LECTURE 6
CHAPTERS 8,9

PHY 100. ELECTROMAGNETISM, WAVES

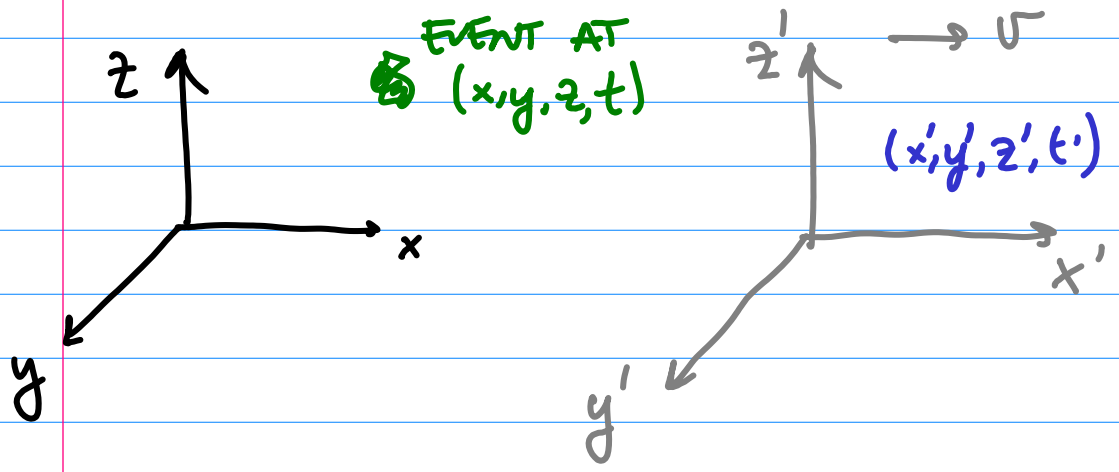
- POSTED PRESENTATION TOPICS: LET ME KNOW IF YOU HAVE A TOPIC I SHOULD INCLUDE, BY FEB. 15.

  → GROUPS WITH ASSIGNED TOPICS SHOULD BE DECIDED BY MARCH 1st.

- EXAM 1 WILL BE ON WED. FEB 17 (TWO WEEKS!)

- NEXT TUESDAY FEB 9 AT 8pm GLEASON 318 PUBLIC LECTURE ON WAVE-PARTICLE DUALITY.

RECAP: SPECIAL THEORY OF RELATIVITY RELATES OBSERVATIONS OF ANYTHING BETWEEN INERTIAL REFERENCE FRAMES



LORENTZ TRANSFORMATION

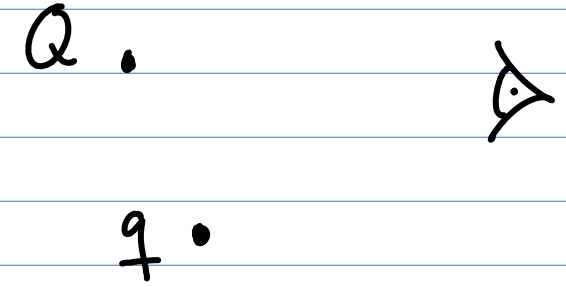
$$x = \gamma(x' + vt')$$
$$y = y'$$
$$z = z'$$
$$t = \gamma\left(t' + \frac{vx'}{c^2}\right)$$

SPACE & TIME GET MIXED UP → SPACETIME

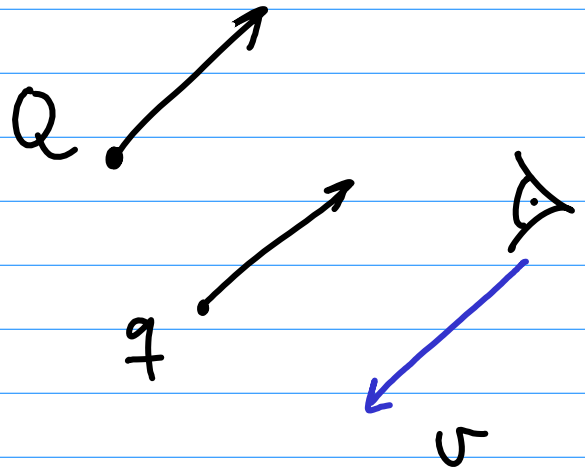
OTHER PHYSICAL QUANTITIES: ENERGY, MOMENTUM, ELECTRIC FIELD...
ALSO TRANSFORM AND CAN GET MIXED TOGETHER:

