The International Astronomy and Astrophysics Competition.

Qualification Round 2019.

Name: Peace Adetayo Adejumobi

Problem A

The earth has a distance of (1) light minutes to our sun. When the moon covers the sun we call this event a (2). There are eight planets in the solar system and (3) is the heaviest of them all. The smallest planet is (4) and it circles the sun in just (5) days. Besides the planets, there are thousands of stars visible in the night sky. The brightest star is called (6) and it is just one of about (7) billion stars in our Milky Way. The (8) galaxy is the closest spiral galaxy to our Milky Way.

Answer

(1) 8 (2) solar eclipse (3) Jupiter (4) Mercury

(5) 88 (6) Sirius(Alpha Canis Majoris) (7) 100 (8) Andromeda

Problem B

The Earth has a radius of $R_E \approx 6371$km and an average density of $\rho_E \approx 5.514\frac{g}{cm^3}$. Jupiter is much bigger and heavier with a radius of $R_J \approx 70000$km and an average density $\rho_J \approx 1326\frac{kg}{m^3}$.

(a)Approximately how many Earths fit into Jupiter (by volume).

(b)How many times heavier is Jupiter compared to Earth?

Answer

a) Volume of Earth= $\frac{4}{3}$ x π x r^3

=$\frac{4}{3}$ x $\frac{22}{7}$ x 6371^3

=1.083642907 x 10^{12}

Volume of Jupiter= $\frac{4}{3}$ x π x r^3

=$\frac{4}{3}$ x $\frac{22}{7}$ x 70000^3

=1.437333333 x 10^{15}

The number of earth that will fit into Jupiter= $\frac{1.437333333 \text{ x } 10^{15}}{1.083642907 \text{ x } 10^{12}}$

=1.326390201 x 10^3

=1326

∴ The number of earth that will fit into Jupiter =1326

b) Density= $\frac{\text{Mass}}{Volume}$

$\rho_E = \frac{M}{V}$ (mass of earth)

$M_E = \rho v$

M_E=5.514x1.083642907x10^{12}

M_E=5.975206989x10^{12}

$M_J = \rho_J V_J$

M_J=1.326x1.437333333

M_E=1.905904x10^{15}

$\therefore \frac{\text{M jupiter}}{\text{M earth}} = \frac{1.905904\text{x}10^{15}}{5.975206989\text{x}10^{12}}$

$= 318.968699$

$\cong 319$

∴ Jupiter is 319 times heavier compared to Earth.

Problem C

Alice and Bob are doing a space race from Earth to the Moon which is $d \approx 384000$km far away. Alice's spaceship flies with a constant speed of $v=500\frac{km}{h}$. Bob's spaceship starts slowly but accelerates constantly with $a=1.4\frac{km}{h^2}$.

Who wins this space race? (Write down your steps.)

<u>Answer</u>

From the 3rd equation of motion

Using, $v^2=u^2+2as$

$V=500kmh^{-1}$ (Alice), $a=1.4kmh^{-2}$ (Bob), $s=d=384000km$ (Alice)

$500^2=0+2 \times a \times 384000$

$\frac{250000}{768000}=\frac{768000a}{768000}$

$a=0.33kmh^{-2}$

$s= ut+\frac{1}{2}at^2$ (from the 2nd equation of motion)

$384000=0+\frac{1}{2} \times 0.33t^2$

$\frac{384000}{0.165}=\frac{0.165t^2}{0.165}$

$t^2=2327272.727$ (Alice)

$t=\sqrt{2327272.727}$

$t=1525.540143hrs$

∴ Alice got to the Moon in 1525.54014hrs

$v^2=u^2+2as$

$v^2=0+2 \times 1.4 \times 384000$

$v^2=1075200$

$v=\sqrt{1075200}$

$v=1036.92kmh^{-1}$

$s= ut+\frac{1}{2}at^2$

$384000=0+\frac{1}{2} \times 1.4t^2$

$\frac{384000}{0.7}=\frac{0.7t^2}{0.7}$

$t^2=548571.4286$

$t=\sqrt{548571.4286}$

$t=740.6560798hrs$

∴ Bob got to the Moon in 740.6560798hrs

∴ Bob won the race.

