AST 3033.
D. Levinthal
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text The Physical Universe
F. Shu
recomended: structure and evolution of Stars
M. Schwarschild

Prob.

Ch 1 ~~Constellations~~
overview, consoellations, solarsystem, greek astronomy

Ch 2 light optics telescopes — 2.3, 2.5

Ch 3 General Physics — 3.4, 3.5, 3.6, 3.7, 3.10, 3.13, 3.16
newtons laws
gravity, gauss' law
conservation of energy
centripetal acceleration.
Electro Magnetism.
Quantum Mechanics.
Uncertainty principle
hydrogen atom.
Pauli exclusion principle
Special relativity
time dilatation
length contraction
doppler shift.
mass-energy equivalence

Ch 4. Statistical mechanics. — 4.1 4.2 4.5 4.8 and problem to be handed out.
thermodynamics, entropy
Second law.
connection of QM to SM
Ideal gas law
Quantum Statistical Mechanics.

Ch 5 Stars 5.1, 5.4, 5.5, 5.11, 5.13 5.14
Sun, Luminosity, Blackbody radiation and problem to be handed
stellar types out.

Stellar structure (schwarzschild)
Hydrostatic equilibrium
radiative transport
Convection.

Ch 6 nuclear energy 6.1, 6.5 6.7 6.10 6.12 6.13 6.14
nucleosynthesis
~~protota~~ proton chain
CNO cycle
Helium burning.
~~Calculation of~~ energy production density of stars

Ch 7 White dwarfs neutron stars black holes
7.1, 7.3 7.4, 7.5 7.7, 7.8, 7.9

Structure of white dwarfs
Chandrasekhar mass limit
neutron stars / pulsars
Black holes / General relativity

Ch 8 Theoretical Hertzsprung-Russell diagram
stellar properties / evolution 8.1 8.3 8.4 8.6 8.[illegible]
Population I / II stars
HR diagram
radiation pressure in high mass stars
red giants
red super giants
planetary nebula
Super novae

Ch 9 Observational Hertzsprung-Russell diagram
9.2 9.5 9.8 9.9 9.10 9.12

Stellar types
distances - magnitudes.
star clusters
H R diagrams
moving cluster distance
Cepheid variables.
Virial theorem of clusters.

Ch 10 Binary stars. 10.1 10.3 10.4 10.5 10.6
orbit paramaters
stellar masses
roche surfaces
mass transfer
contact binaries
Semi detached binaries
Algol type binaries
accretion disks
nova

recomended: Eddington Internal structure of stars
Mathematical theory of relativity.
weinberg General relativity.

lecture 1.

①. Background to course Astro 3033
prof. D. Leviuthal
508 keen
x 6760 / 1492

text: Physical Universe F Shu, $35.00
University Science Books.

highly recomended: Structure and Evolution of Stars.
M. Schwarschild.
Dover press $6.00

②. Student background.
How many have taken calculus
" 2048
" 2049
" Physics majors.

Pass out syllabus.

Grades. 10% homework.
1 or 2 midterms discuss 25% 25% / ~~35%~~
1 final cumulative 40% / ~~55%~~

solutions to problems will be passed out
ie can't be turned in afterwards
note! most problems are trivial plug ins
don't worry about the quantity.

Shu's book will be direct ordered from publisher
this saves ~$12.00 But. ~~we need~~ money orders
should be sent by mon/tues to get them soon
kay Caudill 302 keen will collect money orders!

Pass out syllabus

(1). overview

Stars : structure / evolution, galaxies, cosmology

Astronomy : passive experimental science (for the most part)

Symbols.

x = position — vector

v = velocity $= \frac{dx}{dt} = \dot{x}$ — vector

m = mass — scaler

c speed of light $= 3\times10^{8}$ m/sec. — scaler

F force — vector

a acceleration. $\equiv dv/dt = \dot{v}$ — vector

T = kinetic energy $= \frac{1}{2}mv^2$ — scaler.

