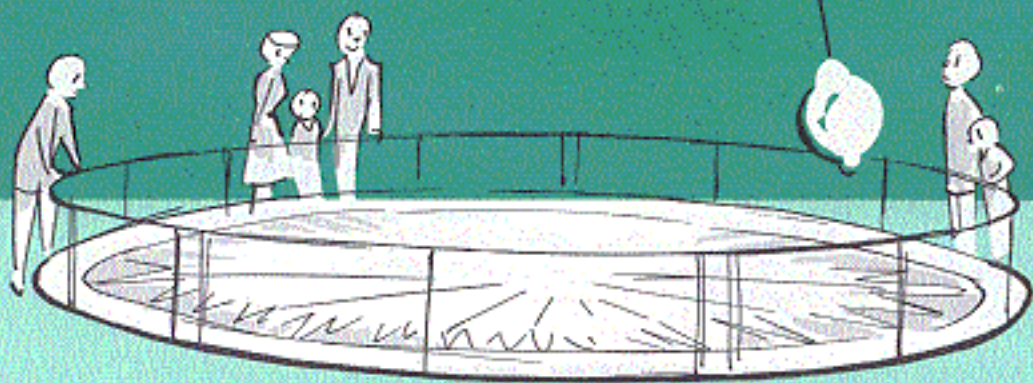


ABOUT FOUCAULT PENDULUMS

and
How They Prove
the Earth **ROTATES!**

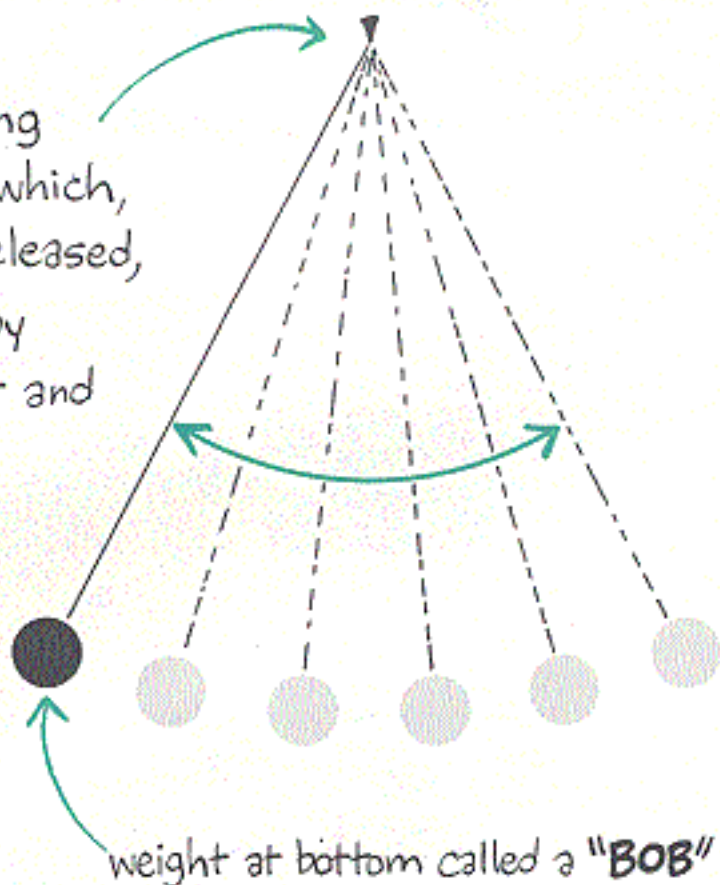


A SCRIPTOGRAPHIC STUDY UNIT

What's a "PENDULUM" anyway?

word comes from
Latin word "pendulus"
which means "hanging!"

Answer: Something hanging
from a fixed point which,
when pulled back and released,
is free to swing down by
force of gravity and then out and
up because of its inertia.*



* **INERTIA:** means that bodies in motion, will stay in motion; and bodies at rest, will stay at rest, unless acted on by an outside force.

