

Physics for future Presidents

Department of Physics, Carnegie Mellon, Fall '19, Deserno

Homework 4, due in lecture on Monday, Sep 16th

Two calculations pertaining to energy efficiency (chapter 2) and gravity (chapter 3)

1. Car engines work by burning fuel. The explosion of a small amount of burned fuel pushes a piston, which transfers its motion in some way through cranks and gears to the wheels. The temperature of the exploding fuel-air mixture can be about 2000 C. Clearly, the motor needs to be constantly cooled to remain at some good operational temperature. The exhaust fumes that finally leave through the tail pipe have a temperature of maybe 80 C.
 - a) What is the largest physically permissible efficiency you would expect such an engine to have?
 - b) Typical combustion engines in cars only achieve an overall efficiency of about 20%. What fraction of the optimal efficiency is this?
2. The force of gravity between two masses m_1 and m_2 a distance d apart is given by the equation

$$F = G \frac{m_1 m_2}{d^2} . \quad (1)$$

The constant $G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$ is called the “gravitational constant”. The numerical value makes sure the magnitude of the force comes out right, and the funny units are needed so that the final units come out right, namely “N”, which appropriately stands for “Newton”.

- a) Our moon has a mass of approximately 7.35×10^{22} kg, and its mean distance from us is about 384,000 km. What is the force of gravity which the moon exerts on a person here on earth who has a mass of about 70 kg?
- b) Some people believe that the moon affects their lives in all kinds of mysterious ways. When one points out that the moon is really far away and cannot have much of a physical impact on them, one sometimes hears this reply: “But look how powerfully the moon affects the ocean when it creates the tides! How much *easier* would it be for the moon to affect me, given that I am so much lighter!” It is true that the moon creates ocean tides, and that this is related to the gravitational force it exerts on it, but there is still something seriously wrong with this argument. What?