ENERGY + MASS: $E = mc^2$

ELECTRIC + MAGNETIC FIELD



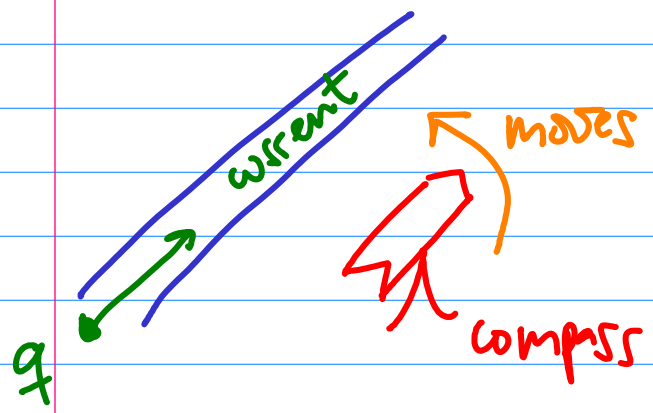
OBSERVER SEES FORCE BETWEEN STATIC CHARGES ⇒ ELECTRIC



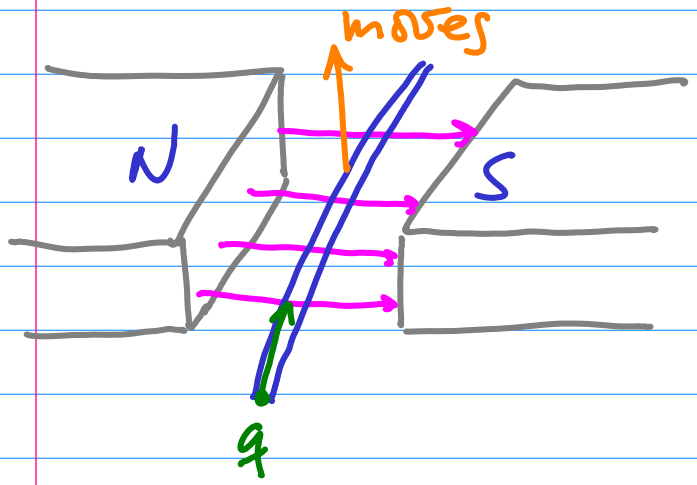
NOW IF THE OBSERVER IS MOVING BY, THE CHARGES WILL LOOK LIKE THEY ARE MOVING (CURRENTS) → THE FORCE IS NOW SEEN TO BE MAGNETIC (IN PART)

WHAT WE PERCEIVE AS ELECTRIC OR MAGNETIC FIELD IS RELATIVE!

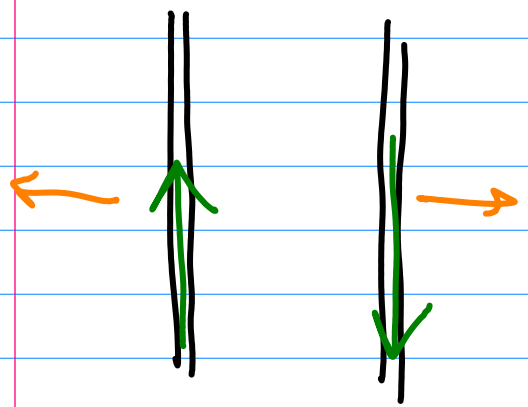
REMEMBER RELATIONSHIP BETWEEN E AND M FIELDS:



MOVING ELECTRIC CHARGE CREATES A MAGNETIC FIELD



MAGNETIC FIELD EXERTS A FORCE ON MOVING CHARGE.



RELATIONSHIP BETWEEN ELECTRIC AND MAGNETIC FIELD IS VERY DEEP.