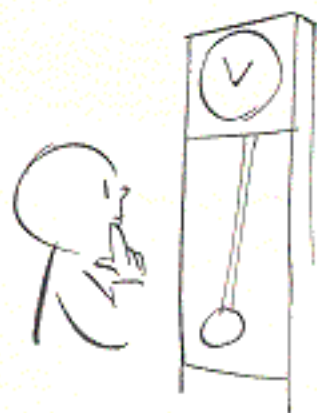
WHY is a pendulum scientifically IMPORTANT?

because

(1) it can be used to provide accurate **TIME-KEEPING**

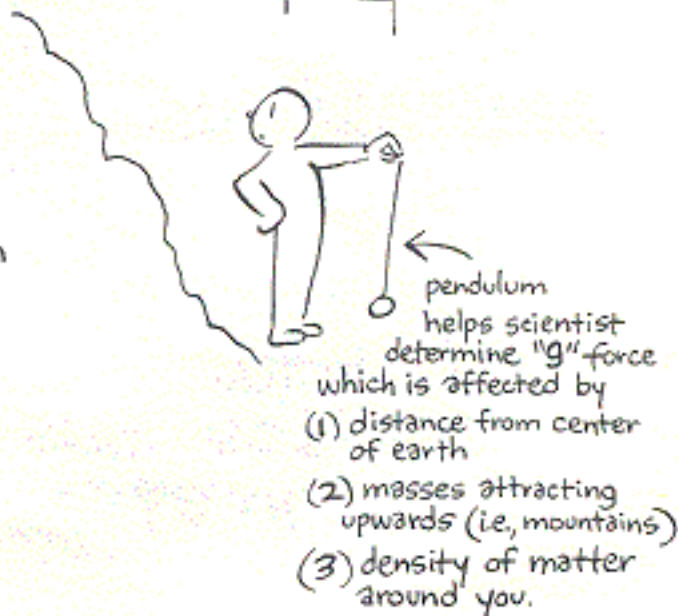
(2) it can be used to measure "g"
(the acceleration due to gravity)
which is important in determining the shape of the earth and the distribution of materials within it (the science of geodesy)

(3) **AND ALSO**
it can be used to show that the **EARTH SPINS!**



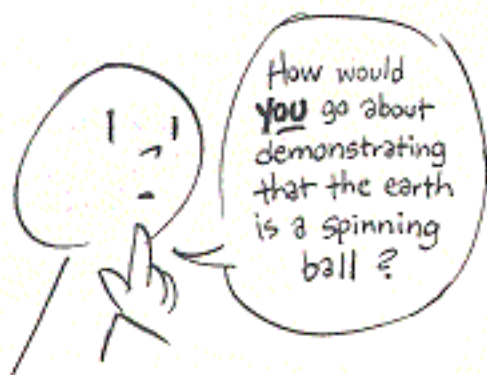
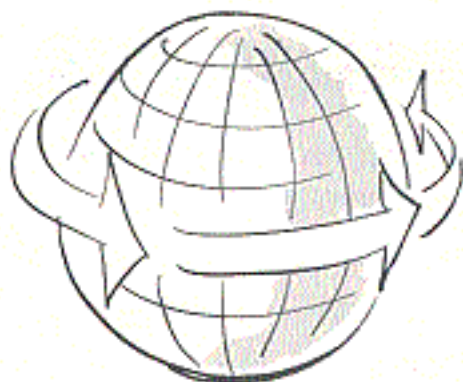
NOTE:

today we use atomic vibrations for the most accurate clocks.



pendulum helps scientist determine "g" force which is affected by

- (1) distance from center of earth
- (2) masses attracting upwards (ie, mountains)
- (3) density of matter around you.



--and then in 1851-- a French physicist named **FOUCAULT** found a way to do it -- via a

