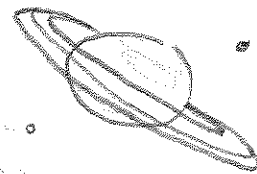
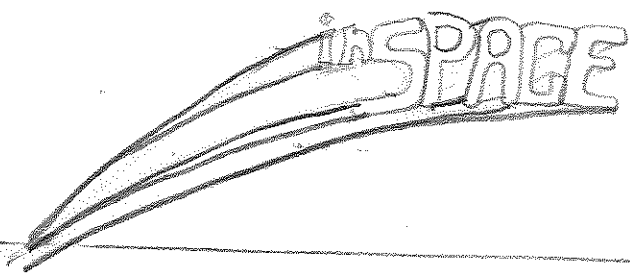


Gravitational Potential Energy



$$1a) GPE = -\frac{GMm}{r} = \frac{-6.67 \times 10^{-11} \frac{Nm^2}{kg^2} (5.98 \times 10^{24} kg)(7500 kg)}{(6.38 \times 10^6 m + 3 \times 10^6 m)} = -3.21 \times 10^{11} J$$

$$b) W_{nc} = \Delta E_k + \Delta E_p ; \Delta E_k = 0 J \text{ (min. min energy means } \vec{v}_i = \vec{v}_f = 0 J!) \\ W_{nc} = \Delta E_p = E_{pf}^0 - E_{pi} = -E_{pi} = 3.2 \times 10^{11} J$$

$$2a) W_{nc} = \Delta E_k + \Delta E_p = E_{pf} - E_{pi} = -\frac{GMm}{r_f} - \left(-\frac{GMm}{r_i}\right) \\ = -GMm \left(\frac{1}{r_f} - \frac{1}{r_i}\right) = -GMm \left(\frac{1}{r_f + 2.6 \times 10^6 m} - \frac{1}{r_e}\right) \\ W_{nc} = 1.0 \times 10^{11} J$$

$$b) W_{nc} = \Delta E_k + \Delta E_p = E_{pf} - E_{pi} = -\left(-\frac{GMm}{r_e + 2.6 \times 10^6}\right) = 2.6 \times 10^{11} J$$

$$3) E_{pg} = -\frac{GMm}{r} = \frac{-6.67 \times 10^{-11} \frac{Nm^2}{kg^2} (7.35 \times 10^{22} kg)(250 kg)}{1.74 \times 10^8 m} = -7.0 \times 10^8 J$$

$$4) W_{nc} = 0 J \quad E_{ki} + E_{pi} = E_{kf} + E_{pf} = 0 \\ \frac{1}{2} m v_i^2 + \frac{GMm}{r_i} = 0 J \\ v_{esc} = \sqrt{\frac{2GM}{r_i}}$$

$$a) v_{esc} = \sqrt{\frac{2G(7.35 \times 10^{22} kg)}{1.74 \times 10^8 m}} = a) \underline{2370 m/s}$$

$$b) v_{esc} = \sqrt{\frac{2G(6.42 \times 10^{23} kg)}{3.40 \times 10^8 m}} = b) \underline{5020 m/s}$$

$$c) v_{esc} = \sqrt{\frac{2G(4.87 \times 10^{24} kg)}{6.05 \times 10^8 m}} = c) \underline{10400 m/s}$$

$$d) v_{esc} = \sqrt{\frac{2G(1.99 \times 10^{30} kg)}{6.96 \times 10^8 m}} = d) \underline{618000 m/s}$$

$$5) \quad W_{nc} = 0 J \\ E_i = E_f \\ \frac{1}{2} m v_i^2 + \left(\frac{-GMm}{r_i + 2.5 \times 10^6}\right) = \frac{-GMm}{r_e}$$

$$v_i = \sqrt{2(-GM) \left(\frac{1}{r_i + 2.5 \times 10^6} - \frac{1}{r_e}\right)} \\ v_i = 5900 m/s$$

$$6) \frac{1}{2}g = \frac{1}{2}(9.80 \text{ m/s}^2) = 4.9 \text{ m/s}^2$$



$$g = \frac{GM}{r^2}$$

$$r = \sqrt{\frac{GM}{g}} = 9.02226 \times 10^6 \text{ m}$$

$$h = r - r_e = 2.6 \times 10^6 \text{ m}$$

6) a. 0 J (F_g is \perp to motion!)

