8.01 Problem Set - I

1.1 5 ft 9 inches $= 5 + \frac{9}{12}$ feet $= 5.75$ ft

$= 5.75 \times 0.3048$ m $=$ $\underline{1.75 \text{ m}}$

1.2 Age of Earth $= 4.5 \times 10^9$ yr $= 4.5 \times 10^9 \times 365 \times 24 \times 3600$ s

$= 141912000 \times 10^9$
$= \underline{1.4 \times 10^{17} \text{ sec}}$.

1.3 a) Harry Potter and the Prisoner of Azkaban
thickness $= 2.1$ cm $=$ ~~210~~ $\underline{21 \text{ mm}}$

b) Uncertainity $=$ $\underline{\pm 1 \text{ mm}}$

c) Relative Uncertainty $= \frac{1}{21} \times 100 \doteq \underline{4.8\%}$

d) Total no. of pages $-$ $\underline{168}$

thicknes ~~of~~ page $= \frac{21 \pm 1 m}{168} = 0.125$ mm $\pm \frac{1}{168}$ mm

$= \underline{125\ \mu m \pm 6\ \mu m}$

e) Uncertainity $=$ $\underline{\pm 6\ \mu m}$

f) Relative Uncertainity $= \frac{6}{125} \times 100 = \underline{4.8\%}$

g) geographical location (climate). humidity of air affects thickness.

1.4 Student's length = 183.2 ± 0.1 cm

Relative Uncertainity $= \frac{0.1}{183.2} \times 100 = 0.05\%$.

Antilope Femur Thickness = 18.3 ± 1 mm

Relative Uncertainity $= \frac{1}{18.3} \times 100 = 5.46\%$.

- The uncertainity of both are the same but as the student's height is much larger than the thickness of the femurs, the relative uncertainity is different.

1.5 $d = 12.4 \times 10^9$ light years

$= 12.4 \times 10^9 \times 3 \times 10^8 \frac{m}{s} \times 365 \times 24 \times 3600\ s$

$= 1.17 \times 10^{26}\ m$

In the figure, 1 unit $= 10^{17}$ m

The quasar will be $\frac{1.17 \times 10^{26}}{10^{17}} = 1.17 \times 10^9$ units from Earth.

$r = 1.17 \times 10^9$

1.7 $M = 73kg$

Oxygen

$M_O = \frac{65}{100} \times 73 = 47.45\ kg = 47450\ g$

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mass of one O atom $= \frac{16g}{N_A} = 2.66 \times 10^{-23} g$

no. of O atoms $= \frac{M_O}{O_m} = \underline{1.78 \times 10^{27}}$

Nitrogen

$M_N = \frac{3.3}{100} \times 73 = 2.409 \text{ kg} = \cancel{20}\ 2409 g$

$N_m = \frac{14}{N_A} = 2.32 \times 10^{-23} g$

no of N atoms $= \frac{M_N}{N_m} = \underline{1.04 \times 10^{26}}$

Carbon

$M_c = \frac{18.5}{100} \times 73 = 13505g$

$C_M = \frac{12}{N_A} = 1.99 \times 10^{-23} g$

no. of C atoms $= \frac{M_c}{C_M} = \underline{6.78 \times 10^{26}}$

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<u>Phosphorous</u>

$M_P = \frac{1}{100} \times 73 = 730g$

$P_M = \frac{31}{N_A} = 5.15 \times 10^{-23} g$

no. of P atoms = $\frac{M_P}{P_m} = \underline{1.42 \times 10^{25}}$

<u>Hydrogen</u>

$M_H = \frac{9.5}{100} \times 73 = 6935g$

$H_M = \frac{1}{N_A} = 1.66 \times 10^{-24} g$

no. of H atoms = $\frac{M_H}{H_M} = \underline{4.18 \times 10^{27}}$

<u>Calcium</u>

$M_{Ca} = \frac{1.5}{100} \times 73 = 1095g$

$Ca_M = \frac{40}{N_A} = 6.64 \times 10^{-23}$

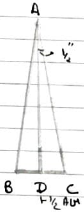
no. of Ca atoms = $\underline{1.65 \times 10^{25}}$

Total Atoms = 6.77×10^{27} //

1.8 (a) pc → AU

from ΔADC,

$$\tan(\tfrac{1}{2}'') = \frac{\tfrac{1}{2}\text{ AU}}{1\text{pc}}$$



$$1\text{pc} = \frac{\tfrac{1}{2}\text{ AU}}{\tan(\tfrac{1}{2}\cdot\tfrac{1}{3600}^{\circ})} = \underline{\underline{2.06\times10^{5}\text{ AU}}}$$