PEND

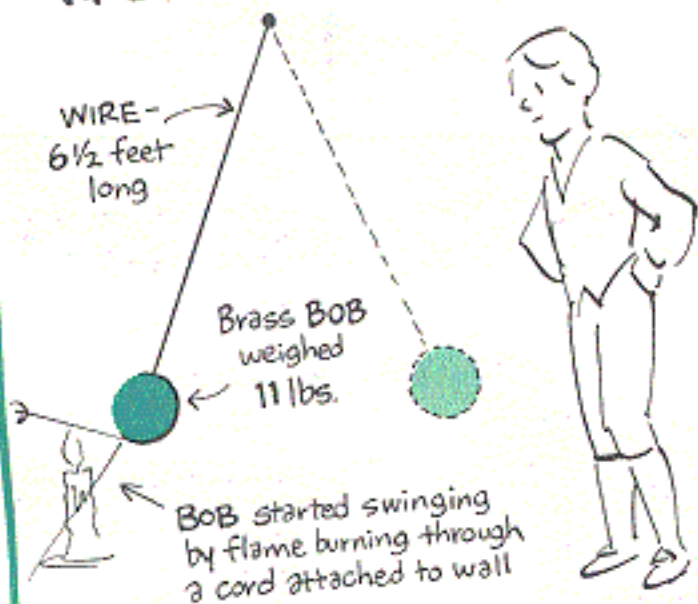


I think I can prove that the earth rotates by swinging a **PENDULUM**

WHO WAS FOUCAULT?

Jean Bernard Leon Foucault was born in 1819, the son of a French publisher. He showed early skill in making mechanical toys, studied medicine, but shifted to physical sciences at the Paris Observatory. He became one of the most versatile experimentalists of all time.

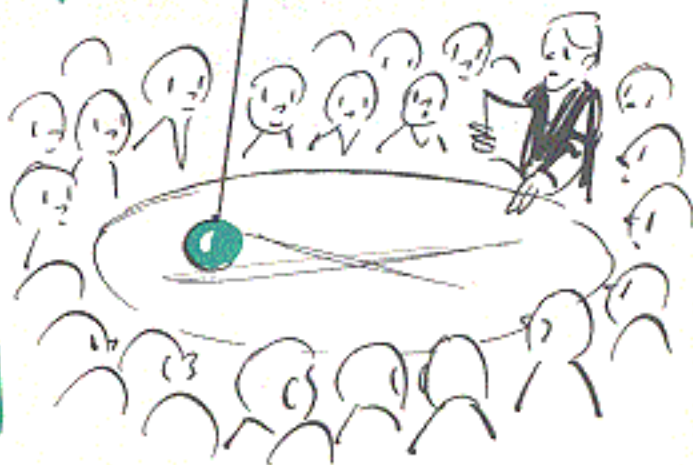
Foucault's **FIRST** demonstration WAS IN HIS CELLAR--



Foucault's **SECOND** demonstration was in the **PARIS OBSERVATORY**

← WIRE - 36 feet long

...the longer WIRE resulted in longer and SLOWER OSCILLATIONS



ULUM--

-- and finally,
Foucault made a **THIRD**
demonstration in the
PANTHEON
in Paris

--here, the steel WIRE
was 220 FEET LONG

--and the BOB
of lead in copper
weighed 61 lbs.

**A RING OF
WET SAND**
in which a pin
on the end of the
bob cut through a
path to show how plane
of oscillation moved

NOTE: A year later, 1852, Foucault also invented
the "GYROSCOPE", a flywheel device that
pivoted freely about its center of gravity. In rapid
motion its axis indicates fixed direction in space.



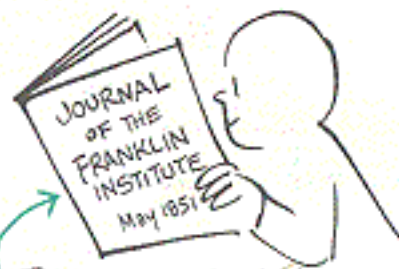
You are invited to
witness the earth
revolve, in the
Southern Hall of the
Paris Observatory,
tomorrow
at half past two.
Francois Arago
DIRECTOR

50000--

Foucault **DEMONSTRATED**

that the plane of
oscillation would
REVOLVE about 270°
in 24 hours per his
prediction,

thus showing the ROTATION OF THE EARTH!



This experiment quickly
reported in the United States--
a translation of the report
in French "Comptes Rendu".

TODAY--

you can see this

FOUCAULT PENDULUM

demonstration
yourself at the

**CALIFORNIA ACADEMY
OF SCIENCES**

how the **FOUCAULT**

What keeps it moving?

Air resistance would normally stop the pendulum after a few hours -- so an

IRON COLLAR is installed on the wire surrounded by an electromagnet that attracts the collar as the bob swings out, then shuts off automatically as it swings back, thus keeping pendulum going.