b. $E_g = -\frac{GMm}{r}$; $\left. \begin{matrix} G \\ M \\ m \end{matrix} \right\} \rightarrow$ all are the same for both satellites

so... $E_g \propto \frac{1}{r}$

so... $\frac{1}{2}r \Rightarrow 2E_{pg}$

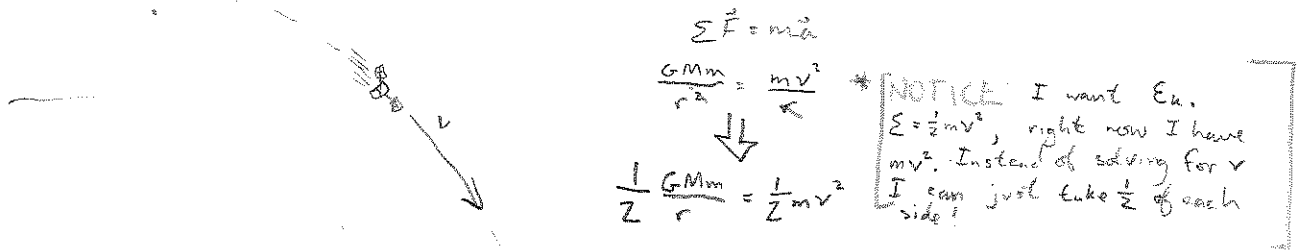
$$E_{pg2} = -13.8 \times 10^{12} \text{ J}$$
$$= -1.4 \times 10^{13} \text{ J}$$

7 a. $E_{pg} = \frac{-GMm}{r_e+h} \Rightarrow r_e+h = \frac{-GMm}{E_{pg}} = \frac{-(6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2})(5.98 \times 10^{24} kg)(38700 kg)}{-1.96 \times 10^{12} J}$

$r_e+h = 7.8755 \dots \times 10^6 m$

$h = 1.50 \times 10^6 m$

b. $E_k = \frac{1}{2}mv^2$; We need to find $v!$ \Rightarrow CIRCULAR MOTION



So... $E_k = \frac{1}{2} \frac{GMm}{r}$; AND $E_p = \frac{-GMm}{r}$ SO... $E_k = -\frac{1}{2} E_p$
 (for a satellite in circular orbit, NOT IN GENERAL)

$E_k = -\frac{1}{2} (-1.96 \times 10^{12} J) = 9.80 \times 10^{11} J$



a. $W_{nc} = \Delta E_k + \Delta E_p = E_k - E_{k0} + E_p - E_{p0}$

$0 = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 + \left(\frac{-GMm}{r_e+h}\right) - \left(\frac{-GMm}{r_e+h_0}\right)$

$v = \sqrt{2 \left[\frac{1}{2}v_0^2 - \left(\frac{-GM}{r_e+h}\right) + \left(\frac{-GM}{r_e+h_0}\right) \right]}$

$v = \sqrt{2 \left[\frac{1}{2}(18000 \text{ m/s})^2 + (6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2})(5.98 \times 10^{24} kg) \left[\frac{1}{6.38 \times 10^6 + 1.2 \times 10^7} - \frac{1}{6.38 \times 10^6 + 1.9 \times 10^7} \right] \right]}$

$v = 2.03788243 \times 10^4 \text{ m/s}$

$v = 2.0 \times 10^4 \text{ m/s} \quad (20 \text{ km/s})$

b. There's a lot here! We have heat lost $\Rightarrow W_{nc} \neq 0$; $W_{nc} = -8.95 \times 10^{17} \text{ J}$
 We have a change in mass! $m_0 = 1.25 \times 10^{20} \text{ kg}$
 $m = 0.30(m_0) = 3.75 \times 10^{19} \text{ kg}$

$$W_{nc} = \Delta E_k + \Delta E_p$$

$$-8.95 \times 10^{17} \text{ J} = \frac{1}{2} m v^2 - \frac{1}{2} m_0 v_0^2 + \left(\frac{-GMm}{r_e} \right) - \left(\frac{-GMm_0}{r_e + h_0} \right)$$

ALGEBRA...

$$v = \sqrt{\frac{2}{m} \left(-8.95 \times 10^{17} \text{ J} + \frac{1}{2} m_0 v_0^2 + GM \left(\frac{m}{r_e} - \frac{m_0}{r_e + 1.9 \times 10^7} \right) \right)}$$

$$v = 2.49585916 \times 10^4 \text{ m/s}$$

$$v = 2.5 \times 10^4 \text{ m/s} ; 25 \text{ km/s}$$

* every thing
 but v is
 known, so
 apart from some
 significant algebra
 we're DONE!

9. B

10. $E_{pg} \propto \frac{1}{r} \Rightarrow$ DOUBLE R , $\frac{1}{2} E_{pg}$

$$\Sigma_{P3B} = \frac{1}{2} \Sigma_{P3A} = -13000 \text{ J}$$

11. 26000 J

12. 13000 J

13. 13000 J