MAXWELL'S EQUATIONS (1864)

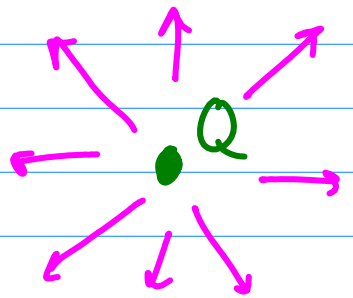
$$F = k\frac{Qq}{d^2}\ ;\ E = \frac{F}{q}$$

E: SYMBOL FOR ELECTRIC FIELD
B: " MAGNETIC "

1) $\oint_S \bar{E}\cdot d\bar{a} = \frac{Q_{enclosed}}{\varepsilon_0}$ ← ε_0: ELECTRIC CONSTANT

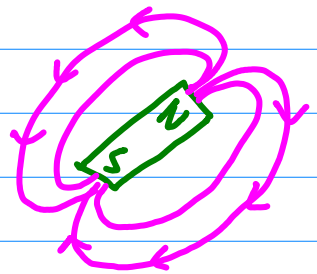
FLUX OF E THROUGH A CLOSED SURFACE S

GAUSS LAW



CHARGED OBJECTS CREATE E FIELDS

2) $\oint \bar{B}\cdot d\bar{a} = 0$ GAUSS LAW OF MAGNETISM.



NORTH POLES AND SOUTH POLES COME IN PAIRS.
MAGNETIC FIELD LINES COME IN LOOPS.

3) $\oint_C \bar{E} \cdot d\bar{\ell} = -\dfrac{d\int_S \bar{B}\cdot d\bar{a}}{dt}$ FARADAY LAW OF INDUCTION

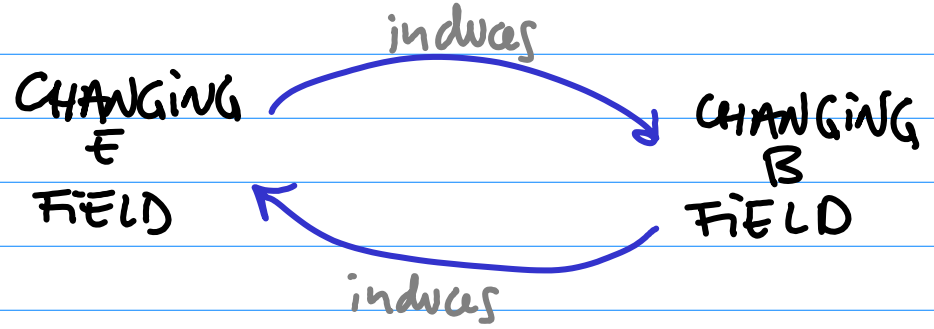
A CHANGING MAGNETIC FIELD INDUCES AN ELECTRIC FIELD

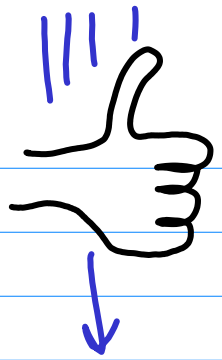
4) $\oint_C \bar{B} \cdot d\bar{\ell} = \mu_0 I_{enclosed} + \mu_0 \varepsilon_0 \dfrac{d\int \bar{E}\cdot d\bar{a}}{dt}$

AMPERE'S LAW WITH MAXWELL'S CORRECTION

MAGNETIC FIELDS CAN BE CREATED BY ELECTRICAL CURRENT AND BY CHANGING ELECTRIC FIELDS.