Magnet is turned on and off by a switch which is activated when the support wire interrupts a beam of light shining across its path.

WIRE CLAMPED
in tapered support which permits bending in a slightly different direction on each swing

WIRE is flexible steel aircraft control cable

30 feet long
The longer the wire, the slower the bob swings and the **LESS** retarded by friction with air

NOTE: Sometimes the bob swings in a narrow elliptical path

1" or 2" wide

caused by slight uncontrolled forces such as vibration of building (or inconsiderate people!)

**A FINE
EXAMPLE OF
INERTIA--**

The **BOB** just swings back and forth-- while the world leaves it behind!

"BOB"

is hollow polished brass ball 15" diameter

WEIGHS

240 lbs.

(must be heavy so as not to be deflected by air currents)

... at the

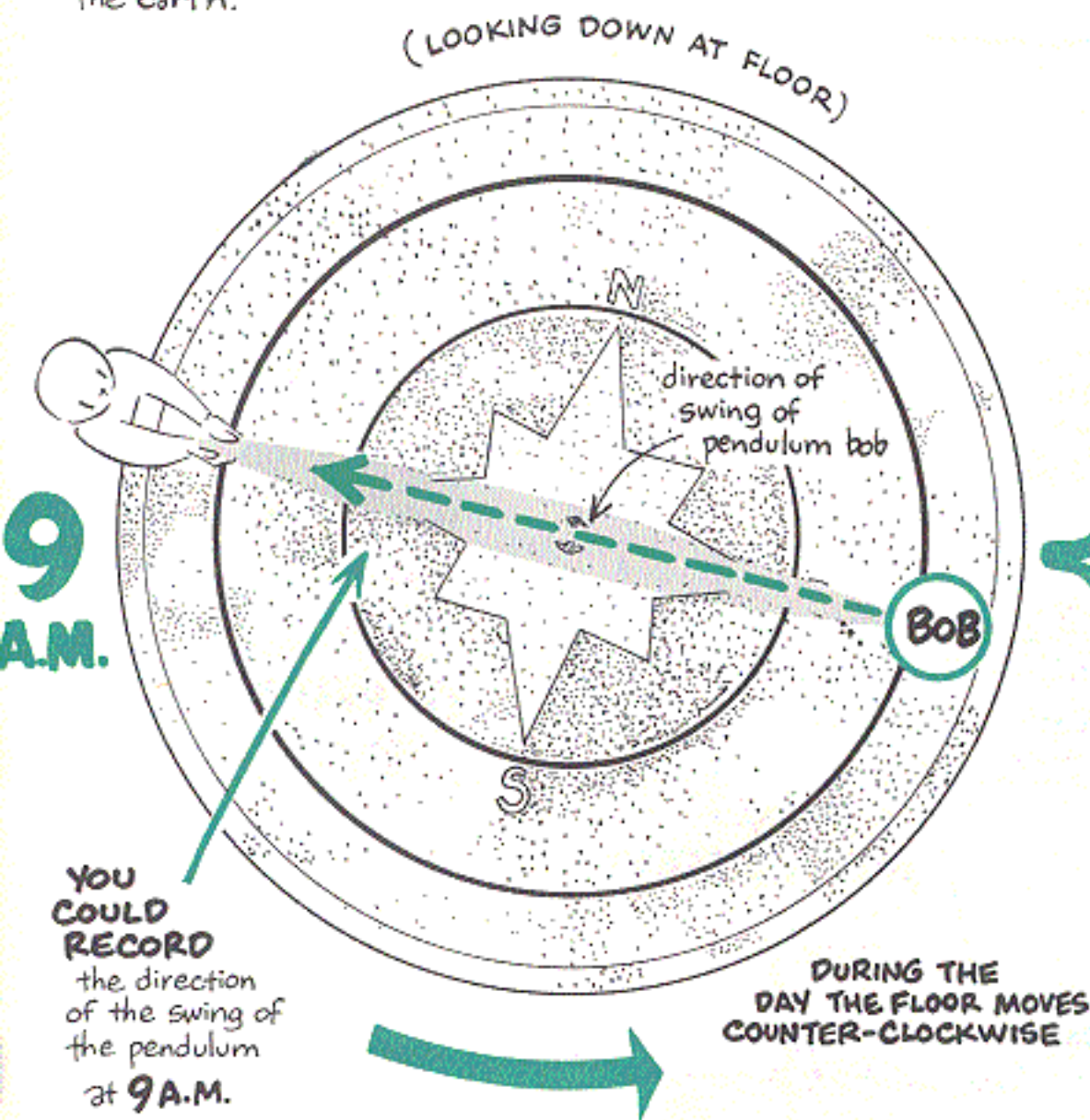
**CALIFORNIA
ACADEMY
OF SCIENCES**
Golden Gate Park
San Francisco, California

