I. MetaThemes

How do I talk about Einstein’s theory without mathematics?

Fortunately, the *principles* of physics are not mathematical in origin.
Index: Rough Draft

A. Mach & Rotational Relativity

B. Rotating Frame Paradoxes

C. Field Rotation & Torsion

D. References

A. Mach & Rotational Relativity

1. Relative Motion

2. Newton’s Bucket and Mach

3. Frame-dragging
A1. Special Relativity

1905 Einstein (26 years old) publishes theory of special relativity

- Speed of light is the same for all observers

- Motion is relative (Galileo)
  - there is no experiment one can do to determine absolute motion relative to “space”.

![Image of baseball game]

As seen by outfielder, ball is approaching her at

\[(30 \text{ m/s}) + (10 \text{ m/s}) = 40 \text{ m/s}\]

A2. Rotational Relativity

Newton argued that water in a rotating bucket will make the shape of a parabola due to centrifugal force.

The presence of centrifugal and coriolis forces confirm that you are in a non-inertial rotating frame of reference.
A3. Mach’s Principle

1883 Mach argued that one can not tell if the bucket is rotating, or instead the stars are rotating around the bucket.

A4. Frame Dragging

Mach argued a centrifugal force will appear in both cases, indicating only a relative rotational motion.

1896 Friedlander attempted (failed) to measure if there is a centrifugal force introduced inside of a big rotating flywheel.

Frame Dragging:
Recently Gravity Probe B has been orbiting the earth to see if there is a similar effect: that the rotating earth pulls the space around with it.
Ernst Mach

The “Mach Principle” was never really written down, but attributed to him by others, which has led to considerable confusion. Some common ones (reference Bondi & Samuel):

- **Mach0**: The universe, as represented by the average motion of distant galaxies, does not appear to rotate relative to local inertial frames.
- **Mach2**: An isolated body in otherwise empty space has no inertia.
- **Mach3**: Local inertial frames are affected by the cosmic motion and distribution of matter.
- **Mach5**: The total energy, angular and linear momentum of the universe are zero.
- **Mach6**: Inertial mass is affected by the global distribution of matter.
- **Mach7**: If you take away all matter, there is no more space.
- **Mach10**: Overall rigid rotations and translations of a system are unobservable.

February 18, 1838 – February 19, 1916

Benedict Friedlaender

- 1896 Friedlander attempted (failed) to measure if there is a centrifugal force introduced inside of a big rotating flywheel.

- The book *Absolute or Relative Motion?* (1896) by Benedict Friedländer and his brother Immanuel contained ideas similar to Mach’s principle.

(July 8, 1866 - June 21, 1908)
### A5. Machian vs GravitoMagnetic

Newton’s gravity is sort of the “electric” part of GR
Frame dragging is sort of a “magnetic” part of GR

If there is 10x more mass rotating, the frame-dragging gravitomagnetic effect should be 10x bigger.

The Machian centrifugal force however should be the same if there is 8 stars out there rotating about the bucket, or a billion

They are not the same!

### B. Rotating Paradoxes

1. Ehrenfest Paradox (1909)

2. Sagnac Effect (1913)

3. Schiff Paradox (1939)
### B1. Lorentz-FitzGerald Contraction

1889 FitzGerald, 1892 Lorentz

- Propose a moving meter stick will appear to shrink in length
  \[ L' = L \sqrt{1 - \left(\frac{v}{c}\right)^2} \]

- 1905 Einstein deduces this from his postulates of relativity.

### B2. Ehrenfest Paradox 1909

Ehrenfest proposes puzzle about a rotating disk.

- **FRAME OF DISK**
  - Radius “R”
  - Circumference \( C = 2\pi R \)

- **FRAME OF Lab**
  - Rotating Disk’s Radius will be unchanged (motion is perpendicular to radius)
  - Circumference is moving so is it shrunk?
  \[ C' = C \left[1 - \left(\frac{v}{c}\right)^2\right]^{1/2} \]

How can a rotating circle have a circumference smaller than \( 2\pi R \)?
Paul Ehrenfest

- 1909 Paradox stated (contradicts Born’s ideas of rigid body motion)

- 1975 Grøn states that the resolution of the paradox stems from the impossibility of synchronizing clocks in a rotating reference frame


B3. Sagnac Effect (1913)

Send laser beams around earth to other side. (67 mns)

**Lab Frame:** because of rotation of earth, eastward beam has to go further, takes longer.

\[ T_{\pm} = \frac{r \pi}{c \mp \omega r} \]

**Rotating Frame:**
- Speed of light appears to change with direction \( (c \pm \omega r) \)
- Time gap measured (0.22 usec)

\[ \Delta T = \frac{2\omega (\pi r^2)}{c^2 - \omega^2 r^2} \]
B4. Absolute Rotation?

Universal Nature of Sagnac Effect

- Independent of physical nature of beams
- Problem synchronizing clocks on earth
- Time asynchronization must somehow be induced by setting frame into rotation

Interpretation(?)

- There is NO special relativity of rotation
- Sagnac effect is a measure of absolute rotation

C. Field Rotation Paradox

1. Barnett experiment
2. Field Rotation Paradox
3. Curvature and Torsion
C1. Barnett’s Experiment (1912)

There are analogies to Mach’s problem for electromagnetic fields in rotating frames.

Consider charged cylinder at rest

- Inside the electromagnetic fields are zero.
- A wire (at rest) inside will have no voltage across it.

C2. Barnett’s Experiment (1912)

Put the cylinder into rotation

Lab Frame
- Magnetic field induced
- Wire moving through magnetic field will have a \((v \times B)\) Lorentz force on it
- A voltage is generated across the wire
C3. Barnett’s Experiment (1912)

Rotating Frame

• When you do the experiment, an electric field is found inside (consistent with Lorentz transformation of magnetic field)

• Hence there is voltage across the wire

• Rotational Relativity would demand Gauss’ Law to hold, hence NO electric field. Hence NO voltage measured. Contradiction!

C4. Field Rotation Paradox

Standard View:
• there is NO theory of special rotational relativity.
• The voltage across the wire is a measure of absolute rotation
• But, absolute relative to what? Empty space?

Non-Standard View:
• Corum (1980) shows rotating electrodynamics is consistent with a frame at rest including TORSION

• Torsion is a “twisty” nature to space, which Einstein excluded in his theory of gravitation (he only included “curvature”)

• In a space with torsion, a static electric charge will create a magnetic field!
C5. Curvature

Einstein’s General Theory of Relativity

Gravity is “curved space”

Big curvature makes a Black Hole that you can fall in and never get out

For example, when people throw things into my tuba, they are never seen again.

C6. Torsion (Teleparallel Theory)

• 1930 Einstein attempted to include Torsion (Cartan 1922), but complained that he could not derive how particles moved in it.
• 1996 Kleinert finally solves it (autoparallel paths, not geodesics!)

• It explains Ehrenfest, Sagnac and Field Rotation Paradoxes
• Unlike curvature, hard to visualize.

Kroner (1950s) showed that the Frank angle of crystal disclinations is equivalent to curvature, and Burges vector of dislocation is a measure of torsion.
Summary

If rotational relativity is wrong:
What is absolute rotation measured against?

OR

If rotation IS relative (Mach is correct)
Paradoxes suggest must include torsion

Can torsion be used to explain away dark matter and dark energy?

D. References

Mach
• E. Mach, Space and Geometry (Open Court, 1908)

Paradoxes:
• R. Feynman, R. Leighton and M. Sands, Lectures on Physics, (Addison-Wesley, 1964) p. 14-7. Note the quote “There is no ‘relativity of rotation’.” I believe he is talking about the Barnett experiment, but does not mention it by name.
• M.G. Sagnac, Compt. Rend., 157, 708 (1913); Another source lists it as

Torsion, Teleparallel, Autoparallels, Spin Mechanics
• Einstein, A.; Math. Annal. 102 (1930), pp. 685-697
• Kleinert, H., “Nonholonomic Mapping Principle for Classical and Quantum Mechanics in Spaces with Curvature and Torsion”, gr-qc/0203029
• Peszaglia, “Dimensionally Democratic Calculus and Principles of Polydimensional Physics”, gr-qc/9912025
Addenda: Schiff Paradox

Consider two concentric spheres with equal and opposite total charges uniformly distributed over their surfaces. When the spheres are at rest, the electric and magnetic fields outside the spheres vanish. When the spheres are in uniform rotation about an axis through their center, the electric field outside vanishes, while the magnetic field does not, since the magnetic moment of each of the spheres is proportional to the square of its radius. Suppose that the spheres are stationary, then an observer traveling in a circular orbit around the spheres should find no field, for since all of the components of the electromagnetic field tensor vanish in one coordinate system, they must vanish in all coordinate systems. On the other hand, the spheres are rotating with respect to this observer, and so he should experience a magnetic field.