Name________________________________

PHY 1033 HIS 3931 IDH 331
Final exam
December 15, 2016 --- SOLUTIONS

Part I (3 points each, 30 points total) Choose the best selection

1. Which of the following did Aristotle **not** teach?

a. Rest is a natural state and need not be explained further
b. The speed of motion is directly proportional to the mover's force ($v \propto F$)
c. The speed of motion is inversely proportional to the resistance of the medium through which the motion occurs ($v \propto 1/R$)
d. All motion requires a mover
e. Uniform motion is a natural state and need not be explained further.

2. An astronaut in the International Space Station feels weightless because

a) Both the Station and the astronaut are accelerating toward Earth at the same rate
b) She is wearing a space suit
c) Earth's gravity is almost zero at this location
d) the Moon's gravity balances Earth's gravity at this location
e) astronauts take anti-gravity pills every day

3. The kinetic energy and the potential energy of a swinging pendulum are at their respective maximum values at what points of the pendulum's swing?

a) lowest point; highest point
b) highest point; lowest point
c) both, at lowest point
d) both, at halfway point between high and low
e) both, at highest point

4. Suppose you look at the huge clock on the Big Ben Tower in London and it reads 12 noon. If you could travel directly away from the clock at the speed of light and view it with a telescope, it would

(a) run faster than usual.
(b) be frozen at 12 noon.
(c) run slower than usual.
(d) be contracted.
(e) be elongated.

5. Who first noticed that changing a magnetic field produced electricity?

a) Faraday
b) Maxwell
c) Franklin
d) Ptolemy
e) Galileo

6. What measurement is Eratosthenes most famous for?

a) Distance to sun
b) Weight of the Earth
c) Circumference of the Earth
d) Electric charge on a proton
e) Distance from Marathon to Athens

7. Maxwell's equations had solutions that could be interpreted as light because
a) they reduced in a charge-free region to Faraday's equations for a moving light pulse
b) they proved the existence of the ether
c) they had exactly the right frequency corresponding to visible light
d) he demonstrated that they could exhibit interference phenomena
e) the speed of a wave in these solutions was equal to the speed of light measured by astronomical means

8. Which of the following are some of Kepler's laws of planetary motion?

a) Planets move in ellipses with the sun at one focus
b) $T^2 \propto R^3$
c) $a=mv^2/R$
d) b and c
e) a and b

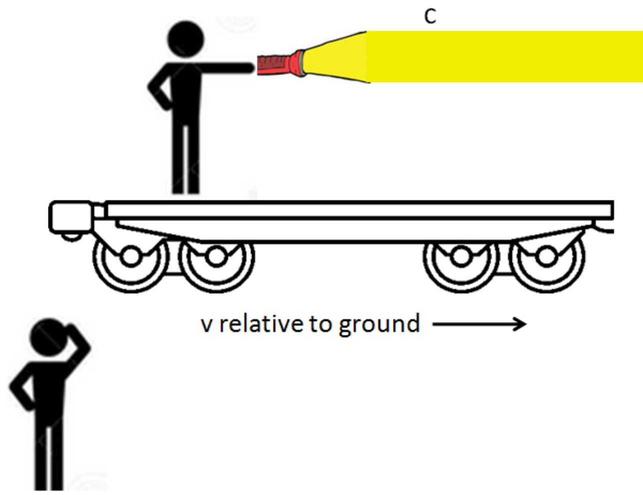
9. Who argued that in order to run a heat engine you need reservoirs at two different temperatures?

a) Boltzman
b) Watt
c) Leibniz
d) Lord Kelvin
e) Carnot

10. Bohr's model was criticized by classical physicists, who believed

a) protons and electrons both had positive charge
b) atoms did not exist
c) the proton should orbit the electron, not vice versa
d) electrons did not exist
e) the atom would collapse because the accelerating electrons would radiate energy

Part II (2 pts each, total 40 points) Answer the following briefly:



1. Supposing you were standing on a train car moving with speed v relative to the ground as shown, and you shine a flashlight in the direction of travel. You observe, and announce that the beam travels with speed c relative to you (the train car). An observer on the ground who believes in Galilean relativity and the ether watches you travel by. What does he expect the speed of the light beam to be? Now suppose the observer is Einstein. What does he expect the speed of the light beam to be? Explain.

The Galilean observer on the ground expects to see that the light velocity will add to the cart velocity, so he will see the beam propagating with velocity v+c. The Einsteinian observer expects to see velocity c, since the speed of light is the same in all reference frames. When the experiment is done, Einstein is right!