**THERE ARE MANY
OTHER
DEMONSTRATIONS**
of the Foucault Pendulum
in the U.S. -- SUCH AS

PENDULUM works...

Note that while the **PENDULUM** seems to change its path during the day -- actually it is the **FLOOR** beneath it that changes, being twisted around by the daily rotation of the earth.

Showing how the direction of the **PENDULUM'S** line of swing changes in relation to floor.



10 A.M.



11 A.M.



12 NOON



1 P.M.



2 P.M.



3 P.M.



4 P.M.



5 P.M.



UNITED NATIONS -- in lobby of General Assembly building (gift of Queen Juliana of the Netherlands). Has a 200 lb. bob, a 75 foot wire, and rotates about 235° in 24 hours.

WASHINGTON, D.C. SMITHSONIAN MUSEUM OF HISTORY and TECHNOLOGY has a $71\frac{1}{2}$ foot wire, rotates about 226° in 24 hours.

At San Francisco latitude, the floor turns about 226° under the pendulum in about 24 hours (at North Pole, it would turn a full circle 360°)

See next page

WHY does the pendulum demonstrate the rotation of the earth?

... BECAUSE

there is no force acting on the pendulum to make its plane of oscillation rotate or go around its own axis.



Let's consider-- what **ARE** the forces acting on the pendulum?

1 it's the pendulum's

INERTIA

that makes it swing straight **OUT** →

and the force of

GRAVITY

that pulls it straight **BACK** ←

(or rather "**DOWN**"-- it's the force of the wire that makes it go in an **ARC** rather than straight **DOWN**.)

3 also minor disturbances such as

AIR CURRENTS

may throw its path an inch or two off center. →

2 and **AIR RESISTANCE**

makes it swing in

SHORTER ARCS ← →

-- but just as straight arcs (in the demonstration, the electromagnet booster merely counteracts this air resistance.)

BUT

because of the way it is suspended

IT WILL NOT TWIST

AROUND if the building twists around.

SO-- if the pendulum seems to rotate with respect to the floor--and we know there is no force available to make the pendulum rotate--**THEN**--it must be the floor that is rotating--and--if the floor is attached to the earth--**THEN IT MUST BE THE EARTH THAT IS ROTATING!**



TO UNDERSTAND THIS, we must understand the difference between

2 kinds of MOTION around the earth's AXIS--

1. "TWISTING"

