PHYS 201 Winter 2010

Recitation Problems (Week 4)

All problems taken from *University Physics,* Young and Freedman, 12th Ed.

30.36. **IDENTIFY:** Evaluate $\frac{d^2q}{dt^2}$ and insert into Eq.(20.20).

SET UP: Equation (30.20) is $\frac{d^2q}{dt^2}+\frac{1}{LC}q=0$.

EXECUTE: $q=Q\cos(\omega t+\phi)\Rightarrow\frac{dq}{dt}=-\omega Q\sin(\omega t+\phi)\Rightarrow\frac{d^2q}{dt^2}=-\omega^2Q\cos(\omega t+\phi)$.

$$\frac{d^2q}{dt^2}+\frac{1}{LC}q=-\omega^2Q\cos(\omega t+\phi)+\frac{Q}{LC}\cos(\omega t+\phi)=0\Rightarrow\omega^2=\frac{1}{LC}\Rightarrow\omega=\frac{1}{\sqrt{LC}}.$$

EVALUATE: The value of ϕ depends on the initial conditions, the value of q at $t=0$.

32.1. **IDENTIFY:** Since the speed is constant, distance $x=ct$.

SET UP: The speed of light is $c=3.00\times10^8$ m/s. 1 yr $=3.156\times10^7$ s.

EXECUTE: **(a)** $t=\frac{x}{c}=\frac{3.84\times10^8\text{ m}}{3.00\times10^8\text{ m/s}}=1.28\text{ s}$

(b) $x=ct=(3.00\times10^8\text{ m/s})(8.61\text{ yr})(3.156\times10^7\text{ s/yr})=8.15\times10^{16}\text{ m}=8.15\times10^{13}\text{ km}$

EVALUATE: The speed of light is very great. The distance between stars is very large compared to terrestrial distances.

32.4. **IDENTIFY:** $c=f\lambda$ and $k=\frac{2\pi}{\lambda}$.

SET UP: $c=3.00\times10^8$ m/s.

EXECUTE: **(a)** $f=\frac{c}{\lambda}$. UVA: 7.50×10^{14} Hz to 9.38×10^{14} Hz. UVB: 9.38×10^{14} Hz to 1.07×10^{15} Hz.

(b) $k=\frac{2\pi}{\lambda}$. UVA: 1.57×10^7 rad/m to 1.96×10^7 rad/m. UVB: 1.96×10^7 rad/m to 2.24×10^7 rad/m.

EVALUATE: Larger λ corresponds to smaller f and k.

32.15. **IDENTIFY:** $I=P/A$. $I=\frac{1}{2}\epsilon_0cE_{max}^2$. $E_{max}=cB_{max}$.

SET UP: The surface area of a sphere of radius r is $A=4\pi r^2$. $\epsilon_0=8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2$.

EXECUTE: **(a)** $I=\frac{P}{A}=\frac{(0.05)(75\text{ W})}{4\pi(3.0\times10^{-2}\text{ m})^2}=330\text{ W/m}^2$.

(b) $E_{max}=\sqrt{\frac{2I}{\epsilon_0c}}=\sqrt{\frac{2(330\text{ W/m}^2)}{(8.85\times10^{-12}\text{ C}^2/\text{N}\cdot\text{m}^2)(3.00\times10^8\text{ m/s})}}=500\text{ V/m}$. $B_{max}=\frac{E_{max}}{c}=1.7\times10^{-6}\text{ T}=1.7\ \mu\text{T}$.

EVALUATE: At the surface of the bulb the power radiated by the filament is spread over the surface of the bulb. Our calculation approximates the filament as a point source that radiates uniformly in all directions.

32.16. **Identify and Set Up:** The direction of propagation is given by $\vec{E}\times\vec{B}$.

Execute: **(a)** $\hat{S}=\hat{i}\times(-\hat{j})=-\hat{k}$.

(b) $\hat{S}=\hat{j}\times\hat{i}=-\hat{k}$.

(c) $\hat{S}=(-\hat{k})\times(-\hat{i})=\hat{j}$.

(d) $\hat{S}=\hat{i}\times(-\hat{k})=\hat{j}$.

Evaluate: In each case the directions of $\vec{E}$, $\vec{B}$ and the direction of propagation are all mutually perpendicular.

32.54. **Identify:** For a totally reflective surface the radiation pressure is $\frac{2I}{c}$. Find the force due to this pressure and express the force in terms of the power output P of the sun. The gravitational force of the sun is $F_g=G\frac{mM_{sun}}{r^2}$.

Set Up: The mass of the sum is $M_{sun}=1.99\times10^{30}$ kg. $G=6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$.

Execute: **(a)** The sail should be reflective, to produce the maximum radiation pressure.

(b) $F_{rad}=\left(\frac{2I}{c}\right)A$, where A is the area of the sail. $I=\frac{P}{4\pi r^2}$, where r is the distance of the sail from the sun.

$F_{rad}=\left(\frac{2A}{c}\right)\left(\frac{P}{4\pi r^2}\right)=\frac{PA}{2\pi r^2 c}$. $F_{rad}=F_g$ so $\frac{PA}{2\pi r^2 c}=G\frac{mM_{sun}}{r^2}$.

$$A=\frac{2\pi cGmM_{sun}}{P}=\frac{2\pi(3.00\times10^8\ \text{m/s})(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(10{,}000\ \text{kg})(1.99\times10^{30}\ \text{kg})}{3.9\times10^{26}\ \text{W}}.$$

$A=6.42\times10^6\ \text{m}^2=6.42\ \text{km}^2$.

(c) Both the gravitational force and the radiation pressure are inversely proportional to the square of the distance from the sun, so this distance divides out when we set $F_{rad}=F_g$.

Evaluate: A very large sail is needed, just to overcome the gravitational pull of the sun.

37.25. **Identify and Set Up:** Source and observer are approaching, so use Eq.(37.25): $f=\sqrt{\frac{c+u}{c-u}}f_0$. Solve for u, the speed of the light source relative to the observer.

(a) Execute: $f^2=\left(\frac{c+u}{c-u}\right)f_0^2$

$(c-u)f^2=(c+u)f_0^2$ and $u=\frac{c(f^2-f_0^2)}{f^2+f_0^2}=c\left(\frac{(f/f_0)^2-1}{(f/f_0)^2+1}\right)$

$\lambda_0=675$ nm, $\lambda=575$ nm

$u=\left(\frac{(675\ \text{nm}/575\ \text{nm})^2-1}{(675\ \text{nm}/575\ \text{nm})^2+1}\right)c=0.159c=(0.159)(2.998\times10^8\ \text{m/s})=4.77\times10^7$ m/s; definitely speeding

(b) $4.77\times10^7\ \text{m/s}=(4.77\times10^7\ \text{m/s})(1\ \text{km}/1000\ \text{m})(3600\ \text{s}/1\ \text{h})=1.72\times10^8$ km/h. Your fine would be \$$1.72\times10^8$ (172 million dollars).

Evaluate: The source and observer are approaching, so $f>f_0$ and $\lambda<\lambda_0$. Our result gives $u<c$, as it must.