Problem D

Alice and Bob will encounter on their space race the so called Lagrange points L_1 at which the forces from Earth and Moon cancel out. The gravitational force on the spaceships is given by

$$F(r) = mG\left(\frac{\mathrm{ME}}{r^2}\frac{MM}{(d-r)^2}\right)$$

a) Use F(r) to find a formula that calculates the distance to the Lagrange point L_1

<u>Answer</u>

$$\frac{F(r)}{mG} = \frac{mG\left(\frac{ME}{r^2}-\frac{MM}{(d-r)^2}\right)}{mG}$$

$$\frac{F(r)}{mG} = \frac{ME}{r^2} - \frac{MM}{(d-r)^2}$$

$LCM=r^2 (d-r)^2$

$$\frac{F(r)}{mG} = \frac{ME(d-r)^\wedge 2 - MM(r^2)}{(r^2)(d-r)^2})$$

Cross multiply

$F(r)\ (r^2)\ (d-r)^2 = mG(M_E(d-r)^2 - M_M(r^2))$

$F(r)\ (r^2)\ (d-r)^2 = mG\ M_E(d-r)^2 - mG\ M_M(r^2)$

$F(r)\ (r^2)\ (d-r) - mG\ M_E\ (d\text{-}r)^2 = -\ mG\ M_M(r^2)$

$(d-r)^2\ [F(r)\ (r^2) - mG\ M_E] = -mG\ M_M(r^2)$

$(d-r)^2\ [F(r)\ (r^2) + mG\ M_E] = Mg\ M_M(r^2)$

$(d-r)^2 = \frac{Mg\ MM(r2)}{F(r)\ (r2)+mG\ ME}$

$d-r = \sqrt{\frac{Mg\ MM(r2)}{F(r)(r2)+mG\ ME}}$

Add r to both sides

$d = \sqrt{\frac{Mg\ MM(r2)}{F(r)(r2)+mG\ ME}} + r$

b) Explain missing aspects in this calculation due to the assumption that the 'Earth-Moon system is at rest.'

The missing aspect in this equation is velocity (v). For an Earth system to be at rest the velocity must be Zero.

Problem E

Since the existence of humans we were fascinated by the natural phenomena of polar lights (aurora). The various colors in the skies have inspired many stories and are a symbol for the beauty of nature. Today, we understand the underlying scientific reasons for the phenomena.

Explain the causes and scientific reasons that explain polar lights.

Answer

A quiescent solar wind flowing past the Earth's magnetosphere steadily interacts with it and can both inject solar wind particles directly onto the geomagnetic field lines that are 'open', as opposed to being 'closed' in the opposite hemisphere, and provided diffusion through the bow shock. It can also cause particles already trapped in radiation belts to precipitate into the atmosphere. Once particles are lost to the atmosphere from the radiation belts, under quiet conditions, new ones replace them only slowly, and the loss-cone becomes depleted. In the magneto tail, however, particle trajectories seem constantly to reshuffle, probably when the particles cross the very weak magnetic field near the equator. As a result, the flow of electron in that region is nearly the same in all directions ("isotropic"), and assures a steady supply of leaking electrons. The leakage of electrons does not leave the tail positively charged, because each leaked electron lost to the atmosphere is replaced by a low energy electron drawn upward from the ionosphere. Such replacement of "hot" electrons by “cold” ones is in complete accord with the 2nd law of thermodynamics. The complete process, which also generates an electric ring around the Earth, is uncertain.

Auroras result from emissions of photons in the Earth’s upper atmosphere, above 80km (50mi), from ionized nitrogen atoms and nitrogen based molecules returning from an excited state to ground state. They are ionized or excited by the collision of particles precipitated into the atmosphere. Both incoming electrons and protons maybe involved. Excitation energy is lost within the atmosphere by the emission of a photon, or by collision with another atom or molecule:

<u>Oxygen emissions</u>

Green or orange-red, depending on the amount of energy absorbed.

<u>Nitrogen emissions</u>

Blue or red; blue if the atom regains an electron after it has been ionized red if returning to ground state from an excited state.