MAXWELL UNIFIED ELE. & MAG. FORCES INTO ELECTROMAGNETISM





FIST FULL OF ELECTRIC CHARGE

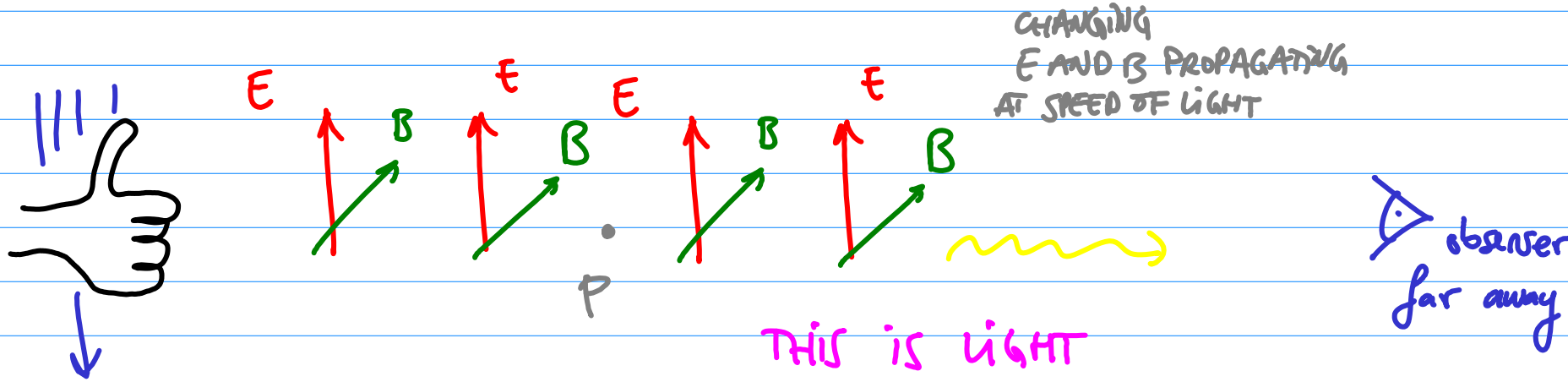
P

AT POINT P, AS FIST SWOOPS BY THERE IS A CHANGING ELECTRIC FIELD.

MAXWELL'S EQNS TELL US THAT THIS CREATES (OR INDUCES) A CHANGING MAGNETIC FIELD IN THE VICCINITY OF P....

AND THIS PRODUCES A CHANGING E FIELD .... etc....

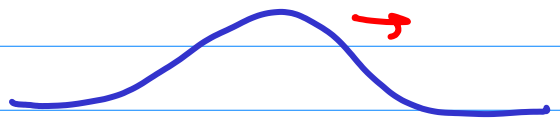
THE CYCLE OF E AND B FIELD CREATION PROPAGATES OUTWARD AT THE SPEED OF LIGHT.



LIGHT IS A WAVE

INTRO TO WAVES

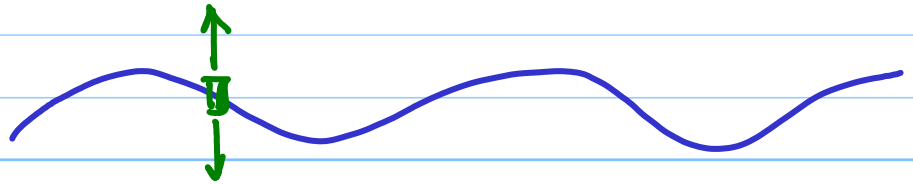
WAVES ARE A WELL KNOWN MECHANICAL PHENOMENON.



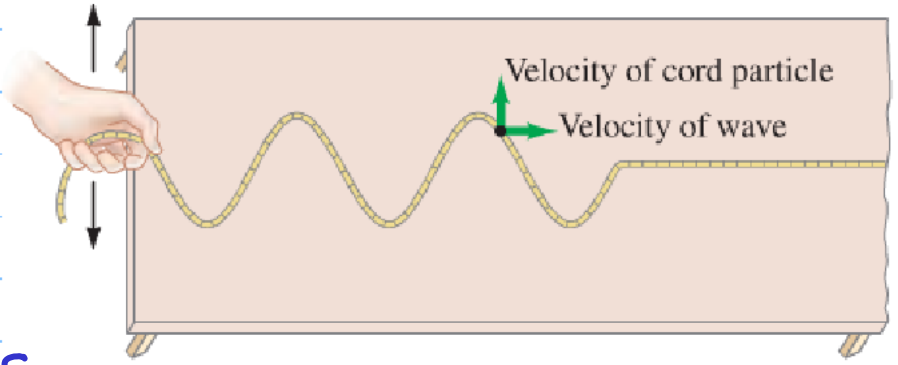
1) WAVE PULSE TRAVELING ON A STRING
2) SOUND WAVES TRAVELING IN AIR
3) WATER WAVES IN THE OCEAN
4) "MEXICAN" WAVE IN A SPORTS STADIUM.
5) LIGHT