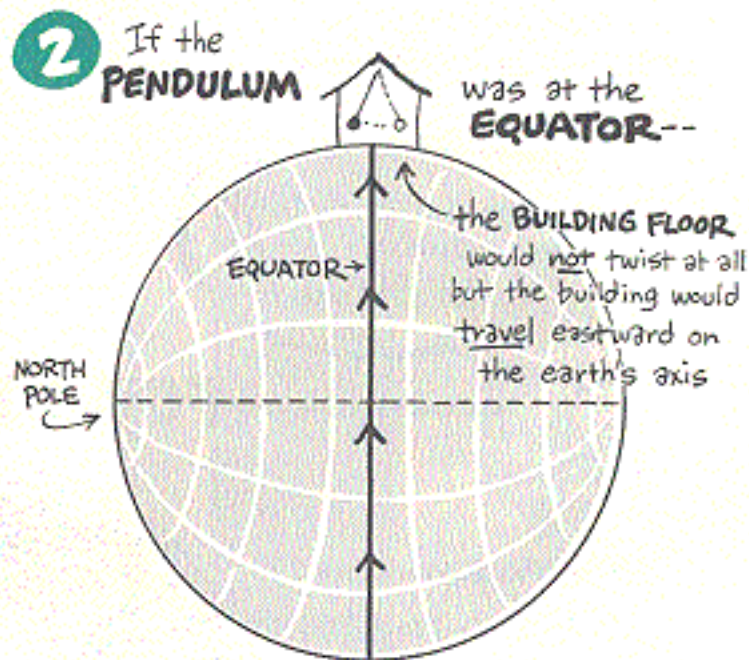
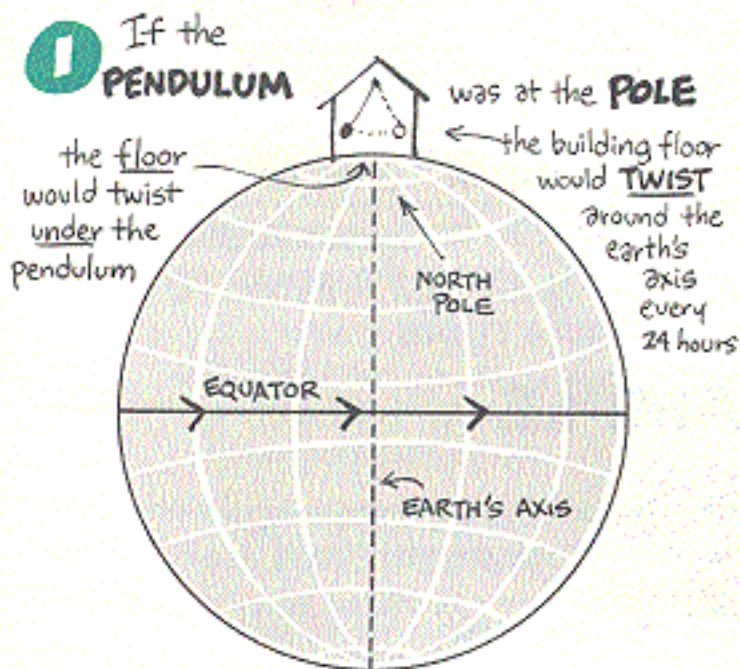


motion of a plane around a perpendicular axis

2. "TRAVELLING"



motion of a plane in a circle around an axis parallel to the plane



BUT-- it is clear that the pendulum--which doesn't twist-- would stay in its original plane.

--and the pendulum--being tied to the building--would travel right along with the building with no visible effect-- since there is no twisting motion.

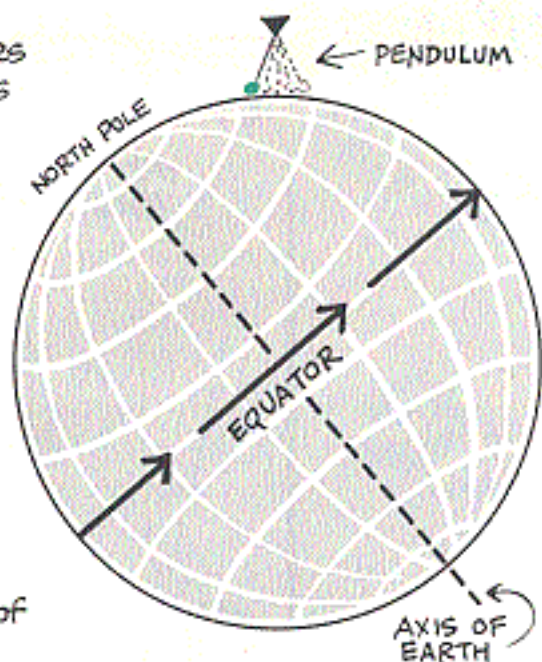


BUT-- what happens at points between the Pole and the Equator?



3 if pendulum was at LATITUDES between North Pole and the EQUATOR--

The amount of twisting motion of the building floor around the earth's axis varies with the latitude but is less than at Pole. The pendulum does not share this motion and therefore lags behind floor--and this can be seen. But the travelling motion of the pendulum eastward with the building is slower than at the Equator--but this you cannot see! That's why the pendulum lags behind only the twisting part of the floor's rotation and hence only loses part of a full circle to it in 24 hours.



