Fields

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Contents

Chapter 1

Fields – Basics

Aims of this section

At the end of this section you should be able to

- Describe the concept of a field
- State the link between potential and fields and calculate field strength from potentials.
- Sketch electric field lines for distributions of charges.

1.1 What is a field?

Recommended reading: Tipler & Mosca 4.2, 21-4

A field is a region of space, where property of that space is characterized by either a number (a scalar field) or by three numbers (a vector field).

The concept of a field circumvents the problem of action at a distance where one inanimate object is "aware" that another has arrived.

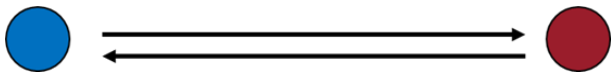

Figure 1.1: image

We understand that the first body sets up a field and the second body interacts with the first via this field. There is no need for action at a distance because the field of the 1st object is present in space whether or not the second object is there.

Figure 1.2: image

1.1.1 Charges

Why does object 1 set up a field? Fields arise when objects have charge. Electric charges cause electromagnetic fields, but other fields arise from different types of charge for example gravitational fields arise from mass. (And the strong field that is responsible for holding quarks inside protons and neutrons arises from the colour charge – see Inside The Atom.)

There are two types of **electric charge**, + and −. "Like" charges repel, while"unlike" charges attract. Electric charge is quantized: the **elementary charge** is $1.6021773 \times 10^{-19}$ C and is the charge on the electron and the proton. Charges measured in laboratories are always multiples of this but the quarks inside protons and neutrons and other hadrons have charges that fractions of this elementary charge. Charge is conserved in all interactions we have observed. Most everyday objects are electrically neutral with the number of protons and electrons balanced, which hides the fact that they contain enormous amounts of + and − charge. Things that we would describe as "charged objects", have a small imbalance in charge.

Gravitational charge: there is one type of gravitational charge, which is mass/energy. Gravitational charges attract. We don't know about quantization of mass. (You can probably spend many hours on the internet reading different opinions on this). Mass/Energy is conserved and all everyday objects are gravitationally charged so they all attract each other but gravity is very weak – we can easily pick up bits of paper with an electrically charged rod when rather few electrons have been moved.

Strong field charge: there are three types of fundamental strong charge (red, green and blue) + three anticharges. Charges attract. Colour is quantised and colour is conserved in interactions. All everyday objects are colour neutral. Colour fields are confined within subatomic particles i.e. to length scales of $\sim 10^{-15}$ m.

1.2 Scalar and vector fields

A scalar field is characterized at each point by a single number. e.g. the temperature, T, at each position in a block of metal heated at some places and cooled at others.

T is a function of position i.e. $T = T(x, y, z)$. At every point we can measure the scalar value of the temperature T. The black lines represent isotherms i.e. lines