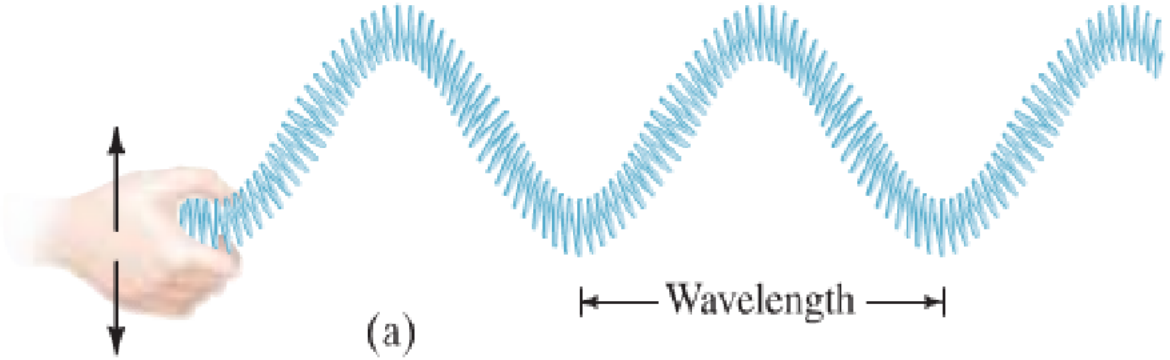
ABSTRACTION: A WAVE IS A DISTURBANCE CARRYING ENERGY IN A MEDIUM

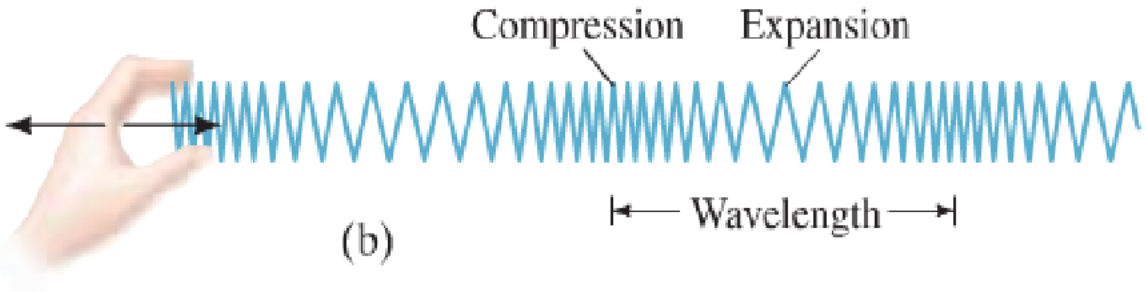
EX: IMAGINE A WAVE TRAVELING ON THE SURFACE OF WATER

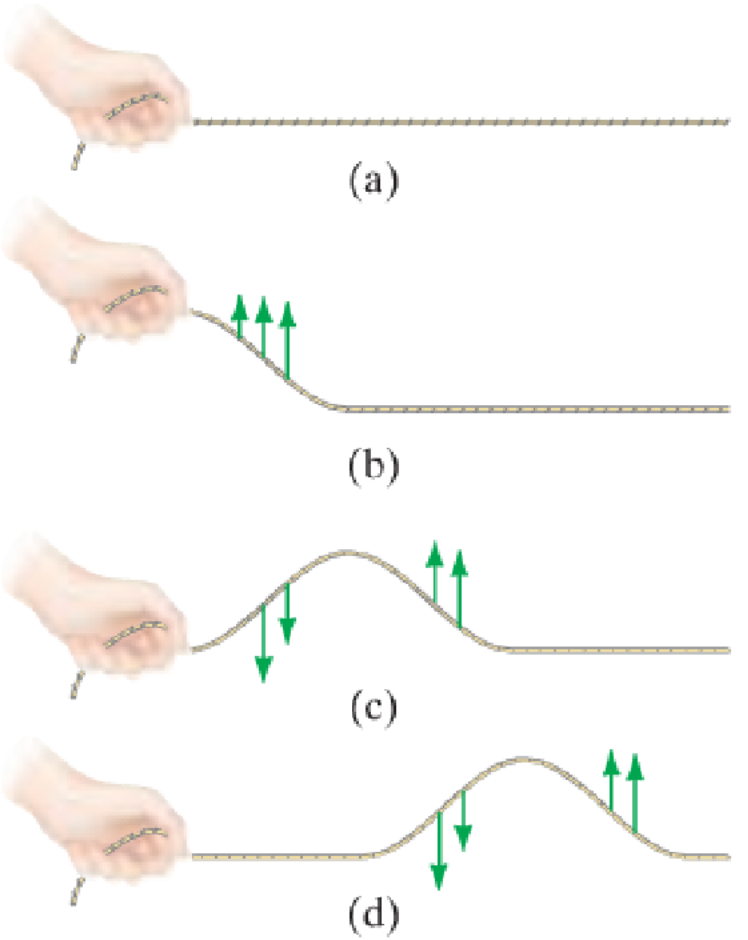


AS WAVE MOVES PAST, THE CORK BOBS UP AND DOWN WITHOUT MOVING LEFT OR RIGHT.

