Phys 4E Week 1 HW

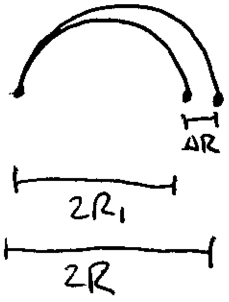
Ch 3: 2, 6, 11, 15, 21, 22, 25, 32, 34, 38, 41, 42, 46

2 a) Mag force $= qvB = \frac{mv^2}{r}$

So $B = \frac{mv}{qr}$.

For ^{197}Au, $m = 197u$, so $\boxed{B = 0.31\,T}$
and it's basically the same for ^{198}Hg.

b So let's say they move in a mag. field of $B = 0.31T$
Their radii will be slightly different, given by



$r = \frac{mv}{qB}$. The distance between them is the difference of their diameters, so

$$\Delta R = 2(r_{Hg} - r_{Au}) = \frac{2v}{qB}(m_{Hg} - m_{Au}) = \frac{2v}{qB}(1u)$$

$$= \boxed{1\,cm}$$

c] If $q \to 2q$, then $B \to \frac{B}{2}$ in step a].

But since $r \sim (qB)^{-1}$, the radii <u>don't change</u>.

6]

a] $2000\ \text{eV} = \frac{1}{2} m_e v^2$. $\quad m_e = \frac{0.511\ \text{MeV}}{c^2}$, so

$$v^2 = \frac{2(2000\ \text{eV})}{0.511\ \text{MeV}} c^2 = 7.8 \times 10^{-3} c^2$$

$$\Rightarrow \boxed{v = 8.8 \times 10^{-2} c = 2.7 \times 10^{7}\ \text{m/s}}$$

Fast, but not relativistic!

b] $t = \frac{d}{v} = \boxed{1.88 \times 10^{-9}\ \text{s}}$

c] $a = \frac{qE}{m}$, and $v = at$, so $v = \frac{qEt}{m} = \boxed{1.1 \times 10^{6}\ \text{m/s}}$

11] a] Gotta go to their website for the eqns here, but the short version is that all you need to know is that the drag force is given by

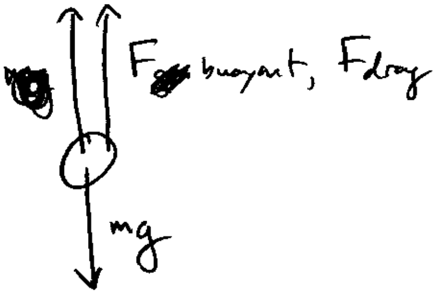
$$F_{drag} = 6\pi \underset{\substack{\uparrow \\ \text{viscosity}}}{\eta}\, \underset{\substack{\uparrow \\ \text{radius}}}{r}\, v \nwarrow \text{speed}.$$

So The forces are:

1) Gravity $= mg = \frac{4}{3}\pi r^3 \rho_{oil}\, g$

2) Drag $= 6\pi \eta r v$

3) Buoyant force $= \frac{4}{3}\pi r^3 \rho_{air}\, g$ (i.e. weight of displaced air).



So $$\boxed{6\pi\eta r v + \frac{4}{3}\pi r^3 \rho_{air}\, g = \frac{4}{3}\pi r^3 \rho_{oil}\, g}$$

$$\Rightarrow \quad \frac{4}{3}\pi r^3 g(\rho_{oil} - \rho_{air}) = 6\pi\eta r v$$

$$\Rightarrow \quad r^2 = \frac{6\pi\eta v}{\frac{4}{3}\pi g(\rho_{oil} - \rho_{air})}$$

~~spec~~

Use $v = \frac{5\,mm}{20\,s} = 2.5\times10^{-4}\, m/s$ and $\rho = (\text{spec. grav})\rho_{H_2O}$
$= (\text{spec. grav})(1000\, kg/m^3)$

to get $\boxed{r = 1.66\times10^{-6}\, m}$ so $m = \frac{4}{3}\pi r^3 \rho_{oil} = \boxed{1.44\times10^{-14}\, kg}$

b] $F_{elec} = qE$, $F_{grav} = mg$

So $\frac{F_{elec}}{F_{grav}} = \frac{qE}{mg} = \boxed{0.57}$

15]

a] $\lambda_m = \frac{2.898\times10^{-3}\,m}{2.7K} = \boxed{1.07\times10^{-3}\,m}$

b] $f = \frac{c}{\lambda} = \boxed{2.8\times10^{11}\,Hz}$

c] $\frac{Power}{Area} = \sigma T^4 = 3.01\times10^{-6}$

$Area = 4\pi(R_{\oplus Earth})^2 = 4\pi(6.38\times10^{6}\,m)^2$

So $Power = \sigma T^4 (4\pi R_E)^2 = \boxed{1.54\times10^{9}\,W}$

21] Equilibrium: Power absorbed = Power emitted.

At any given time, the Sun shines on $\frac{1}{2}$ the Earth:

So $P_{abs} = (1.36\times10^{3})\,\frac{1}{2}$(Surface area of Earth)

But $P_{emitted} = \sigma T^4$(Surf. area of Earth)

assuming the whole Earth blackbody radiates. :

$$\therefore \quad T^4 = \frac{1.36\times10^{3}}{2\sigma} \Rightarrow \boxed{T = 330K = 57°C}$$

Seems a little high...

