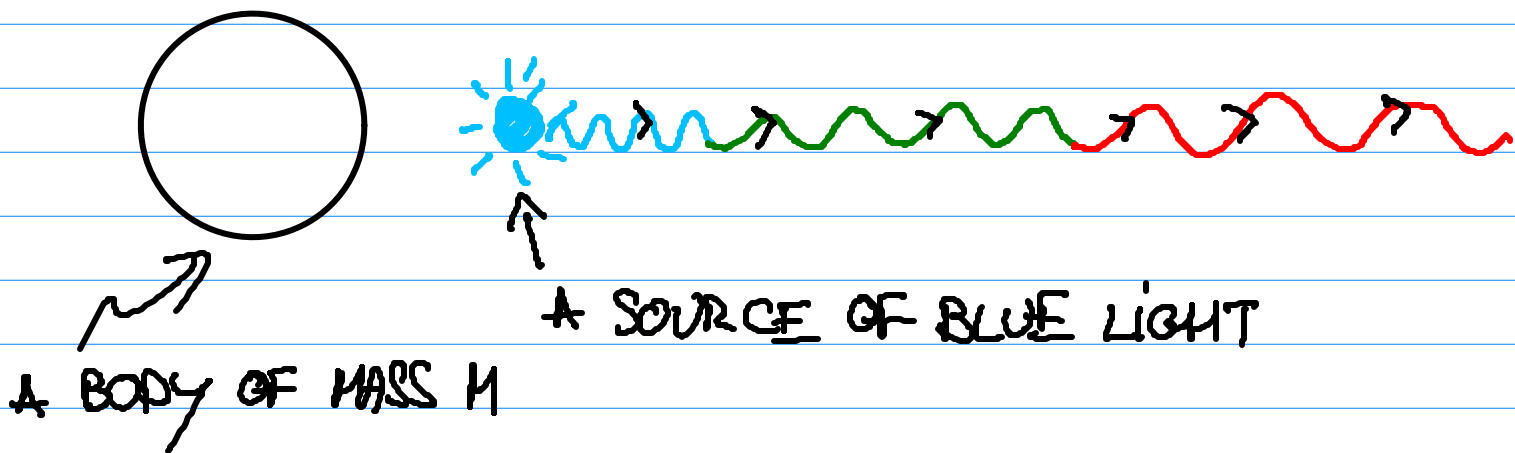


IMPORTANT RESULTS OF THE GENERAL THEORY OF RELATIVITY:

GRAVITATIONAL REDSHIFT:



AS THE PHOTON ESCAPES THE GRAVITATIONAL PULL BY MASS M IT LOSES ENERGY AND THE WAVELENGTH OF LIGHT INCREASES:

$$\text{PHOTON ENERGY} = \frac{h c}{\lambda}$$

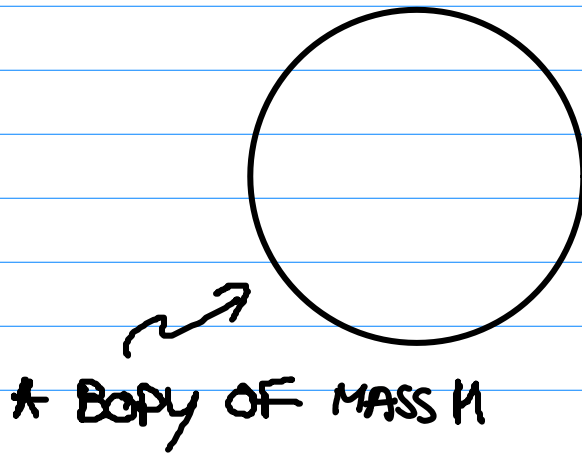
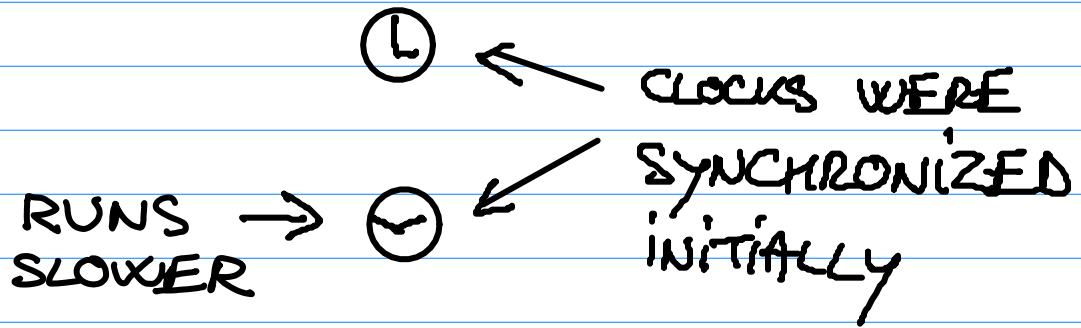
PLANCK CONSTANT

SPEED OF LIGHT

WAVELENGTH

THE GRAVITATIONAL REDSHIFT IS DIFFERENT FROM THE ONE CAUSED BY THE DOPPLER EFFECT WHEN THE SOURCE IS MOVING AWAY FROM THE OBSERVER.