2. Name two contexts in which Newton's inverse square law was challenged and/or vindicated in the eighteenth century.

Possible answers: a) delayed return of Halley's comment (Clairaut prediction); b) measurements of the shape of the Earth; c) disproval of Clairaut's proposal that a $1/r^4$ term was necessary to account for the influence of the sun on the motion of the moon; d) apparent shrinking of moon's orbit (shown by Laplace to be slow oscillatory change in moon's period due to influence of other planets)

3. Identify and explain briefly Einstein's 3 discoveries from his *Annus Mirabilis* 1905.

i) Photoelectric effect. The process whereby light ejects electrons from a metal surface. Einstein explained that one could understand the minimum kinetic energy of ejected electrons by making the Planck quantization hypothesis.

ii) Special relativity. Einstein showed that space and time were not independent if the principle of relativity were to be preserved for electromagnetism.

iii) Brownian motion. Einstein explained the apparently random motion of small particles immersed in a fluid,as due to collisions from the fluid molecules.

4. The Age of Realism showed itself in numerous contexts in the second half of the nineteenth century other than in physics. Name two such contexts and give an example of each.

Bismarck's Realpolitik, realism in literature (Flaubert, Stendahl), in art (Courbet, photography), in religion (Feuerbach), in philosophy (Buchner). Emergence of new technologies

5. What was it that Osiander said in the Foreword to Copernicus's book to try to make it more acceptable?

That the motion of the earth was just a hypothesis**,** a calculational tool**,** but that Copernicus did not say that the earth "really" moved.

6. The Greeks argued that all heavenly bodies must move in perfect circles at uniform velocity. What two individuals were the first to violate/challenge

   a. the notion that heavenly motion must involve geometrically perfect circles only
   b. the uniformity (constant speed) of circular motion

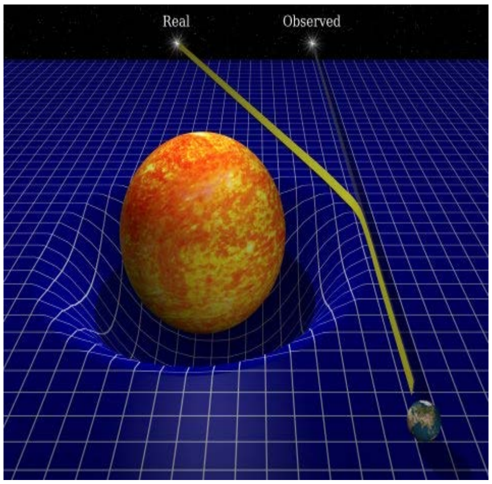
   a. Kepler
   b. Ptolemy

7. There were several developments in the early twentieth century that, in utilizing Planck's notion of quantizing energy, confirmed its importance for physics. Name and explain briefly one of these developments.

   Photoelectric effect. The process whereby light ejects electrons from a metal surface. Einstein explained that one could understand the minimum kinetic energy of ejected electrons by making the Planck quantization hypothesis.

   Bohr atom. Quantization of electron orbits around a proton

8. Explain how Eddington verified Einstein's theory that light bent in a gravitational field. Use a sketch if helpful.



Eddington was looking for the bending of light from a distant star as the light passed the sun on its way to the Earth. He needed the eclipse to allow the star to be visible.

9. State at least one property of the ether, the medium that 19th century physicists thought allowed light waves to propagate.

Could say that the ether was "stiff", because the speed of light was so fast; or that it was practically unresistant, because planets, etc move through it.

10. Many 19th century physicists believed generally in "determinism". What, according to Laplace, could a sufficiently great intellect do if given the positions and velocities of all the particles in the universe at one time?

Given the positions and velocities of all the particles in the universe, he/she could predict the exact motion of every particle at any time in the future or in the past.

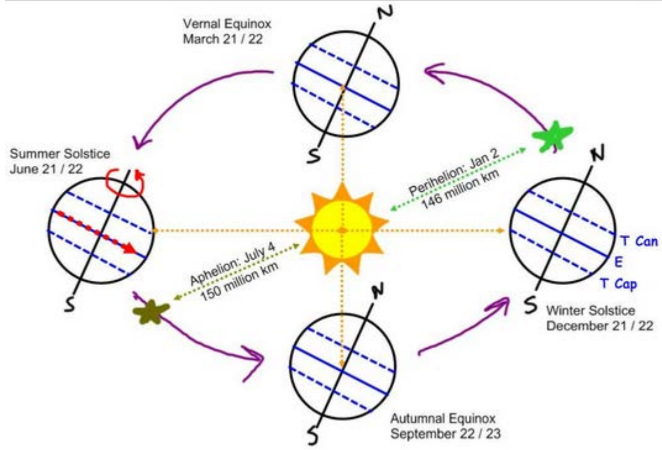
11. Gravity is a much weaker force than the electrical force. Yet we see manifestations of gravity all around us, but rarely natural manifestations of electricity. Why?

