Physics Club - Fields

Aditya C

October 2025

1 Introduction

In this session, we'll look at two kinds of fields and forces: gravitational and electric. As you should know by now, gravity is the force of attraction between two objects with mass. The electrostatic force (between two charges) is slightly different in that it is attractive if the charges are opposite, but repulsive if the charges are the same. Here are the laws for electrostatic and gravitational forces:

$$F_g = \frac{GMm}{r^2}$$

$$F_e = \frac{kQq}{r^2}$$

Problem 1 (Physics Club Original) For two electrons 1 metre apart, calculate the ratio of the magnitudes of the electrostatic repulsion between them to the gravitational attraction between them.

Problem 2 (BPhO) A person may reasonably jump a height of 1 metre on Earth, how high would the person be able to jump on a planet with an average density two thirds that of the Earth and a radius twice that of the Earth?

The gravitational potential energy and the electric potential energies can both be defined from the force equations as the work required to move an object to that point i.e. $U = \int F dr$

$$U_g = -\frac{GMm}{r}$$

$$U_e = \frac{-kQq}{r}$$

Similarly, the gravitational and electrical fields can be described as the potential energy per unit mass and charge respectively, like so:

$$V_g = \frac{GM}{r}$$

$$V_e = \frac{kQ}{r}$$

Question 3 (BPhO) Two spheres, of uniform density, one of mass m_1 and radius r_1 and the other of mass m_2 and radius r_2, attract each other gravitationally. What is their relative speed at the instant of collision if they are released from rest when a great distance apart?

HINT (not given in real exam): A great distance apart basically means infinite distance apart, so gravitational potential energy is ≈ 0

2 Extension and challenge

Question 4 (Isaac Physics) If the Earth is a sphere of radius r and mass M, what is its mean density? Calculate the gravitational force of a mass m at the surface of the Earth in terms of its density. What is the relationship between this force and the radius?

Question 5 (Physics Club Original) Write an expression for the potential energy of an electron around a hydrogen nucleus a distance r from the nucleus. What stops the electron from "falling into" the nucleus?

A couple of interesting things today: firstly, you may know that gravity doesn't actually work exactly in the Newtonian model, but is much more accurately described by Einstein's general relativity. The maths of general relativity is quite complicated, but if you're interested, a rudimentary, qualitative understanding can be gained by looking around online for some further reading.

As always, the Isaac Science website and the BPhO website are great sources of enriching physics problems.

If you want a deeper look at some of these topics, look into the MIT OpenCourseWare website and search for whatever you're looking for! They have hundreds of free courses, excellently taught by MIT professors.

Thank you all for coming!