

• CHAPTER 13 •
ELECTRIC FIELDS

CONSIDER
GRAVITATION!



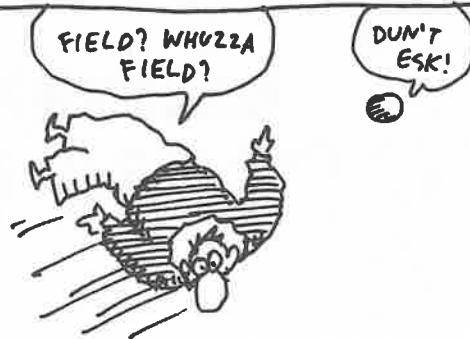
THE EARTH EXERTS A FORCE ON THE MOON, A BODY THOUSANDS OF MILES AWAY. SIMILARLY, ONE ELECTRIC CHARGE EXERTS FORCES ON OTHER CHARGES WHICH ARE SEPARATED FROM IT IN SPACE.

HOW CAN ONE OBJECT EXERT A FORCE ON ANOTHER WHICH IT IS NOT TOUCHING? HOW CAN THE FORCE GET ACROSS SPACE? HOW FAST DOES IT GET THERE?

FASTER THAN
A SPEEDING
CAFFEINE
ADDICT?



A BEGINNING OF THE ANSWER IS TO IMAGINE THAT THE EARTH FILLS SPACE WITH A **GRAVITATIONAL FIELD**. IT IS THE FIELD (WHATEVER IT IS!) THAT CAUSES THE FORCES ON MASSES WITHIN IT.



SIMILARLY, A CHARGE FILLS SPACE WITH AN **ELECTRIC FIELD**.

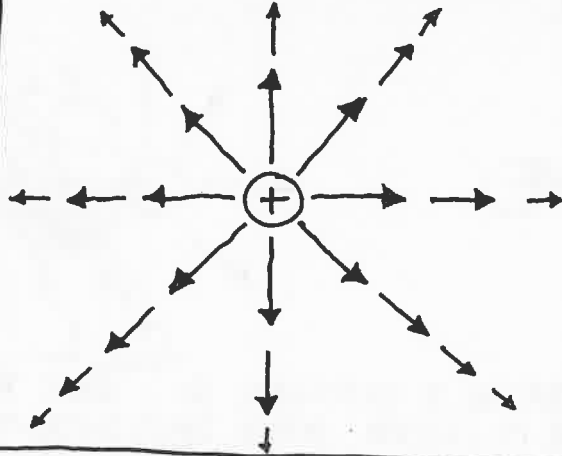
WHEN ANOTHER CHARGE IS IN THE ELECTRIC FIELD, ELECTRIC FORCES ACT ON IT!



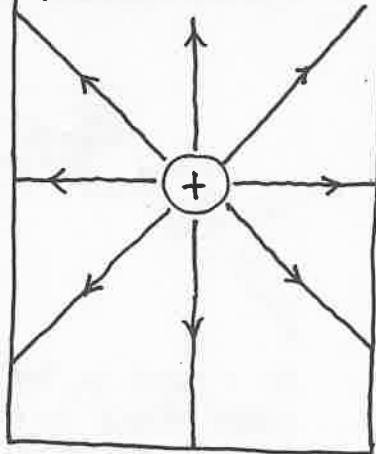
WE CAN VISUALIZE THE ELECTRIC FIELD BY IMAGINING THAT WE ARE CARRYING A SMALL POSITIVE TEST CHARGE AROUND AND MAPPING THE DIRECTION OF THE FORCE ON IT. HERE, RINGO HAS A SINGLE POSITIVE CHARGE, AND I'M MOVING THE TEST CHARGE AROUND.



