(3.3)

classical $qV = \frac{1}{2}mv^2$

$$V = \frac{\frac{1}{2}mv^2}{q}$$

$$= \frac{9.1 \times 10^{-31}\,\text{kg} \cdot (2 \times 10^{7}\,\text{m/s})^2}{2\,(1.6 \times 10^{-19})}$$

$$= 1137.1\ \text{V}$$

relativistic

$$qV = \gamma mc^2 - mc^2$$

$$\gamma = \frac{1}{\sqrt{1-(0.066)^2}} = 1.00223$$

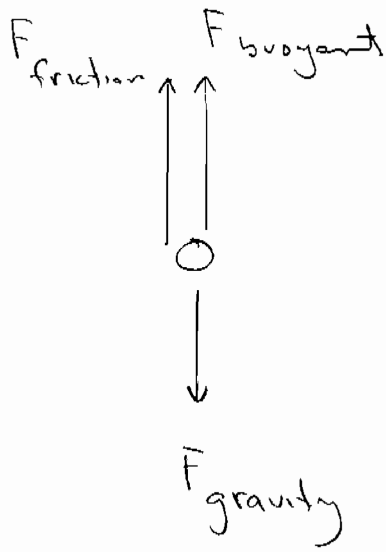
$$\Rightarrow V = \frac{(1.00223 - 1)\,0.511\ \text{MeV}}{e}$$

$$= 1139.3\ \text{V}$$

relativity is not needed unless precision better than 0.2% is required

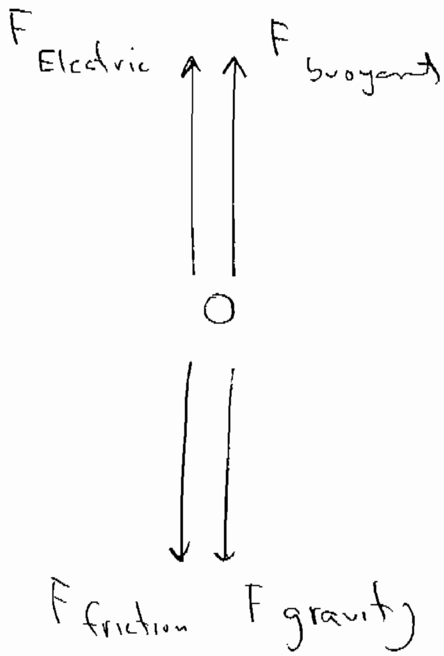
(3.5)

a)



F friction
F buoyant
F gravity

b)



F Electric
F buoyant
F friction
F gravity

3.14

a)

Balmer $n=2$

$3 \to 2$	red	656.5 nm
$4 \to 2$	blue-green	486.3
$5 \to 2$	violet	434.2
$6 \to 2$	violet	410.3

b) observed

537.5

480.1

453.4

the $3 \to 2$ red line has been red shifted out of the visible range

$\Rightarrow$ source is receding

c)

$$f = \frac{\sqrt{1-\beta}}{\sqrt{1+\beta}} f_0$$

$$a = \frac{\lambda_{obs}}{\lambda_{source}} = \frac{\sqrt{1+\beta}}{\sqrt{1-\beta}}$$

$$(1-\beta)a^2 = 1+\beta$$

$$a^2 - a^2\beta = 1+\beta$$

$$\beta(a^2+1) = a^2 - 1$$

$$\beta = \frac{a^2-1}{a^2+1} = \frac{\left(\frac{\lambda_o}{\lambda_s}\right)^2 - 1}{\left(\frac{\lambda_o}{\lambda_s}\right)^2 + 1}$$

e.g. $\lambda_o = 453.4$ nm $\Rightarrow \beta = 0.0995$
$\lambda_s = 410.3$ nm

a rotating source would give a spread of shifted wavelengths

3.20

a

$$\lambda T = 2.898 \times 10^{-3}\ \mathrm{mK}$$

$$\lambda = \frac{2.898 \times 10^{-3}\ \mathrm{mK}}{273 + 37} = 9.35\ \mu\mathrm{m}\ \ (\mathrm{IR})$$