V (or U sometimes) Potential Energy $F_x = -\frac{dV}{dx}$

L Lagrangian $T-V$

H hamiltonian = total energy $= T+V$

$\psi(x,t)$ wave function. (psi)

h planks constant.

$\hbar = h/2\pi$

G gravitational constant.

e charge of an electron

r distance between two objects
or radius.

λ wave length.

f or ν (neu) frequency.

$\beta = v/c$

$\gamma = \frac{1}{\sqrt{1-v^2/c^2}} = \frac{1}{\sqrt{1-\beta^2}}$ (gamma)

K used in 2 ways.

k ~~[illegible]~~ constant in electrostatic force law
similar to G in concept.

or wave number $1/\lambda$.

$J = mvr$ = angular momentum.

θ angle. theta.

Ch 1.

Coordinates:

①. constellations

brightest to dimmest $\alpha, \beta, \gamma, \delta$

countries / cities

Cellestial sphere fixed stars.

north } south } celestial pole

zenith.

meridian — great circle connecting zenith to poles.

celestial equator.

longitude latitude

right ascension declination

Sun → ecliptic.

zero right ascension intersection of equator / ecliptic.

② Time.

mean solar day. meridian crossing to meridian crossing. average over one year

sidereal day same but with a particular star. = 23 hr 56 min 4 sec (solar time).

right ascension = sidereal time.

year: sidereal yr. sun obscures same star. 365.2564 m solar days.

Precession of earth axis.

wobbles celestial sphere not ecliptic.

⇒ intersection of ecliptic / celestial eq. moves around 360° every 26,000 yrs

tropical yr. vernal eq. to vernal eq.
365.2422 days

julius ~~[illegible]~~ Caeser 365 1/4.

by Pope Gregory $\boxed{XIII}$ 1582.

vernal equinox off by 10 days.

adds 10 day and.

only centuries divisible by 400 leap yrs.

⇒ 1700 1800 1900 not leap years

2000 is.

Gregorian year 365.2425.

also occaisonal adjustments for wobbles.

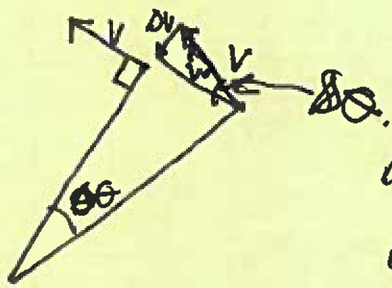
ex. 1 extra second was added at end of this last yr 1987

Ch 2.

Newtons laws.

1. principle of inertia concept of mass.
2. $F = ma$ $\qquad F = \frac{dP}{dt}$. $\qquad P = mv$.

$$a = \frac{dv}{dt} \equiv \dot{v}$$



$$\Delta v = v\,\Delta\theta$$

$$\frac{\Delta v}{\Delta t} = v\,\frac{\Delta\theta}{\Delta t} \rightarrow v\frac{d\theta}{dt}.$$

$$v = r\,\frac{d\theta}{dt} \Rightarrow \frac{v}{r} = \frac{d\theta}{dt}$$

centripetal acceleration.
$$\boxed{a = \frac{dv}{dt} = v\frac{d\theta}{dt} = \frac{v^2}{r}}$$

light. Electromagnetic wave

Changing electric field cause changing magnetic field & vice versa.

a. Speed of propagation in vaccuum $= C = 3\times10^8$ m/sec
b. wave length.

$$f\lambda = C \qquad \nu\lambda = C.$$

c. Polarization. transverse wave.

direction of E field $\perp$ to B field $\perp$ to direction of motion.

carries energy.

energy density $= \frac{1}{8\pi}\left(\bar{E}\cdot\bar{E} + \bar{B}\cdot\bar{B}\right)$

flux. = Poynting's vector

$$f = \frac{c}{4\pi}\left(\bar{E} \times \bar{B}\right)$$

for light $\langle E\rangle_t = \langle B\rangle_t$

$E \perp B$

$$\Rightarrow \frac{c}{4\pi} EB = \frac{c}{8\pi}\left(E^2 + B^2\right) = c \times \text{energy dens.}$$

source are charges ie charged particles

~~force~~ electrons / protons.

$$F_q = q\left(E + \frac{v}{c} \times B\right) \quad \text{Lorentz force.}$$

↑ cross product. right hand rule.

force $\perp$ to v and B.

