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Name (Last, first)

Astronomy 110 Homework 10

Write the answers to the questions on this sheet.
Homework due by 11.30 am April 22nd 2005

We have met the idea of "Escape velocity" several times in this course. Now we are going to make some calculations based on the idea. We will see how a concept that we first discussed in terms of the Earth can also lead to very interesting results in the case of a very high gravitational field (a neutron star) and a very low gravitational field (an asteroid).

It is fairly easy for a physicist to use Newton's laws of motion and Newton's law of gravity to show that the escape velocity v from a spherical planet of average density D and radius r is given by:

$$v = r\sqrt{\frac{8\pi}{3}GD} \tag{1}$$

where G is the universal constant of gravitation which has the value 6.67 x 10^{-11} Newton meter^2 per kilogram^2. If you express the density in units of kilograms per cubic meter and the radius in meters you will get a velocity in units of meters per second. [Note that this formula looks different from the one we used in class, because this one uses the average density of a planet and the other one used the total mass of the planet; you will get a bonus point if you can prove to me that the formulae are equivalent to each other]

a) Calculate the escape velocity from the Earth in meters per second assuming a density of 5000 kilograms per cubic meter and a radius of 6400 kilometers. Remember to convert all distances to meters before inserting them into the formula. Convert your answer to miles per hour and check whether your answer agrees with the one we used in lectures.

b) Repeat the calculation for a neutron star, using a radius of 10 km and a density of 10^{18} kilograms per cubic meter. Leave the answer in meters per second. Comment on how your answer compares with the speed of light.

c) We can use the same formula to examine how small an asteroid has to be for an astronaut to be able to escape from it by taking a running jump into space.

First estimate how fast you can run in meters per second wearing a space suit. (Hint: first think of Olympic track records)

Now turn equation (1) around so that you can express r in terms of v and D

Now calculate r assuming the density of the asteroid is a sphere with the same density the Earth

Give an example of something that has about the same size as this asteroid.