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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

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

$$\gamma = \frac{1}{\sqrt{1 - (0.06)^2}} = 1.00223$$

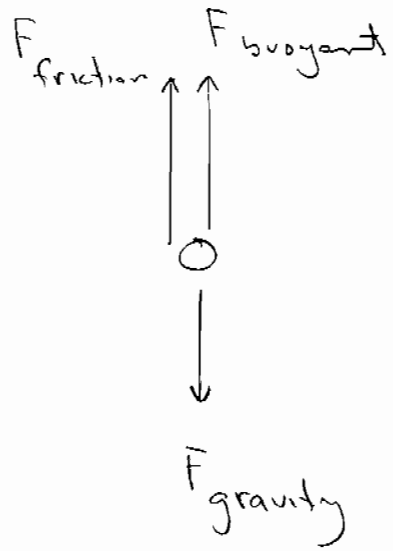
$$\Rightarrow V = \frac{(1.00223 - 1) 0.511 \text{ MeV}}{e}$$

$$= 1139.3 \text{ V}$$

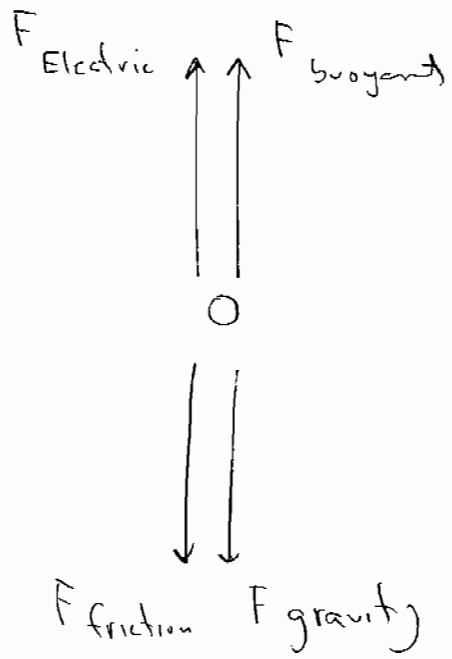
relativity is not needed unless precision better than 0.2% is required

3.5

a)



b)



3.14

a)

Balmer $n=2$

3 → 2	red	656.5 nm
4 → 2	blue-green	486.3
5 → 2	violet	434.2
6 → 2	violet	410.3

b) observed

537.5

480.1

453.4

the 3 → 2 red line has been red shifted
out of the visible range

⇒ source is receding

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

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

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

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

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

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

$$\text{e.g. } \lambda_o = 453.4 \text{ nm}$$

$$\lambda_s = 410.3 \text{ nm}$$

$$\Rightarrow \beta = 0.0995$$

a rotating source would give a spread of shifted wavelengths

3.20

a

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

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

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

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

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

$$= 760 \text{ W}$$

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

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

⏟
volume of the
spherical shell

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

$$\Rightarrow r = \frac{2L f}{c}$$

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

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

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

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

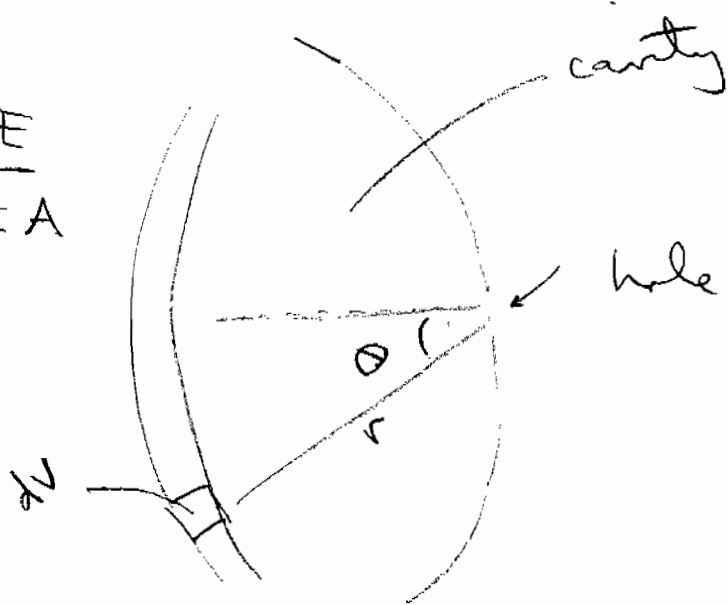
3.30

in class we calculated the energy density of blackbody radiation

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

we want the

$$\text{intensity } I = \frac{E}{tA}$$



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 cdt

13.782 670 SHEETS, FILLER 5 SQUARE
12.381 50 SHEETS EYE-GLASS 5 SQUARE
12.382 75 SHEETS EYE-GLASS 5 SQUARE
12.383 100 SHEETS EYE-GLASS 5 SQUARE
12.384 150 SHEETS EYE-GLASS 5 SQUARE
12.385 200 SHEETS EYE-GLASS 5 SQUARE
12.386 100 RECYCLED WHITE 5 SQUARE
12.387 200 RECYCLED WHITE 5 SQUARE
Made in U.S.A.



consider a volume element in the shell

$$dV = r^2 dr \sin\theta d\theta d\phi$$

note the hole isn'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

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

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

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$$\frac{A \cos \theta}{4\pi r^2} \cdot \overset{cdt}{r^2} d\Omega = A dI dt$$

$$\frac{Uc}{4\pi} \cos \theta \sin \theta d\theta d\phi = dI$$

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

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

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

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