$\Rightarrow$ particle goes in a circle.

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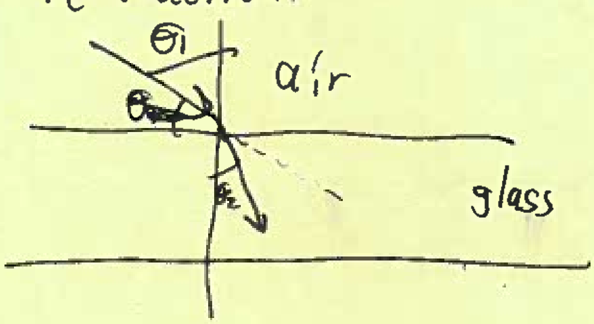
interaction with material (telescopes / spectrum analyzers)

re fraction.



Snells law $\dfrac{\sin\theta_1}{\sin\theta_2} = \dfrac{n_2}{n_1}$

n = index of refraction

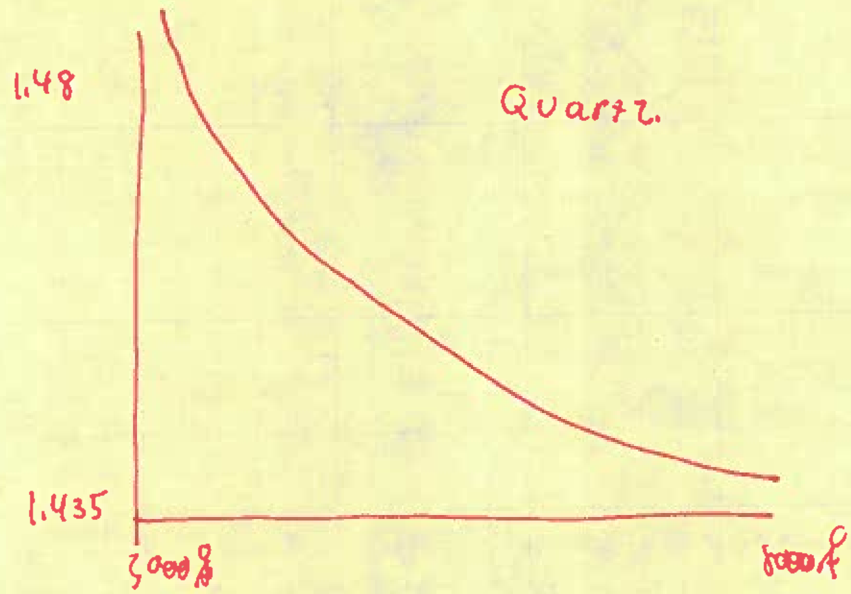
air = vac = 1

water ~~glass~~ = 1.3333

glass 1.5 → 2.

diamond 2.4.

The index of refraction of materials typically depends on wavelength.



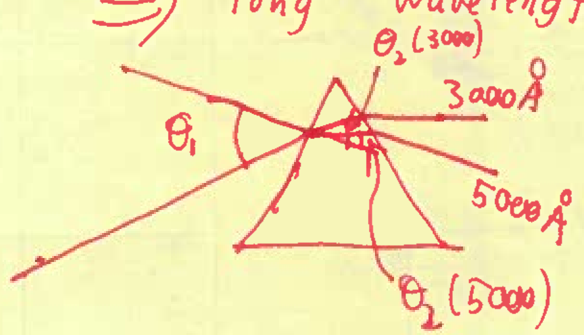
So at the interface of air (medium 1 = vacuum) and Glass (medium 2)

$$\frac{\sin\theta_1}{\sin\theta_2(\lambda)} = n_2(\lambda)$$

$$\boxed{\text{or} \quad \frac{\sin\theta_2(\lambda)}{\cancel{\sin\theta}} = \frac{\sin\theta_1}{n_2(\lambda)}}$$

