Radiation

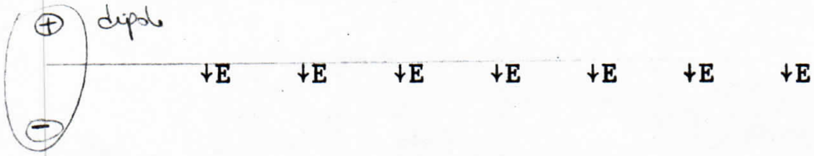
We clearly have the key to the properties of matter. Although we have seen how they come about only in a very qualitative manner, we know exactly what the problem involves (the electrical force between atoms) and in principle what would be involved if we wanted to correctly and precisely calculate detailed properties. We understand pretty well everything about our apple experiment now — except perhaps why an apple is red! In fact we really can't say anything about the property of materials to do with colour. There is more to be understood. Let's try to start looking into that particular question by asking another one. We now know from our model of a gas that heat is just kinetic energy, or motion of bodies, and to heat up an object it is necessary to transfer energy from a hotter body to a cooler one. This can be done quite easily by gas atoms "transporting" the kinetic energy from one object to the other. But how can it happen if there is nothing between the two objects - no solid connecting them, no gas in between? If there are no atoms around to move the energy from one body to the other surely no heating can occur. But in fact we know that it can happen. The earth is constantly heated by the sun, and there is nothing but a vacuum between them. How is this possible? What have we forgotten about? The answer is, once again, the electric force. The electric force is capable of exerting a push or a pull over vast distances, and that push or pull (acceleration) means increased motion - increased kinetic energy - increased temperature. This transfer of energy via the electric force through space is generally called electromagnetic radiation.

Radiating fields

It is quite easy to see how this works by thinking about the motion of charges in atoms. We decided that almost all matter consists of paired + and - charges, so we will look at the forces associated with a pair of positive and negative charges (normally called a dipole)

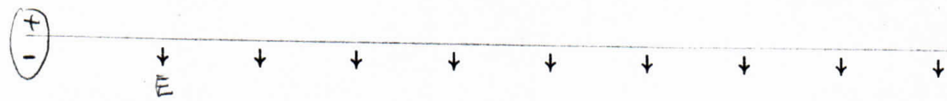
For simplicity let's find the force on a "test charge" some distance from the two charges at a point which is equally far away from both charges

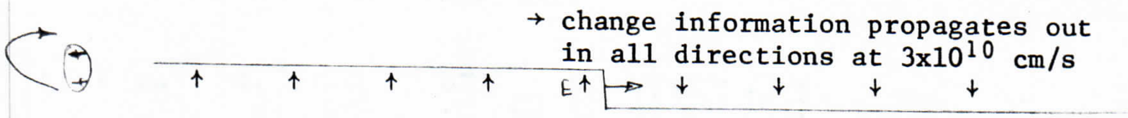
The two positive charges repel each other, so the force on the test charge is away from the positive charge; the negative charge attracts the test charge, so the force on it is towards the dipole. When these two forces are added up, the net result is a force perpendicular to the line joining the test charge and the dipole. We would get some kind of force on our test charge no matter where we put it. In fact we don't even need to use a charge; we know there would be a force anywhere in space on a test charge due to our dipole if the test charge were placed there - so we ~~don't~~ need not even bother putting the charge there. We can just say there is an electric field which exists throughout all space (we will denote it as $\vec{E}$), and is a property of the charge(s) that "generate" it.



If a charge gets into this electric field it will experience a force. It is as if the electric field $\vec{E}$ "announces the presence" of the dipole to other charges.

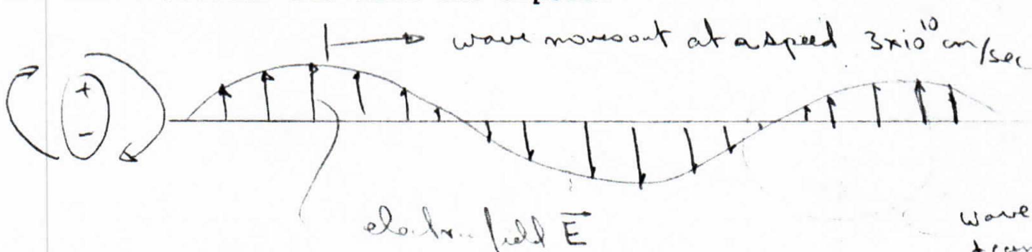
What happens to this field if the dipole is charged? Say the dipole is flipped over instantaneously. Does the whole field, which extends to infinity in all directions, flip over at that same instant? No.