-- some "TWISTING" and some "TRAVELLING" takes place-- the amount of twist being made visible by the pendulum, but the amount of travel cannot be seen.

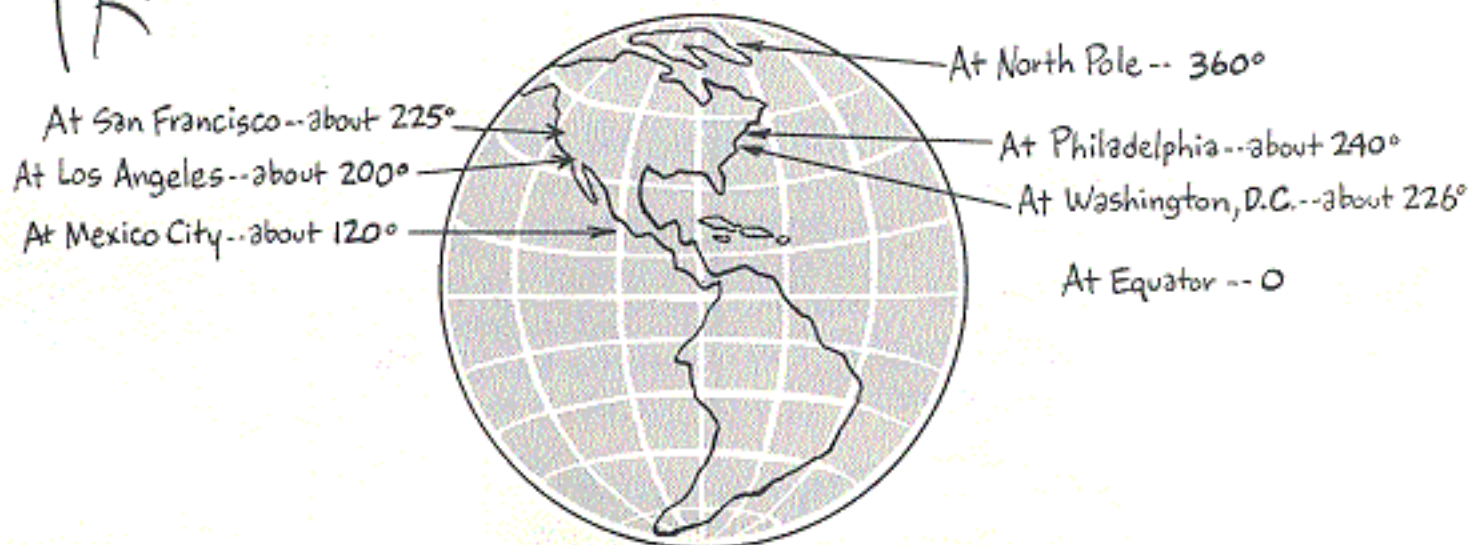
DEGREES of "TWIST" per day may be determined mathematically by this formula

$$n = 360^\circ \sin \theta \rightarrow \text{see p. 15}$$

and can be demonstrated by using the pendulum

This is more difficult to visualize--but it's **LOGICAL!**

FOR EXAMPLE--



Sooo-- by a **Foucault PENDULUM**, man can **DEMONSTRATE** at any point on the **EARTH'S** surface (except on the equator) that the earth rotates --

HOW the ROTATION of the EARTH affects our LIVES--

FOR EXAMPLE--

IN PLANE FLIGHTS



Navigators must allow for deviation to right when flying in northern hemisphere--and to left in southern hemisphere.

SPACE FLIGHTS



The rotation of the earth will create special problems on flights to and from the moon.

ALSO--

WINDS

created by high to low pressure have a **RIGHT HAND** deflection that creates cyclones, hurricanes and typhoons, in the northern hemisphere.