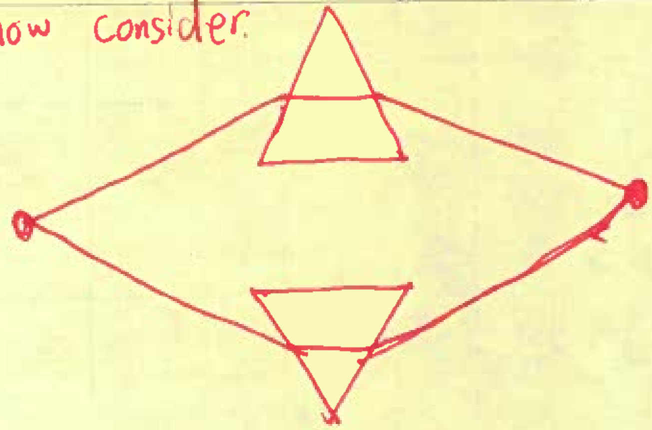
note $n_2(3000\text{Å}) > n(5000\text{Å})$

$\Rightarrow$ long wavelengths bend less.

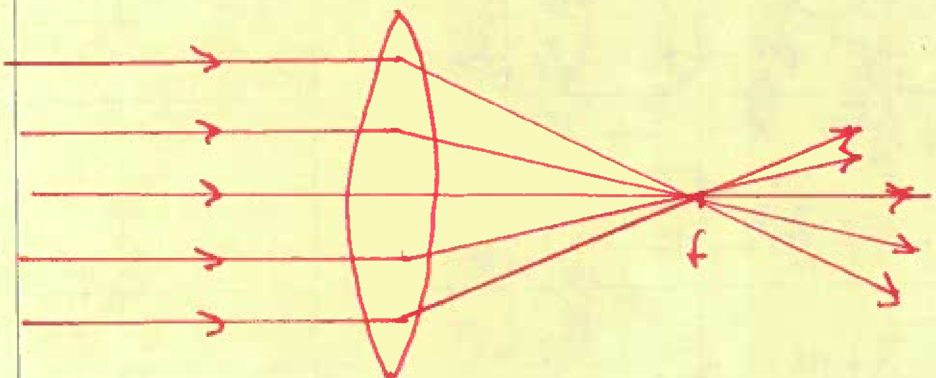


ie refraction can be used to disperse the light spectrum into a rainbow.

now consider.

