ASSIGNMENT # 11
Problem 1 SOLUTION

1. Since the speed of light is 20 miles/hr moving at 18 miles per hour the value of gamma is γ= 2.3 and as a result the car inertia is more than twice larger (i.e. the car is more than twice heavier) and it is difficult to accelerate.
2. The height of the car does not change but its length shrinks in Mr. Sceptic's frame by gamma, it namely becomes 3/2.3 meters. As a result the aspect ratio changes from 3 to 1.3.
3. In Mr. Sceptic's frame the width of the car is 1/2.3 meters=.43 meters. The car that had a three to one aspect ratio now has 6.9 aspect ratio. Looks as made out of rubber. The same for the ratio of height to width that was1:1 and now 2.3
4. The car looks squashed since it moves at 12m/hour past Mr.Sceptic and in his frame he sees the same height but a length2.3 longer.
5. Since they move with the same speed there is no transformation. All normal in their reference frame.
6. From 4:36 to 4:16 -> 20 minutes. From 4:50 to 4:16-> 34 minutes.