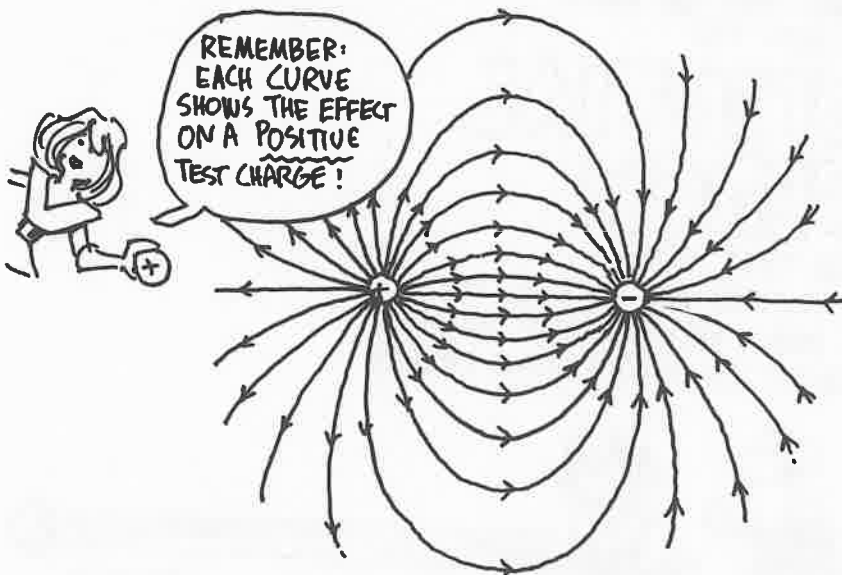
IF WE DRAW ARROWS IN THE DIRECTION OF THE FORCE, WITH LENGTH PROPORTIONAL TO ITS STRENGTH, WE GET A PICTURE OF THE ELECTRIC FIELD OF RINGO'S CHARGE:



AND IF WE CONNECT THE ARROWS WITH **FIELD LINES**, THE PICTURE BECOMES:

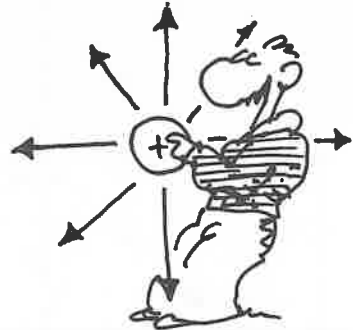


FIELD LINES GIVE A VERY CONVINCING PICTURE OF ELECTRIC FIELDS; FOR EXAMPLE, FOR TWO ATTRACTING CHARGES:



THE FIELD LINES BEGIN AT THE POSITIVE CHARGE AND END AT THE NEGATIVE CHARGE: THE NEGATIVE CHARGE PULLS A POSITIVE TEST CHARGE IN FROM ANY DIRECTION.

SINCE THE ELECTRIC FIELD EXERTS FORCES ON CHARGES, THERE IS ENERGY ASSOCIATED WITH THE POSITION OF A PARTICLE IN THE FIELD. HERE RINGO HOLDS A POSITIVE CHARGE, AND, STARTING FAR AWAY, I BRING A SMALL POSITIVE TEST CHARGE IN CLOSE TO IT.



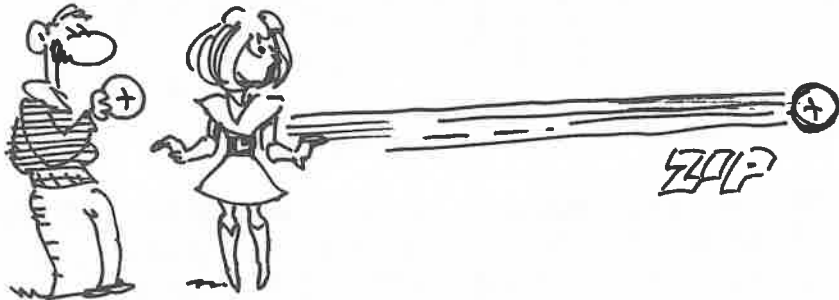
AS I MOVE IN, THE CHARGE IS REPELLED, SO I HAVE TO EXERT FORCE TO PUSH IT CLOSER. FORCE TIMES DISTANCE EQUALS **WORK** = I DO WORK ON THE TEST CHARGE.