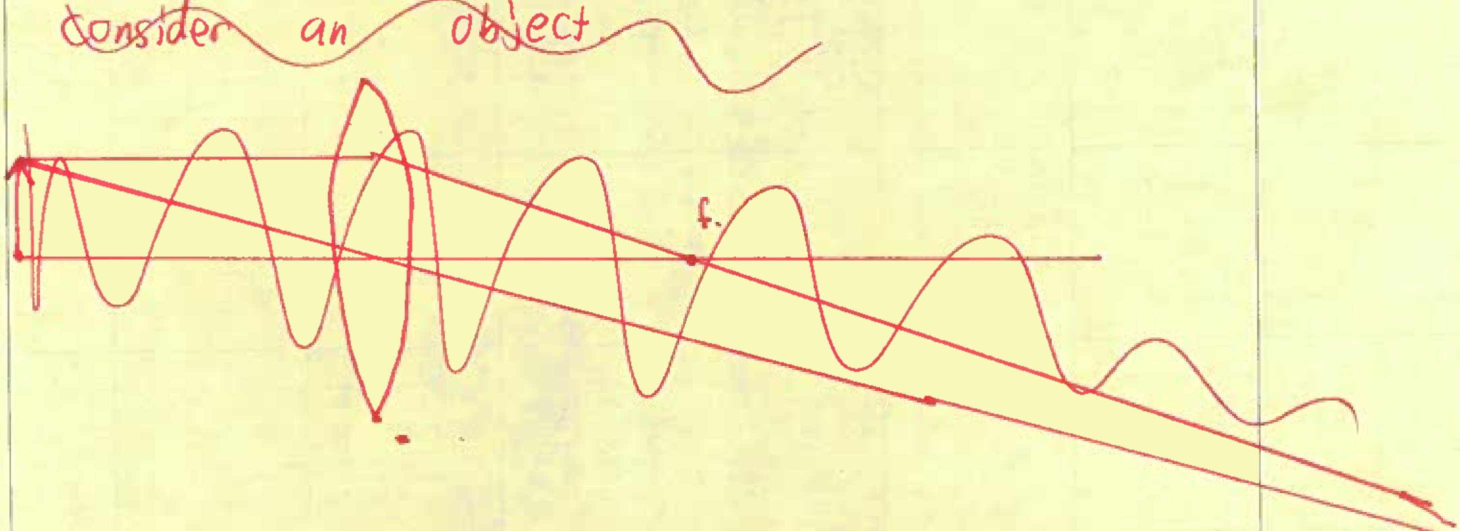


lens. (ray tracing.).

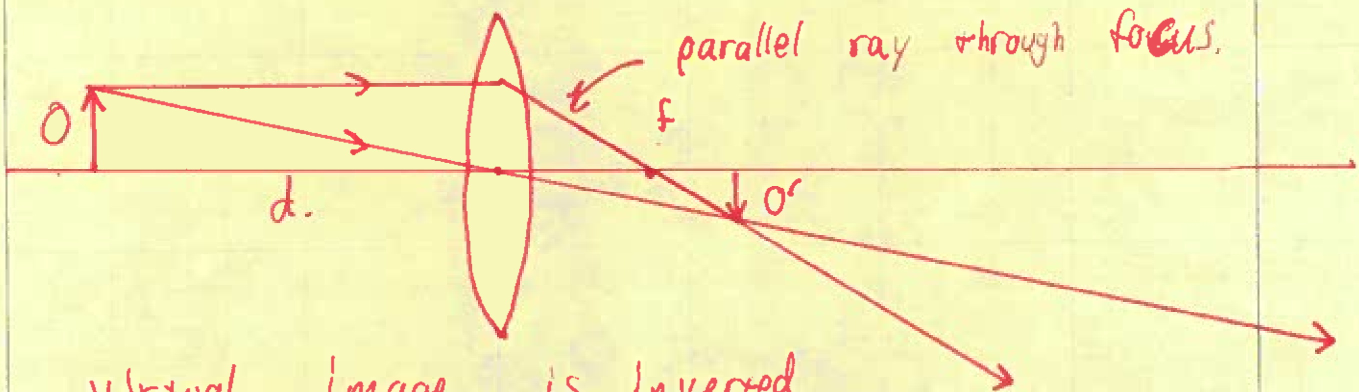


parallel light is all converged on the focus.

consider an object.



note: the ray which passes through the center of the lens is undeflected.



virtual image is inverted

matrix technique of lens systems.

a ray of light is written as a 2 component vector.

$$\begin{pmatrix} x \\ x' \end{pmatrix} \quad \text{where} \quad x' \equiv \frac{dx}{dz} = \text{slope.}$$

the position of the ray after a distance L is.

$$x(L) = x + x' \cdot L.$$

~~can be w~~ the slope is still $x' \Rightarrow x'(L) = x'$

this can be written as.

$$\begin{pmatrix} x(L) \\ x'(L) \end{pmatrix} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ x' \end{pmatrix}$$

with the matrix being the drift matrix.

