PHYSICS 1020

Homework set 5

27 January 1997

[**5.2**] Does Earth's gravity pull more strongly on a block of wood or on a block of iron with the same mass?
Answer:
If they have the same mass, both blocks feel the same gravitational pull.

[**5.3**] What is the magnitude (strength) and direction of the gravitational force on you right now?
Answer:
This depends on the weight of the person answering the question. Assuming a weight of 150 pounds, the force would be 150 pounds (remember: the pound is a force unit!), which, at 4.448 newtons per pound, corresponds to approximately 670 newtons.

[**5.13**] The giant planet Jupiter is more than 300 times more massive than Earth. It seems, then, that an object on Jupiter's surface should weigh 300 times more than it weighs on Earth. But it actually weighs only about 3 times as much. Explain.
Answer:
The weight is due to the gravitational force at the surface of the planet. The gravitational force on a given object is proportional to the mass of the planet, and inversely proportional to the square of the planet's radius. Jupiter's mass is about 318 Earth masses, and its radius is about 11.2 Earth radii. So we expect an object's weight on Jupiter to be $(318/11.2^2)$ or about 2.5 times that of an object on Earth. (See also exercise 5.19.)

[**5.16**] Suppose that the gravitational force between an apple and an orange placed a short distance apart is one-trillionth $= 10^{-12}$ newton. What would the force be if the distance were doubled? halved? tripled? quartered?
Answer:
Since the gravitational force is inversely proportional to the square of the distance, it drops to a quarter at twice the distance i.e. $= (1/4) \times 10^{-12}$ N ;
half distance $\Rightarrow$ 4 times the force, i.e. $= 4 \times 10^{-12}$ N;
triple distance $\Rightarrow$ force drops to 1/9, i.e. $= 1/9 \times 10^{-12}$ N;
1/4 the distance $\Rightarrow$ force increases by factor 16, i.e. $= 16 \times 10^{-12}$ N.

[**5.19**] Making estimates: Earth's mass is about 100 times the Moon's mass, and Earth's radius is about 4 times larger than the Moon's radius. From this information, use the law of gravity to estimate how much more an object weighs on Earth than on the Moon.

Answer:

The gravitational force felt by an object of mass m on the surface of a planet (its weight) is

$$F_g = G\frac{m \cdot M}{R^2},$$

where R is the radius and M the mass of the planet. The gravitational acceleration g on the surface is = force divided by the mass of the object:

$$g = \frac{F_g}{m} = \frac{G \cdot M}{R^2}$$

Therefore g (grav. acceleration on Earth) = (100/16 = about 6) times that on the Moon.

[**5.20**] Making estimates: estimate the gravitational force, in newtons, that you exert on a person standing near you.

Answer:

The gravitational force between two objects of masses m_1, m_2 at distance R from each other is given by

$$F_g = G\frac{m_1 \cdot m_2}{R^2}.$$

Let us assume that the masses of the two persons in question are 60 and 70 kg, and the distance is about 1 foot (i.e. about 0.32 meters). This gives

$$F_g = 6.67 \times 10^{-11}(\mathrm{Nkg^{-2}m^2}) \cdot \frac{60\mathrm{kg} \cdot 70\mathrm{kg}}{(0.32\mathrm{m})^2}$$

$$= 6.67 \times 10^{-11}\mathrm{Nkg^{-2}m^2} \times 4.10 \times 10^4(\mathrm{kg/m})^2$$

$$= 2.73 \times 10^{-6}\mathrm{N} \approx 6.1 \times 10^{-7} \text{ pounds.}$$

(Remember that 1 newton is approximately 4.45 pounds.)

[**5.21**] Suppose that the Sun collapsed tomorrow to become a black hole but that it collapsed "quietly", with no explosive or other direct effects on regions outside the Sun. Would Earth's orbit be any different after the collapse than it is now? What important feature affecting life on Earth would be different?

Answer:

Earth's orbit would not be affected, since the Sun's mass and distance from Earth would be unchanged; but essentially all emission of radiation from the Sun would cease, and life on Earth would die.

[5.27] According to the most widely accepted theory of the creation of the universe, the universe during the first few moments (much less than 1 second) of its existence was extremely hot, full of densely packed matter and was very tiny – smaller than an atom. What theory or theories would be needed to explain what was happening during these first few moments?

Answer:

Newtonian physics provides a good approximative description of the world of "everyday phenomena": events at small speeds, medium distances and medium masses. The implicit approximations made in formulating its laws break down for very high speeds (comparable to the speed of light), very high masses and very large distances, and also for very small distances. The theories obtained by generalization from Newtonian physics into these realms are: *theory of special relativity* for high speeds, *general relativity* for high masses and/or very large distances, and *quantum theory* for small distances. A description of the first second of existence of the universe requires a combination of all of these theories, since it involves events at high speeds (high speeds of random motion due to extremely high temperatures), very high mass and very small distances.