22] a] $\lambda_m T = 2.898\times10^{-3}\,K \Rightarrow \boxed{\lambda_m = 8.78\times10^{-7}\,m}$

$$\boxed{f = \frac{c}{\lambda} = 3.4\times10^{14}\,Hz}$$

b] $E_{photon} = hf.$

$$P_{bulb} = 40\,J/s \Rightarrow \frac{Photons}{sec} = \frac{40}{hf} = \boxed{1.77\times10^{20}}$$

c] Intensity $= \frac{40W}{4\pi(5m)^2} \Rightarrow \frac{Power}{sec} = \frac{40W}{4\pi(5m)^2}\cdot\left(\pi(2.5mm)^2\right)$

$$\Rightarrow \frac{\#photons}{sec} = \frac{40\cdot\cancel{\pi}\cdot(.0025)^2}{4\cancel{\pi}\cdot25\cdot hf} = \boxed{1.10\times10^{13}}$$

25]

a] $\frac{hc}{\lambda_{max}} = \phi \Rightarrow \boxed{\lambda_{max} = 255\ \text{nm}}$

b] The total power is $\int_0^{\infty} R(\lambda)\,d\lambda$. The only λ's that eject electrons are $\lambda < 255\ \text{nm}$, so that much power is $\int_0^{255\,\text{nm}} R(\lambda)\,d\lambda$. $\Rightarrow$ Fraction $= \frac{\int_0^{255\,\text{nm}} R(\lambda)\,d\lambda}{\int_0 R(\lambda)\,d\lambda}$.

We know that

$$R(\lambda) = \frac{c}{4}\,\frac{8\pi hc\,\lambda^{-5}}{e^{hc/\lambda kT}-1}$$

$\Rightarrow$ We need integrals like

$$2\pi hc^2 \int \frac{\lambda^{-5}}{e^{hc/\lambda kT}-1}\,d\lambda \xrightarrow{x = \frac{hc}{\lambda kT}\ \text{(See p.140)}} 2\pi hc^2 \left(\frac{kT}{hc}\right)^4 \int \frac{x^3}{e^x-1}\,dx.$$

The only difference is the limits of integration:

$\lambda = 0 \Rightarrow x = \infty$; $\lambda = \infty \Rightarrow x = 0$,

$\lambda = 255\ \text{nm} \Rightarrow x = \frac{hc}{(255\,\text{nm})kT} = 9.7$

$$\Rightarrow \text{Fraction} = \frac{\int_{27}^{\infty} \frac{x^3}{e^x-1}\,dx}{\int_0^{\infty} \frac{x^3}{e^x-1}\,dx} = \frac{\overset{\text{Numerically!}}{0.077}}{\pi^4/15} = \boxed{1.19\times10^{-2}}$$

32] $\frac{hc}{\lambda_{max}} = \phi \Rightarrow \boxed{\phi = 1.9\,eV}$

b] $KE = \frac{hc}{\lambda} - \phi = \boxed{2.23\,eV}$

34] Work function is negligible $\Rightarrow 80\,keV = \frac{hc}{\lambda}$

$$\Rightarrow \lambda = \frac{hc}{80\,keV} = \frac{1240\,nm}{80{,}000} = \boxed{1.55\times10^{-2}\,nm}$$

38] a] $E = \frac{hc}{\lambda} = 1.74\times10^{4}\,eV = \boxed{17.4\,keV}$

b] $\Delta\lambda = 2\lambda_c = 0.00486\,nm \Rightarrow \boxed{\lambda' = .0760\,nm}$

c] $E = \frac{hc}{\lambda} = \boxed{16.3\,keV}$

d] $\frac{hc}{\lambda} - \frac{hc}{\lambda'} = \boxed{1100\,eV}$

41] a] $\lambda_c = \frac{h}{mc} \Rightarrow \lambda_{c,e^-} = 0.0024$ nm

$$\lambda_{c,p} = 1,32 \text{ fm}$$

b] 1) $\frac{hc}{\lambda_{c,e}} = \boxed{0.52 \text{ MeV}}$

2) $\frac{hc}{\lambda_{c,p}} = \boxed{939 \text{ MeV}}$

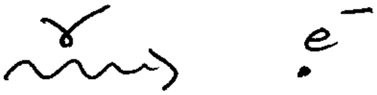
42] $eV_1 = \frac{hc}{\lambda_1} - \phi$

$$eV_2 = \frac{hc}{\lambda_2} - \phi$$

b] Subtract: $e(V_1 - V_2) = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$

$$\Rightarrow h = \frac{e(V_1 - V_2)}{c\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)} = \boxed{6.624 \times 10^{-34}}$$

a] $\phi = \frac{hc}{\lambda_1} - eV_1 = \boxed{2.24 \text{ eV}}$

46| Before: 

After: 

Let's say the initial (and final) momentum is zero.

This frame looks like 

$$\therefore \; p_\gamma = p_{e^-} \equiv p$$

But we also have Energy Conservation:

$$pc + \sqrt{p^2c^2 + m^2c^4} = mc^2$$

$$\Rightarrow \quad pc - mc^2 = -(p^2c^2 + m^2c^4)^{1/2}$$

$$\Rightarrow \quad p^2c^2 - 2pmc^3 + m^2c^4 = p^2c^2 + m^2c^4$$

$$\Rightarrow \quad 2pmc^3 = 0$$

$$\Rightarrow \boxed{p = 0}$$

But light can <u>never</u> have $p = 0$ — that means there's no photon! ⊗ Contradiction.