the effect of a thin lens is

$$x(\text{after lens}) = x(\text{before lens}) \qquad \text{infinitely thin.}$$

$$x'(\text{after}) = \frac{x(\text{before})}{-f} + x'(\text{before})$$

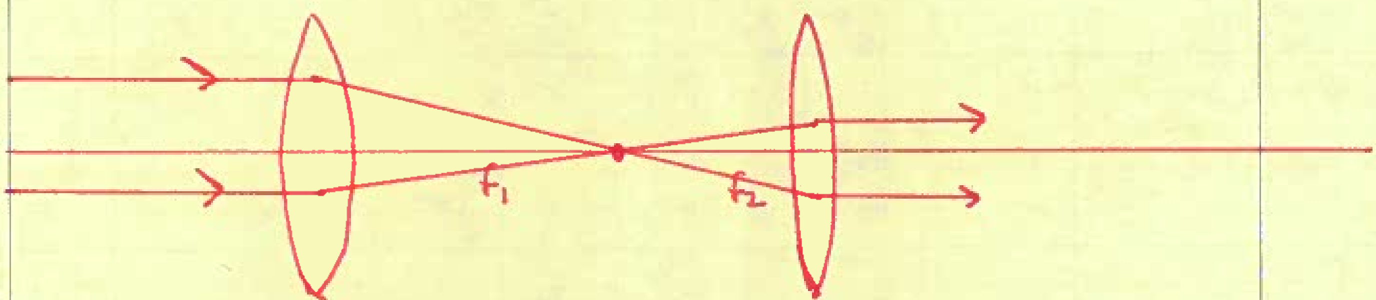
where f is the focal length.

thus, a lens has the effect.

$$\begin{pmatrix} x \\ x' \end{pmatrix}_{after} = \begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix} \begin{pmatrix} x \\ x' \end{pmatrix}_{before.}$$

the matrix being the focussing matrix.

consider a compound system



if. $f_1 \gg f_2$ then the parallel light is concentrated ie an infinitely far away object appears brighter to the eye

in matrix notation this would become.

$$\begin{array}{cccc} \text{lens}_2 & \text{drift.} & \text{lens 1} & \\ \begin{pmatrix} 1 & 0 \\ -\frac{1}{f_2} & 1 \end{pmatrix} & \begin{pmatrix} 1 & f_1+f_2 \\ 0 & 1 \end{pmatrix} & \begin{pmatrix} 1 & 0 \\ -\frac{1}{f_1} & 1 \end{pmatrix} & \begin{pmatrix} x \\ 0 \end{pmatrix}. \end{array}$$

$$\begin{pmatrix} 1 & 0 \\ -\frac{1}{f_2} & 1 \end{pmatrix} \begin{pmatrix} 1-\left(\frac{f_1+f_2}{f_1}\right) & f_1+f_2 \\ -\frac{1}{f_1} & 1 \end{pmatrix} \begin{pmatrix} x \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 1-\frac{f_1+f_2}{f_1} & f_1+f_2 \\ \frac{f_1+f_2}{f_1 f_2} - \frac{1}{f_1} - \frac{1}{f_2} & 1-\frac{f_1+f_2}{f_2} \end{pmatrix} \begin{matrix} x \\ 0 \end{matrix}$$

$$\begin{pmatrix} \left(1-\left(\frac{f_1+f_2}{f_1}\right)\right)x \\ 0 \end{pmatrix} = \begin{pmatrix} 1-\frac{f_1+f_2}{f_1} & f_1+f_2 \\ 0 & 1-\frac{f_1+f_2}{f_2} \end{pmatrix} \begin{pmatrix} x \\ 0 \end{pmatrix}$$

The significance of the lower left element being zero is that the outgoing ray's direction is idependent of it's incoming position hence parallel light coming in is parallel light going out though direction may be changed (comment on beam lines/accelerators Quads = lens)

Telescopes can also be made with mirrors like the one we used last night. This is much more common because it is vastly less expensive.

A parabola has the property that it focus' ~~light~~ parallel light at the parabolic focus. This is well illustrated in the book so I won't harp on it. As far as the matrix aproach is concerned mirrors can be treated like lens'. There are a variety on standard reflecting telescope configurations.

Prime
newtonian
cassegrain (like the one we used)
Coudé

Two imporoant features of telescopes

1. Signal.
   The brightness focussed onto your eye or a camera is proportional to the area of the telescope. ie $B \propto D^2$.