The information that the dipole has flipped propagates out in all directions at a finite speed, charging the field as it goes. (This fact is obtained from a careful study of the laws governing the electric (coulomb) force).

If the dipole is "smoothly" varied, what happens as we look along the midpoint line is that we see the electric field oscillating up and down, picking a wave which travels out from the dipole.

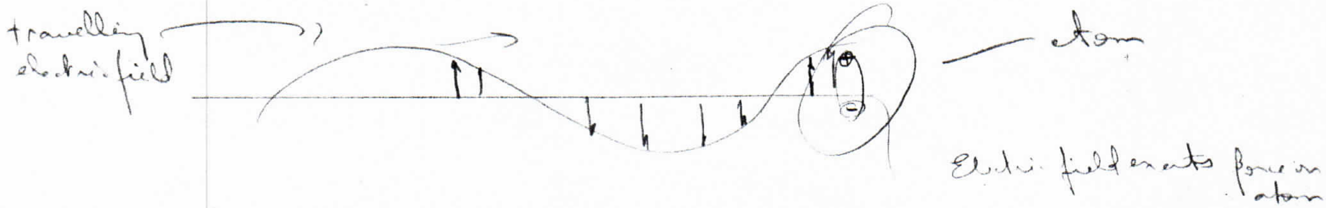


wave is called transverse electromagnetic wave

The frequency of the oscillation of the field is the same as the frequency of inversion ~~is determined by the rate of oscillation~~ of the dipole. (The wave can also be described by a wavelength; the higher the frequency the ~~best~~ less distance between adjacent crests of the wave, hence the shorter the wavelength). Now of course when these pairs of charges in one body move (oscillate - vibrate - rotate), they set up a travelling transverse

not defined

electric field which "strikes" charged particles in the second body



and cause <u>them</u> to oscillate back and forth, hence increasing temperature. This effect can easily be observed by ~~considering~~ *Turning on* a light bulb. ~~There~~ *In the bulb* the atoms in the filament are heated (put into rapid motion) *by passing an electric current through them* and they emit ~~transverse~~ electromagnetic radiation. The filament is surrounded by a vacuum, but nevertheless we can feel heat coming from the bulb when it is turned on. What <u>else</u> happens, though is that there is <u>light</u> emitted. Light is ~~this~~ *basically the* <u>same</u> *kind of* ~~transverse~~ electromagnetic radiation as heat - but at a higher frequency. In fact there is a whole spectrum of radiation which is due to our electromagnetic field.

Mention that changing magnetic fields also involved, hence electromagnetic.

~~Colour, light, and~~ *Electromagnetic* radiation <u>as</u> <u>well</u> <u>as</u> the states of matter are all basically due to, and described by our two forces and Newton's laws. So once again we have grossly expanded our basic understanding of things around us. We have now come a long way in understanding nature from those first attempts by the Greeks. The tools that Newton showed the world were *very soon* seen ~~very soon after tim~~ to be <u>tremendously</u> <u>powerful</u>.

All things are governed by the laws of Newton, and we know those laws. ~~We, mankind, are now the master of our own fate as~~ rulers of the universe! At least if we do not rule it, we know the rules, and that is almost as good. It would be difficult indeed not to be caught up in such zeal on realizing the absolute success that all physics put its hand to. Although ~~what~~ we have seen here ~~is~~ only qualitative, those pictures are ~~backed~~ by ~~cold, hard~~ calculations.

~~This~~ almost religious belief in science ~~was paralleled - or the progenitor of~~ - a great revolution in society - the industrial revolution, where at every hand man saw further proof of the mastery over nature by ~~man's~~ science.

However all was not yet conquered. There were still confirmation of scientific understanding to be carried out. Indeed, as an integral part of the underlying philosophy of science there was (and still remains!) an obligation to explore every consequence of all theories - ~~all science, and so far~~ the details of radiation ~~are untested, for us now,~~ as it was for mankind in general during the great surge of faith in physics before the turn of the twentieth century.

Just as there was a great gain in understanding by looking in a more detailed way at the properties of gases expected from our basic understanding expect that by looking at this newly understood phenomenon - electromagnetic radiation - in a more careful, quantitative way, further gains in understanding must occur.