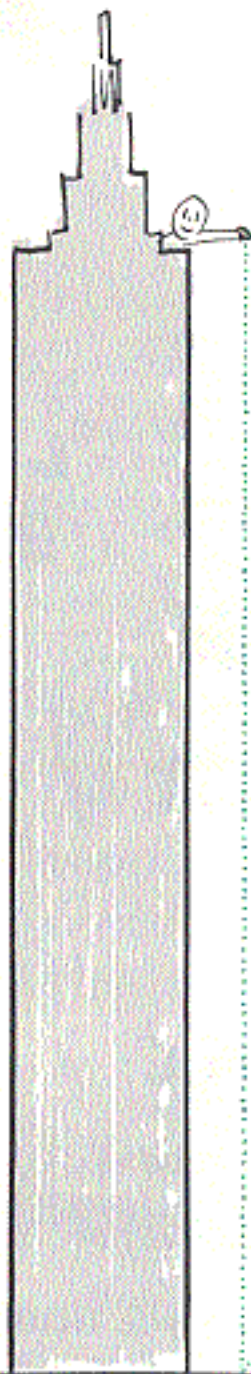
ALSO --and **MOST IMPORTANT**--

the rotation of earth results in wider distribution of rain over the earth.



If no frequent spin, there would be a steady flow of cool air from pole to equator. The cool air would be near the surface; as it warmed, the air would gradually rise and flow back toward the pole, dropping its water content as it again cooled. This would tend to produce constant rain near the equator and deserts in the northern and southern parts of the world. The rotation of the earth helps break up this north-south cycle by introducing an east (or west) deflection.

DID YOU KNOW THAT--



IF you could drop a **GOLF BALL** from the **EMPIRE STATE BUILDING** -- with no wind -- it would land nearly **5"** to the **EAST** of the true vertical

↓
due to **EARTH'S ROTATION**



HOW to FIGURE the PERIOD of a simple PENDULUM

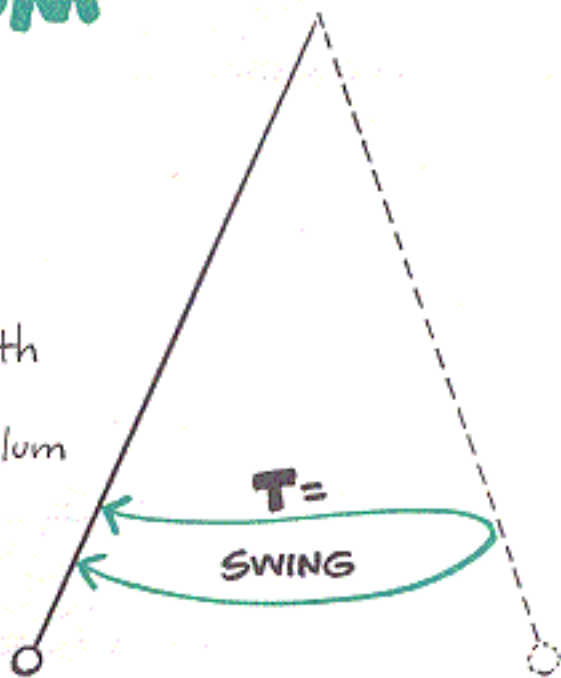
IF

Period of swing = **T**
Length of pendulum = **L**
Acceleration of gravity = **g**

THEN

$$T = 2\pi \sqrt{\frac{L}{g}}$$

L =
Length
of
pendulum



T = PERIOD
of the swing
(“BEAT” = 1/2 Period)

EXAMPLE: At California Academy of Sciences

the length of the pendulum is -- 30 ft. = **L**

The acceleration of gravity at this location is -- 32 ft./sec.² = **g**

USING EQUATION -- **T = 6.1** seconds -- time for simple
pendulum to swing from side
to side and back.



HOW to FIGURE

the NUMBER of DEGREES of ROTATION of EARTH beneath pendulum in 24 hours

The number of degrees of a circle that the earth will "twist" under a pendulum in 24 hours at any given latitude (n) may be determined by the following formula:

$$n = 360^\circ \times \sin \text{ of Latitude}$$

ϕ = **LATITUDE** = angular distance of a place from the equator.



EXAMPLE: At San Francisco

Latitude ϕ California Academy of Sciences = $37^\circ 46.2'$

$$\sin \phi = .6125$$

$$n = 220.5^\circ \text{ in 24 hrs.}$$

$$1 \text{ revolution} = 39.18 \text{ hrs.}$$