(b) $1\text{pc} = 2.06\times10^{5}\text{ AU} \times \frac{1.496\times10^{11}\text{ m}}{1\text{ AU}}$

$$= \underline{\underline{3.09\times10^{16}\text{ m}}}$$

(b) $1\text{p} = 3.09\times10^{16}\text{ m} \times \frac{1\text{ ly}}{9.45\times10^{15}\text{ m}} = \underline{\underline{3.27}}$ light years

1.9(56) $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

Mass $= 2.0\times10^{30}$ kg

Volume $= \frac{4}{3}\pi(7.0\times10^{8})^3\text{ m}^3 = 1.44\times10^{27}\text{ m}^3$

$$\text{Density} = \frac{2.0\times10^{30}\text{ kg}}{1.44\times10^{27}\text{ m}^3} = 1388.89\text{ kg/m}^3$$

$$= 1388.89\frac{\text{kg}}{\text{m}^3}\times\frac{1000\text{g}}{1\text{kg}}\times\left(\frac{1\text{m}}{100\text{cm}}\right)^3$$

$$= 1.389\text{ g/cm}^3$$

(57)

$$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$

$$\text{Volume} = \frac{4}{3}\pi (20000)^3 \ m^3 = 3.35 \times 10^{13} \ m^3$$

$$\text{Mass} = 2 \times 10^{30} \ kg$$

$$\text{Density} = \frac{2 \times 10^{30}}{3.35 \times 10^{13}} = 5.97 \times 10^{16} \ kg/m^3$$

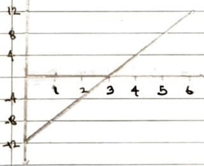
$$= 5.97 \times 10^{16} \frac{kg}{m^3} \left(\frac{1 \text{ tonne}}{1000 kg}\right) \cdot \left(\frac{1 m}{100 cm}\right)^3$$

$$= \underline{\underline{5.97 \times 10^{7} \text{ tonne}/cm^3}}$$

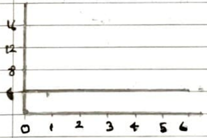
1.10 a)

$x = 16 - 12t + 2t^2$ m

b) $v = \frac{dx}{dt} = -12 + 4t$ m/s



c) $a = \frac{dv}{dt} = 4 \ m/s^2$



d) $v_0 = -12 + 4 \cdot 0 = -12 \ m/s$
$v_2 = -12 + 8 = -4 \ m/s$
$v_4 = -12 + 16 = 4 \ m/s$

e) $a_0 = a_2 = a_4 = 4 \ m/s^2$

f) $v = 0$ when $t = 3$
$x = -2 \ m$

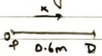
g) $\bar{v}_{-1,3} = \frac{x_3 - x_{-1}}{3 - -1} = \frac{-2 - 30}{4} = \frac{-32}{4} = \underline{\underline{-8}} \ m/s$

h) $\bar{v}_{0,6} = \dfrac{x_6 - x_0}{6-0} = \dfrac{16-16}{6} = \underline{\underline{0}}\ m/s$

i) ave. speed $= \dfrac{\text{distance}}{\text{time}} = \dfrac{18+18}{6} = \underline{\underline{6}}\ m/s$

j) At $t=3$, the object reverses its direction from negative to positive.

1.11 Initially



$\cancel{x_p =}\ V_0 = 50\ km/h = 14\ m/s$
$a = -200\ m/s^2$

for the person, $x_0 = 0$, $v_0 = \cancel{50}\ 14\ m/s$, $a = 0$

$x_p = 14t$

for the automobile, $x_0 = 0.6$, $v_0 = 14$, $a = -200\ m/s^2$

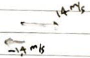
$x_D = 0.6 + 14t - \dfrac{200t^2}{2}$

Let the collision happen at t_c

$x_p = x_D \quad (t = t_c)$
$14t_c = 0.6 + \cancel{14t_c} - 100t_c^2$

$t_c = \sqrt{\dfrac{0.6}{100}} = 0.077s$

At $t = t_c$,



$v_P = 14 \text{ m/s}$

$v_D = 14 - 100t_c = -1.4 \text{ m/s}$

this means that the car reached $v = 0$ before t_c and is now reversing

$v_{rel} = 14 - -1.4 = \underline{\underline{15.4 \text{ m/s}}}$

1.12 Divide the earth into latitudes and longitudes. The points which ~~have~~ meet the condition are –

- The <u>North Pole</u> – All longitudes meet at this point.

- Consider circles of circumference 10 km, near the south pole. Moving 10 km east will bring you back to the same point you started.
  This is true for all circles with circumference $\frac{10}{k}$ km where $k = 1, 2, 3, \ldots$

All points (circles) which are 10 km north of these circle satify the condition.