The sources of gravity (masses) have only one sign, positive, and gravity is always attractive. On the other hand there are two types of electrical charge, so the + and – particles are formed into tightly bound neutral combinations called atoms. The forces between the neutral entities are very weak.

12. How did Galileo use a thought experiment to disprove Aristotle's contention that falling bodies that are twice as heavy fall twice as fast? (Hint: he considered two objects tied together)

Aristotle would say that two individual bodies, one with mass m and one with mass 2m, would fall individually with different speeds v and 2v. However Galileo pointed out that if they were tied together, this would mean that the light object would retard the heavy one, and make it fall more slowly. On the other hand, if you regarded the combined object as mass 3m, it should fall faster – hence a contradiction!

13. Explain why we have seasons, using a diagram. What days mark the beginning of each season in the northern hemisphere? Show where the Earth is on your diagram at the beginning of each season.



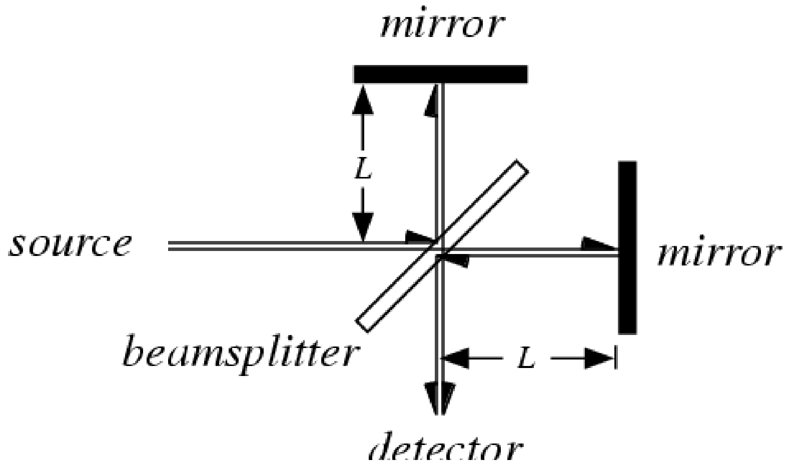
14. Galileo used objects sliding and rolling on inclined planes for his experiments on motion to refute Aristotle. What was the main purpose of this apparatus?

To slow down the acceleration of falling bodies so that they could be observed more accurately.

15. Heisenberg derived an "uncertainty principle". Explain briefly what it means.

$\Delta x \Delta p \sim h$. You can't measure the position and the momentum of an object simultaneously with arbitrary precision. Here Δx is the uncertainty in position and Δp the uncertainty in momentum. Another way to say it is that if you know exactly where something is, you can say nothing about its momentum, or velocity.

16. Draw a diagram of the Michelson Morley experiment, and explain what they were attempting to measure.



The interferometer was designed to detect the delay in the arrival of a light pulse due to the “ether wind” along the direction of the Earth’s motion through the ether.

17. A helium atom weighs a little bit less than four hydrogen atoms. Explain how this relates to the Sun’s energy.

The missing mass is released in the form of energy ($E=mc^2$) in nuclear fusion. This process powers the stars.

18. Name 2 of the 4 motions of the earth identified by Copernicus.

a) Revolution
b) Rotation
c) Precession of equinoxes
d) Weird twisting of Earth’s axis in order to make it point always towards the pole star.

19. Explain why, according to current understanding, the lengths of the seasons (time between equinox and solstice) are not quite equal.

Because the Earth's orbit is elliptical, not circular, and the Earth moves faster when it is closer to the sun (northern hemisphere winter).

20. Cecelia Payne's thesis called "the most brilliant Ph.D. thesis ever written in astrophysics" What was her great discovery?

That the composition of the sun and other stars was mostly hydrogen and helium

Part III. (30 pts) Essay. Choose **one** of A, B, C or D (Do not do more than one).

A. Discuss ideas of scientists & philosophers about the nature of light through history: Is it a particle or a wave? Is it different or similar to matter? (mention ideas of Descartes, Newton, Maxwell, Hertz, pioneers of quantum mechanics, Einstein)

B. Discuss ideas of scientists & philosophers about how one body influences another body in nature. Describe the nature and diversity of forces through history (Greeks, medievals, Descartes, Newton, Faraday, pioneers of quantum mechanics, Einstein)

C. Determinism: Contrast the approach to physical cause and effect using the ideas of Aristotle, Laplace & Descartes, and Heisenberg. What are the implications for our ability to understand the universe?

D. By describing the cosmos at the time of Aristotle and Ptolemy, at the time of Newton, and in the modern era, explain how the Western view of " The Universe and Humanity's Place in It" evolved.