YEAR 12 PHYSICS ANSWERS TO ASSIGNMENT #5

Q1. (a) $E_{TOTAL} = E_K + E_P = ½\,m\,v^2 + -\dfrac{G\,M\,m}{r}$

But for (minimum) escape velocity $E_{TOTAL} = 0 \quad \therefore ½\,m\,v^2 = \dfrac{G\,M\,m}{r}$

$\therefore \quad v^2 = \dfrac{2\,G\,M}{r} \quad \therefore v_{ESC} = \sqrt{\dfrac{2\,G\,M}{r}}$

(b) i/ $v_{ESC} = \sqrt{\dfrac{2\,G\,M}{r}} \quad \therefore v_{ESC} = \sqrt{\dfrac{2\times\left(6.67\times10^{-11}\right)\times\left(1.99\times10^{30}\right)}{6.96\times10^{8}}} = 6.17\times10^5\ m\ s^{-1}$

ii/ $v_{ESC} = \sqrt{\dfrac{2\,G\,M}{r}} \quad \therefore v_{ESC} = \sqrt{\dfrac{2\times\left(6.67\times10^{-11}\right)\times\left(7.35\times10^{21}\right)}{1.74\times10^{6}}} = 750\ m\ s^{-1}$

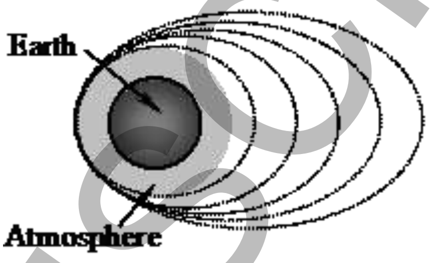
iii/ $v_{ESC} = \sqrt{\dfrac{2\,G\,M}{r}} \quad \therefore v_{ESC} = \sqrt{\dfrac{2\times\left(6.67\times10^{-11}\right)\times\left(8.66\times10^{25}\right)}{2.56\times10^{7}}} = 2.12\times10^5\ m\ s^{-1}$

Q2. (a) A person standing on any stationary surface on Earth is in equilibrium because the weight force F_W acting downwards is balanced by the *normal* reaction force F_N of the ground. The same is true when the person moves at a constant velocity upwards or downwards. The one force they *actually* feel is the normal reaction – not weight! When astronauts are revolving around the Earth within a capsule, they are in "free fall" just as the capsule is, so there is no force acting between them. Although the weight force still acts (and is the reason why they revolve around the Earth), they do not feel the reaction force, hence they feel "weightless".

(b) $I_r = \dfrac{I_0}{r^2} \quad \therefore 1440 = \dfrac{I_0}{10^2} \quad \therefore I_0 = 144\,000$ units i/ $\therefore I_{30m} = \dfrac{144\,000}{30^2} = 160$ units ;

ii/ $\therefore I_{80m} = \dfrac{144\,000}{80^2} = 22.5$ units ; iii/ $\therefore I_{4.0m} = \dfrac{144\,000}{4.0^2} = 9000$ units .

(c)



The principal cause of orbital decay is the drag of the atmosphere, which is significant to several hundred kilometres above the ground. Especially when the orbit of a spacecraft is elliptical, it enters the region of most drag when its gravitational potential energy is least, so its kinetic energy → speed is greatest, maximising the air resistance every orbit, eventually losing sufficient energy in the form of heat to melt, to "burn up" or to break into fragments, which finally fall to Earth.

(d) $E_P = -\dfrac{G\,m_E\,m_{SS}}{r} = -\dfrac{\left(6.668\times10^{-11}\right)\times\left(6.0\times10^{24}\right)\times 70\,000}{\left(6.38+0.13\right)\times10^{6}} = -4.30\times10^{12}\ J$.

$E_K = ½\,m_{SS}\,v^2 = ½\times m_{SS}\times\dfrac{G\,m_E}{r} = ½\times m_{SS}\times\dfrac{G\times m_E}{r} = +2.15\times10^{12}\ J$

(e) E_{TOTAL} (in the 130-km orbit) $= E_P + E_K = -2.15 \times 10^{12}$ joules.

On the ground, $E_K = 0$ (the Shuttle is stopped).

$$E'_P = -\frac{G\,m_E\,m_{SS}}{r} = -\frac{(6.668\times10^{-11})\times(6.0\times10^{24})\times 70\,000}{6.38\times10^{6}} = -4.39\times10^{12}\ \text{J}$$

Hence its total energy on the ground at Williams Air Base is -4.39×10^{12} J

It can be seen that 2.24×10^{12} J of energy has been lost by the Space Shuttle, mainly being converted into heat as it is returning to Earth.

(f) (i) The *entry corridor* is a narrow range of angles allowing successful return into Earth's atmosphere; if too steep, astronauts would experience excessive *g-load*, while the craft overheated. If too shallow, insufficient drag would apply; so the craft returns into space

(ii) Wings allow the Shuttle to glide from its point of re-entry to the landing strip.

(iii) Flaps allow the pilot to control the direction of the Shuttle to the landing strip.

(iv) The blunt nose creates turbulence in font of the Shuttle; this produces greater heat, and a detached shockwave, reducing noise, vibration, and the actual heating of the craft.

(v) The tiles are insulators, protecting the Shuttle from much of the heat. They have a high melting point, and hence resist the heat; they also absorb large amounts of heat energy as they sublime [this is called *ablation*], so although they need replacement for the next flight, this is a further way they protect the Shuttle, and its crew from high temperature.

Q3. (a) i/ Liquid fuels rather than solid fuels, since they can be turned off when necessary;

ii/ Hotter and lighter exhaust gases (especially from hydrogen fuel) more efficient;

iii/ Defined escape velocity, and determined the escape velocity from the Earth;

iv/ Designed "multi–stage" rockets by stacking one on top of another.

(b) i/ Was able to separate the payload from the rocket, and land it by parachute;

ii/ Invented use of vanes in the rocket exhaust to control the direction of the craft;

iii/ Designed pumps and valves to control the flow of fuel to the rocket motor;

iv/ Used liquid oxygen to cool the rocket motor as it was flowing into the fuel.

[alternatives exist]

(c) i/ Tsiolkovski was a theoretician, a schoolteacher, whereas Goddard was a college professor and an experimentalist, who learned by constructing and testing models;

ii/ Goddard attempted to keep his investigations secret, believing his work would be of national importance, but Tsiolkovski was fascinated by the idea that humankind might one day be capable of exploring the rest of the Universe, and hoped that others would be inspired to follow that path.

iii/ Tsiolkovski achieved little recognition in his lifetime, but in spite of Goddard's efforts at secrecy, people did hear about, and were inspired by, his achievements.

[alternatives exist]

(e) Because Tsiolkovski's work was carried out in a town well away from Moscow, and in a period of great turmoil in Russia, outsiders heard nothing of his theories, but his work was known in the U.S.S.R. The multi-stage rocket was of special importance to the Soviet space programme, since it allowed a greater payload to be carried by a launcher of the same mass, and carrying the same amount of fuel.