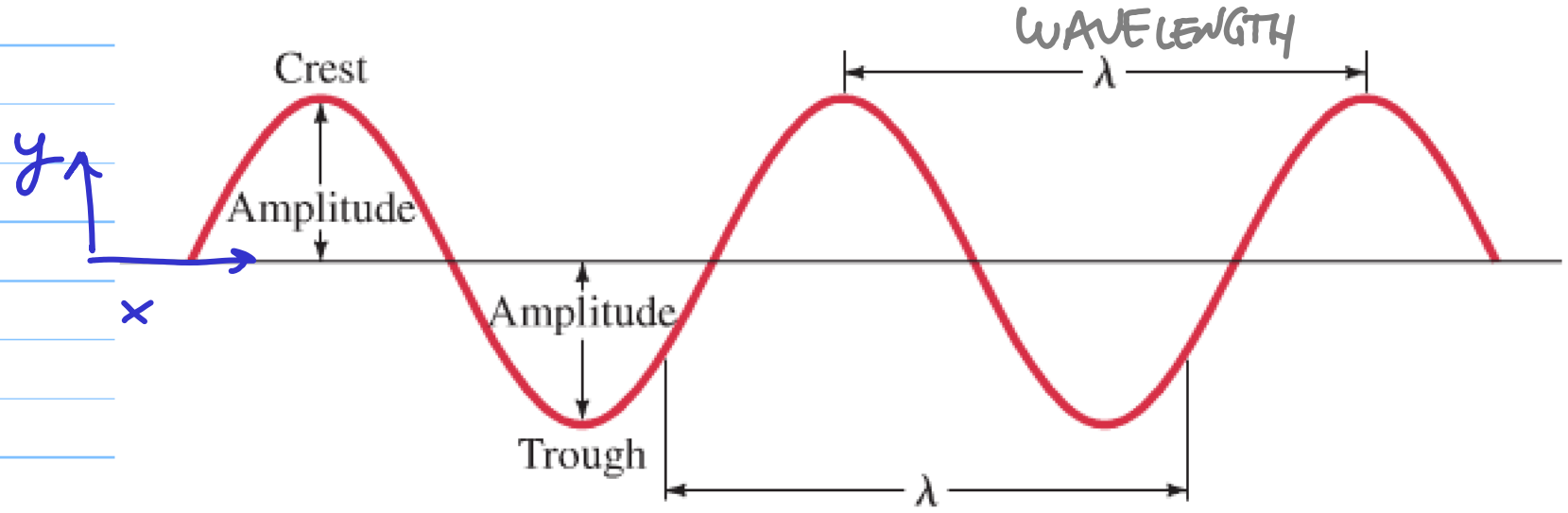








CHARACTERIZING A WAVE



1) DIRECTION OF MOTION
2) AMPLITUDE : MEASURE OF ENERGY AND INTENSITY.
3) WAVELENGTH : λ LENGTH WITH WHICH WAVE REPEATS
4) PERIOD : THE AMOUNT OF TIME IT TAKES CORK TO BOB THROUGH A FULL CYCLE.

T THE WAVE MOVES A DISTANCE λ IN A TIME T (ONE PERIOD)

5) FREQUENCY : $f = \frac{1}{T} = \frac{1}{\text{seconds}} \equiv Hz$ (HERTZ)

FREQ CORRESPONDS TO PITCH IN SOUND WAVES.

SOUND WITH HIGH f → YOU PERCEIVE IT AS HAVING HIGH PITCH

LOW f → LOW PITCH

FREQ. CORRESPONDS TO COLOR IN LIGHT WAVES

HIGH f → MORE BLUE

LOW f → MORE RED

VELOCITY OF A WAVE: $v = \frac{\lambda}{T} = \lambda f$ BECAUSE $f = \frac{1}{T}$

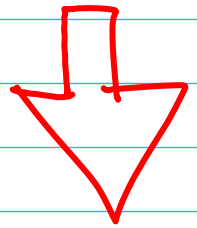
LIGHT IN VACUUM: $c = \lambda f$

SPEED IS A PROPERTY OF THE MEDIUM

LINK BACK TO MAXWELL: BY SOLVING HIS EQNS

MAXWELL REALIZED THAT E AND B SPREAD OUTWARDS FROM MOVING CHARGED FIST AT SOME FINITE SPEED $c = 3 \times 10^8$ m/s

"HIS" c COINCIDED WITH THE NUMERICAL VALUE KNOWN FOR THE SPEED OF LIGHT!



LIGHT IS AN ELECTROMAGNETIC WAVE