WE SAY THAT THE WORK GOES INTO THE

POTENTIAL ENERGY

OF THE TEST CHARGE.

IF I RELEASE THE CHARGE, IT FLIES AWAY, AND POTENTIAL ENERGY IS CONVERTED INTO KINETIC ENERGY.



WE WOULD LIKE TO ATTRIBUTE THE POTENTIAL ENERGY SOLELY TO THE ELECTRIC FIELD OF RINGO'S CHARGE, SO WE DIVIDE OUT MY TEST CHARGE AND WRITE:

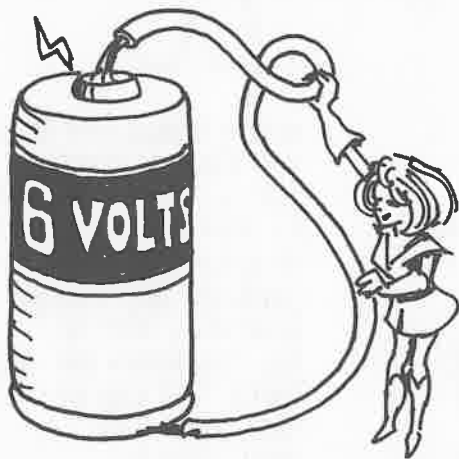
$$\text{Potential} = \frac{\text{POTENTIAL ENERGY}}{\text{CHARGE}}$$



THIS EQUATION DEFINES A NEW QUANTITY, THE ELECTRIC POTENTIAL.* POTENTIAL MEASURES ENERGY PER CHARGE. ITS UNITS ARE JOULES PER COULOMB, WHICH WE GIVE A NAME ALL ITS OWN, THE **VOLT**.

$$1 \text{ Volt} = 1 \frac{\text{JOULE}}{\text{COULOMB}}$$

AS WITH ANY NEW DEFINITION IN PHYSICS, IT IS IMPORTANT TO UNDERSTAND THE BASIC CONCEPT.



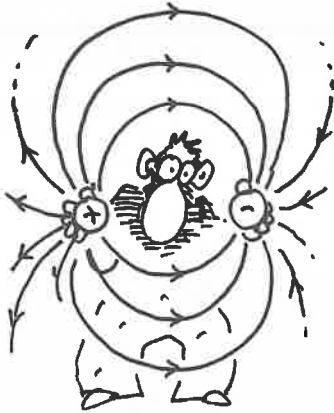
IF A BATTERY IS RATED AT 6 VOLTS, THAT MEANS IT IS PREPARED TO GIVE 6 JOULES OF ENERGY TO EVERY COULOMB THAT IS MOVED FROM ONE TERMINAL TO THE OTHER.

* THERE IS ALSO A GRAVITATIONAL POTENTIAL. IF $P.E. = mgh$, THEN $\frac{P.E.}{m} = gh$ IS THE ABILITY OF THE GRAVITATIONAL FIELD TO TRANSMIT ENERGY TO ANY MASS AT HEIGHT h .

O.K... SO HERE'S A CHARGE... BUT I STILL DON'T GET IT...



WHAT IS A CHARGE, ANYWAY?? I MEAN, IT MUST BE SOMETHING — MUSN'T IT...?



AND THIS ELECTRIC "FIELD," WHAT'S THAT ?



HOW CAN IT "CARRY" A FORCE? HOW CAN SOME IDEA THAT "FILLS SPACE" CARRY ANYTHING ??

I'M JUST AS CONFUSED AS EVER!!

HMM...



SORRY, RINGO, OLD BOY, BUT YOU HAVE A POINT... CLASSICAL E & M NEVER ANSWERS THOSE QUESTIONS. IT ONLY DESCRIBES HOW CHARGES AND FIELDS BEHAVE... BUT IF YOU CAN HANG ON UNTIL THE END OF THE BOOK, I'LL TELL YOU A LITTLE ABOUT WHAT QUANTUM THEORY SAYS CHARGES AND FIELDS "REALLY ARE..."