$$R = \sigma T^4 = (5.67 \times 10^{-8})(310)^4 = 524\ \mathrm{W/m^2}$$

$$P = R \cdot A = (524)(2\pi r^2 + 2\pi r h)$$

$$= (524)(2\pi)(0.13^2 + 0.13 \cdot 1.65)$$

$$= 760\ \mathrm{W}$$

3.29

$$r = (n_x^2 + n_y^2 + n_z^2)^{1/2}$$

$$n_x, n_y, n_z > 0$$

$\Rightarrow$ dN between r and $r + dr$ is

1/8 of a sphere

$$dN = \frac{1}{8} \underbrace{4\pi r^2 dr}_{\text{volume of the spherical shell}}$$

or $\quad r^2 = n_x^2 + n_y^2 + n_z^2 = \dfrac{\Omega^2 L^2}{\pi^2 c^2} = \dfrac{4 L^2 f^2}{c^2}$

$$\Rightarrow \quad r = \frac{2Lf}{c}$$

$$\Rightarrow \quad dr = \frac{2L}{c}\, df$$

$$dN = \frac{1}{8} 4\pi r^2 dr$$

$$= \frac{1}{8} 4\pi \frac{4L^2 f^2}{c^2} \frac{2L}{c} df$$

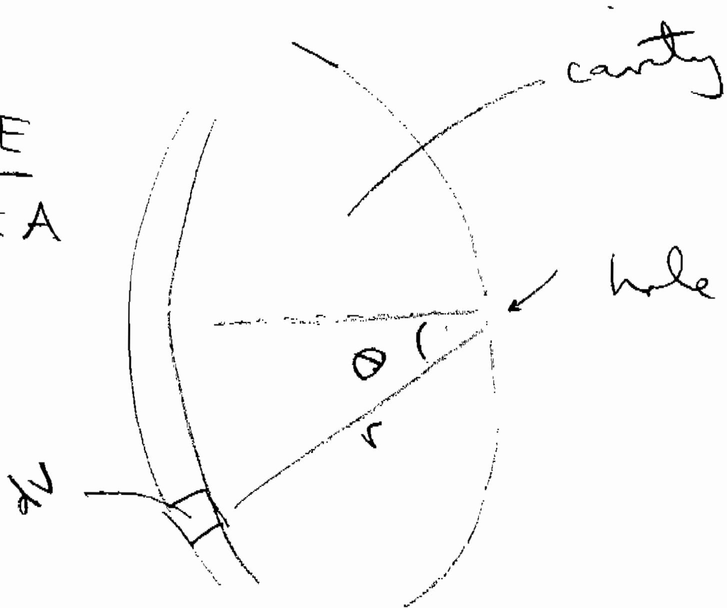
$$= \frac{4\pi L^3}{c^3} f^2 df$$

3.20

in class we calculated the energy density of black body radiation

$$U = \frac{E}{V}$$

we want the intensity $I = \frac{E}{tA}$



light that is $r = ct$ away from the hole can make it through the hole

energy leaving the hole in dt must come from a shell thickness $c\,dt$

consider a volume element in the shell

$$dV = r^2 dr \sin\theta \, d\theta \, d\varphi$$

note the hole won't perpendicular to r - only light perpendicular to r will ~~escape~~

fraction escaping from dV

$$\frac{A \cos\theta}{4\pi r^2}$$

energy escaping from dV

$$\frac{A \cos\theta}{4\pi r^2} dE = A \, dI \, dt$$

$$\frac{A \cos\theta}{4\pi r^2} U dV = A \, dI \, dt$$

$$\frac{\cancel{A}\cos\theta}{4\pi \cancel{r^2}}\, U \cdot \cancel{r^2}\, \overset{cdt}{dr} \sin\theta \, d\theta \, d\varphi = \cancel{A}\, dI\, dt$$

$$\frac{U}{4\pi} c \cos\theta \sin\theta \, d\theta \, d\varphi = dI$$

$$I = \frac{Uc}{4\pi} \int_0^{2\pi}\int_0^{\pi/2} \cos\theta \sin\theta \, d\theta , d\varphi$$

$$= \frac{Uc}{4\pi}\, 2\pi \cdot \frac{1}{2}$$

$$I = \frac{Uc}{4}$$

$$I \Delta A = \frac{Uc}{4} \Delta A$$