THE STRONGER THE FORCE OF GRAVITY,
THE SLOWER THE CLOCKS RUN :

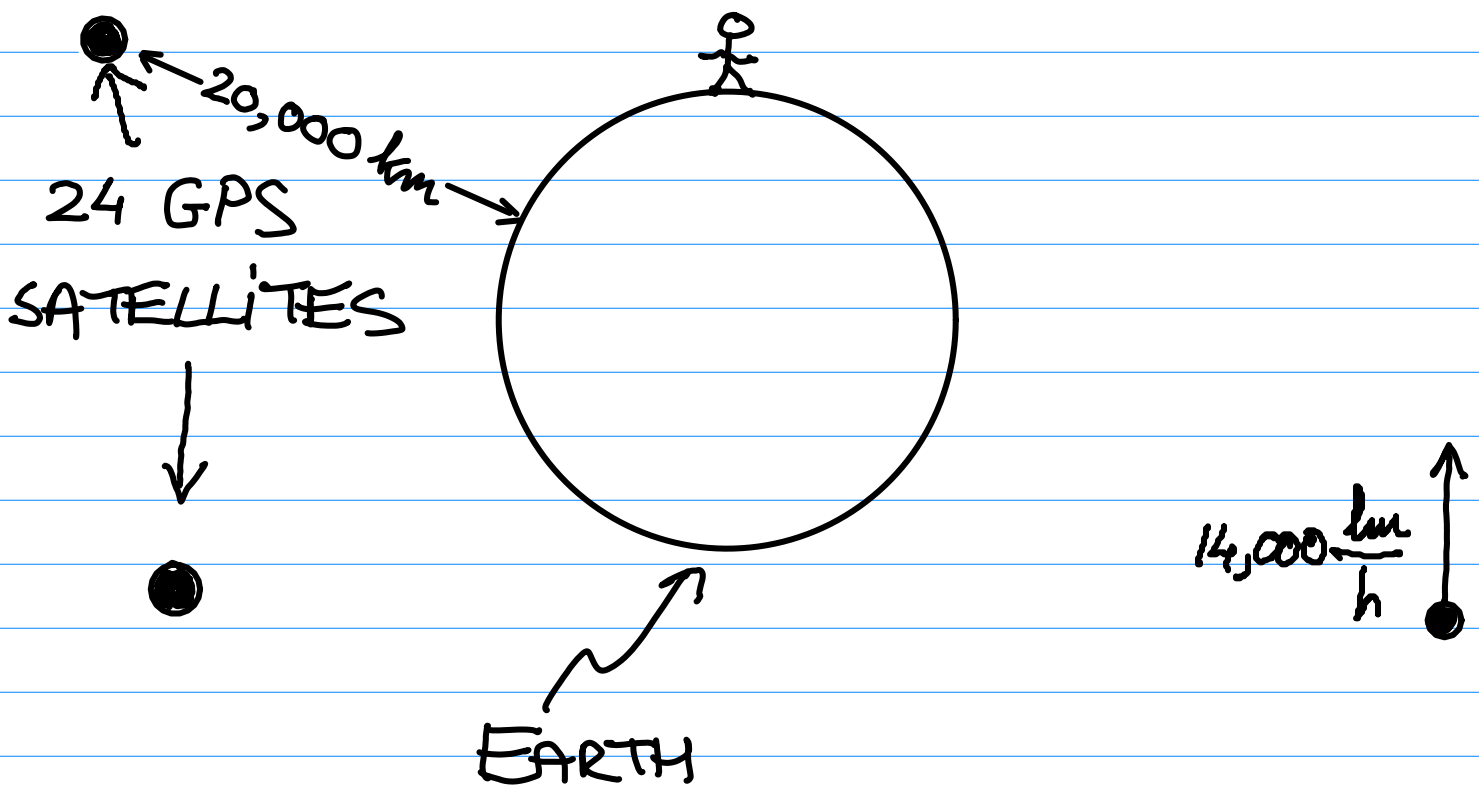


THE RELATIVISTIC EFFECTS (BOTH SPECIAL AND GENERAL THEORY OF RELATIVITY) MUST BE TAKEN INTO ACCOUNT WHEN DESIGNING THE

GPS ← SYSTEM

↗ ↖

GLOBAL POSITIONING



THE CLOCKS ON THE SATELLITES RUN $45 \mu\text{s} = 45 \times 10^{-6}$ S FASTER PER DAY THAN THE GROUND CLOCKS (GENERAL RELATIVITY).

BECAUSE THE SATELLITES ARE MOVING AT $14,000 \text{ km/h}$ RELATIVE TO THE GROUND THEIR CLOCKS ARE RUNNING $7 \mu\text{s}$ SLOWER PER DAY THAN THE GROUND CLOCKS (SPECIAL RELATIVITY).

THE NET EFFECT IS THAT THE SATELLITE CLOCKS RUN $45 \mu\text{s} - 7 \mu\text{s} = 38 \mu\text{s}$ TO FAST PER DAY COMPARED TO THE GROUND CLOCKS.

THE SPEED OF LIGHT $\approx 1 \frac{\text{foot}}{\text{ns}}$ ($1 \text{ ns} = 10^{-9} \text{ s}$)

THE DISTANCE THE LIGHT TRAVELS IN $38 \mu\text{s}$ IS

$$\frac{38000 \text{ ns}}{38 \mu\text{s}} \cdot 1 \frac{\text{foot}}{\text{ns}} / \text{PER DAY} = 38,000 \text{ foot} / \text{PER DAY} \approx$$

$\approx 11 \text{ km} / \text{DAY}$. THE DISTANCES WOULD BE OFF BY THAT MUCH IF THE RELATIVISTIC EFFECTS WERE IGNORED IN THE DESIGN OF GPS.

THE MILKY WAY GALAXY (CH. 16)



A DIFFUSE BAND OF LIGHT ACROSS THE SKY.

IN 1609 GALILEO OBSERVED THAT IT CONSISTS OF VERY MANY FAINT STARS - FAINT BECAUSE THEY ARE AT A GREAT DISTANCE.

IN THE 18TH CENTURY IT WAS PROPOSED BY THOMAS WRIGHT AND BY IMMANUEL KANT THAT WE OBSERVE IT BECAUSE WE LIVE IN A DISK OF STARS:

