Physics 107 – Fall 2011 – Test 1 Summary - Lectures 1-10, Chapters 1-5

**Lectures** (test has one question per lecture):
1. What is physics?
2. Solar System models
3. Theories of matter
4. Atomic model; units; powers of 10
5. Kinematics (g=constant, inertia, speed and velocity)
6. Kinematics (average vs instantaneous speed, acceleration)
7. Dynamics (force, mass, F=ma, action reaction pairs)
8. Dynamics (force diagrams, momentum, centripetal force)
9. CNGS/OPERA result and background
10. Classical law of gravity

**What is physics?**

Physics is the science focused on most “fundamental” aspects of nature
- **theory**: model, with math, of how things may work
- **observation/experiment**: compare empirical data with theory to support or rule it out

Ideal-based theories: closer to religion, e.g. Ptolemy and Copernicus solar system models
Data-based theories: further from religion, e.g. Kepler's solar system, Newton's law of gravity

**Planetary Astronomy**

Geocentric solar system model: complex system with epicycles, etc.
- explained retrograde motion of planets
- accurately predicted positions of planets in sky

Heliocentric solar system model: much simpler system
- explained full phases of Venus
- Kepler – elliptical orbits give excellent agreement with more accurate Tycho measurements

**Matter**

Atomic theory dates back to Greeks
- explains odors (tiny, invisible 'essence')
- explains chemical reaction ratios (whole number ratios)
- explains Brownian motion (random motion)
- explains elements (basic building blocks)

Four states of matter: solid, liquid, gas and plasma

Radioactive decay (1900) – natural materials emit energetic particles:
- $\alpha$ particles: $\text{charge}=+2$, $\text{mass}=4$ (He nucleus)
- $\beta$ particles: $\text{charge}=\pm 1$, $\text{mass}=\text{small}$ (electron/positron)
- $\gamma$ particles: $\text{charge}=0$, $\text{mass}=0$ (photons=light)
Rutherford gold foil (Geiger-Marsden) experiment (1911) showed that matter is 99.99999% empty space. Leads to “planetary” atomic model.

1920s – quantum atomic model explains new observations, electrons like 'charged cloud'

**Units and Orders of Magnitude**

Review units of length, time, mass, force; review scientific notation

Physics spans **extreme** range of length, time, mass, etc.

**Kinematics – mathematical description of motion**

Galileo: objects all fall at same **acceleration**  $g = 9.8\, m/s^2$  IF no friction, air drag

Newton: if no external force, object has constant velocity (which may be zero)

**velocity** = combination of speed and direction, e.g. “40 mi/hr northeast”

average velocity = (total distance)/(total time taken)

instantaneous velocity = (distance)/(very small time taken)

**acceleration** = rate of change of velocity; can be due to change of speed, direction or both

average acceleration = (total change in velocity)/(total time taken)

instantaneous acceleration = (change in velocity)/(very small time taken)

Equations:

- distance, given speed and time        $d = vt$  (if speed constant)
- speed, given acceleration and time    $v = at$  (if acceleration constant)
- distance, given acceleration and time $d = \frac{1}{2} a t^2$  (if acceleration constant)

**Dynamics – mathematical theory of motion**

Newton introduced **force** and **mass**, said acceleration caused by force on mass:

$$F = ma$$  force units: 1 Newton = 1 N = 1 kg-m/s$^2$ (lbs in English units)

Most everyday forces are **contact** forces, ultimately caused by **electric force** between molecules, atoms and within atoms. **Gravity** is a fundamental, non-contact force, “action at a distance”.

Force diagrams (or “free body diagrams”): (1) isolate object, (2) draw only **external** forces acting ON that object, (3) add forces, net force gives acceleration.

Forces come in action/reaction pairs, since forces are **interaction** between two objects.

**Momentum** characterizes object's state of motion; force changes momentum:

$$p = mv, \quad F = \frac{\Delta p}{\Delta t}$$

If zero net force, then momentum is constant.
**Centripetal force** holds moving object in an orbit; for circle:

\[ F_c = m a_c = m \frac{v^2}{r} = m r \omega^2 \]

where \( \omega \) is angular speed in radians/second

**Gravity – classical theory**

**Gravitational force** depends on interacting masses and distance apart:

\[ F_g = G \frac{mM}{r^2} \]

where \( G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \)

Explains:
- elliptical orbits (Kepler observation), including comets
- exact periods of Moon around Earth, Earth around Sun, etc.

At surface of Earth, \( g = \frac{GM}{R^2} \), so 1798 Cavendish measurement of \( G \) provided mass of Earth, since \( g \) and \( R \) were known!

**CNGS/OPERA result (announced 9/22)**

If neutrinos travel faster than light, then special relativity is **wrong**, even if \( c \) is exceeded by only by a very small amount!

Purpose of experiment: observe “neutrino oscillation”, conversion of muon neutrinos from CNGS to tau neutrinos detected in OPERA. If neutrino oscillation exists, then neutrinos have mass (according to standard theory).

Tiny effect reported: neutrinos **arrive early** at OPERA detector in Gran Sasso by 60 ns out of 2.4 ms flight time from CNGS through earth. Distance: 730.5 km.

speed of light: \( c = 299,792,458 \text{ m/s (exactly, meter = distance traveled by light in one second)} \)

measured speed of neutrinos: \( v = 299,799,953 \text{ m/s, only 0.0025\% faster than light!} \)

Believable? Need independent measurements for confirmation:
- MINOS in USA (Fermilab near Chicago to detector in northern Minnesota)
- T2K in Japan