2. resolution

$$\theta_{\text{diff. limit}} \simeq 1.22\,\lambda/D \quad \text{(in radians)}$$
$$= 206265 \cdot 1.22\,\lambda/D \quad \text{(in seconds of arc)}$$

The shorter the wavelength the better the resolution therefore two very close stars will be blurred into one object in the red but resolvable in the blue

The largest optical telescope is in the soviet Union with a diameter of 6 meters. The largest in the west is on Mt. Palomar Calif and is 200 in (~ 5 m.)

the resolution of this device at say 5000 Å

$$\theta_{min} = 2.063 \times 10^5 \cdot 1.22 * \frac{5 \times 10^{-7} m}{5.}$$

$$= .025 \text{ sec of arc.}$$

This cannot be acheived ~~due~~ to atmospheric distortions and the air limits it to

$$\theta_{seeing} \sim .25 \text{ sec of arc.}$$

On Mauna Kea hawaii 14,000 ft.!

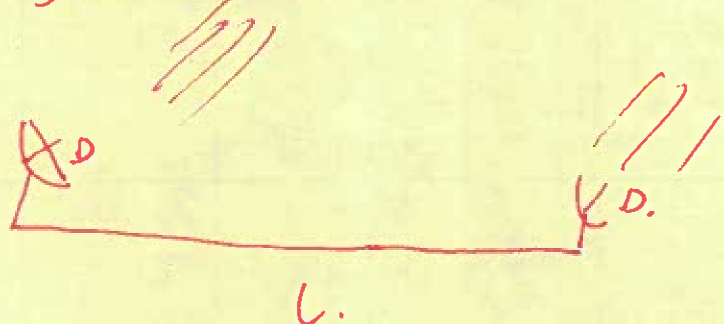
$$\theta_{seeing} \sim .1 \text{ sec of arc.}$$

the space telescope (2.4 m.) which will be above the atmosphere will acheive its theoretical resolution and because it is above the water vapor can be run in the Ultra Violet

$$\lambda \sim 1000 \rightarrow 2000 \text{ Å}$$

appeture Synthesis radio telescopes

telescopes can be made to run at radio wavelengths using metallic parabolic reflectors. The signals can be added electronically presevling the phase information to create the interference pattern which corresponds to focussing. hence.



two telescopes of diameter D sepparated by a length L can have a resolution.

$$\theta = 2.063 \times 10^5 \cdot 1.22 \cdot \lambda / L.$$

and a signal α $2 D^2$.

VLA very large array in NM. has
75 25 m dishes spread out
on rail road track 15 miles long
laid out in a Y

At optical wavelengths the frequencies are far too high to play this game but large ~~mirrors~~ telescopes can be made using multiple mirrors to gather more signal.

What can be done is.
moving mirror
Specle interferometry

$1/r^2.$

Ch 3.

forces.

There are four known forces in nature

the gravitational force 10^{-40}
the weak nuclear force 10^{-10}
the electro magnetic force 1
the strong nuclear force 100

To date ~~thes~~ two of these forces (the weak nuclear and electromagnetic forces) have been unified into a single mathematical description. Gravity is described geometrically by general relativity and the strong nuclear force is currently best described by a theory something like electromagnetism but with some major differences

1. The force mediators (like the EM photon) are "charged." (Non Abelian).
2. there are three charges instead of one in EM.

Gravity is the force we will mainly be concerned with it has the form,

$$\bar{F}_g = -G\frac{M_1 M_2}{r_{12}^3}(\vec{r}_1 - \vec{r}_2)$$

$G = 6.67 \times 10^{-11}\ m^3/kg\,sec^2$
$6.67 \times 10^{-8}\ cm^3/gm\,sec^2$.

mechanics has led to certain understandings of the universe among them that there exist certain physical quantities whose values do not change in time. ~~among them~~. These conserved quantities in fact are fundamentally tied to the invariance properties of the universe.

Conserved quantity	invariance
① Energy	laws of physics are constant in time
② momentum	laws of physics are independent of absolute position
③ angular momentum	laws of physics are independent of rotations.

The assigned problem 3.1 is to explicitly show that for gravitation Energy is conserved