YOUR NAME – _____

# PHYSICS 121 – FINAL EXAM

**Useful constants:** $\sigma = 5.67 \ \ 10^{-8} \ \frac{W}{m^2 K^4}$, $G = 6.67 \ \ 10^{-11}$

$m_{ELECTRON} = 9.1 \ \ 10^{-31} \ kg$

$1 Joule = 6.0 \ \ 10^{18} \ electon - Volts \ (eV)$

$\rho_{OLIVE\ OIL} = 0.9 \ \frac{g}{cm^3}$ $g = 10.0 \ \frac{m}{s^2} \ (for \ \ convenience)$

**Conceptual or short answer questions [4 points each –** *You are not required to explain your answers, but you may if you want to justify the answer or explain an assumption you made in choosing that answer***.]**

1) What are the proper SI units for:
a) the Gravitational constant "G",
b) for momentum,
c) angular momentum,
d) torque ?
[There is more than one correct answer to each of the parts of this question – you only need to provide one.]

2) Write down the formulae for:
a) Circumference of a circle
b) Area of a circle
c) Surface area of a sphere
d) Volume of a sphere

3) A steel ball of volume $3 \ m^3$ is immersed in pure olive oil. (Density is listed above). What is the buoyant force on the ball (in Newtons)?

4) A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed. The constant horizontal force applied by the woman:
(A) has the same magnitude as the weight of the box.
(B) is greater than the weight of the box.
(C) has the same magnitude as the total force which resists the motion of the box.
(D) is greater than the total force which resists the motion of the box.
(E) is greater than either the weight of the box or the total force which resists its motion.

5) If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
(A) with a constant speed that is double the speed in the previous question.
(B) with a constant speed that is greater than the speed in the previous question, but not necessarily twice as great.
(C) for a while with a speed that is constant and greater than the speed in the previous question, then with a speed that increases thereafter.

(D) for a while with an increasing speed, then with a constant speed thereafter
(E) with a continuously increasing speed.

6) Two metal balls of different masses are held 2 meters above level ground and released as follows:
The first ball is released from rest and falls straight down.
The second ball is given an initial horizontal velocity of 9.8 m/s, and released at the same instant as the first ball.

(A) The more massive ball hits the ground first.
(B) Both balls hit the ground at the same time.
(C) The ball with zero horizontal velocity hits the ground first.
(D) The ball with initial horizontal velocity of 9.8 m/s hits the ground first.
(E) More information is needed.

7) You are throwing a ball straight up in the air. At the highest point, the ball's
(A) velocity and acceleration are zero.
(B) velocity is nonzero but its acceleration is zero.
(C) acceleration is nonzero, but its velocity is zero.
(D) velocity and acceleration are both nonzero.

**Long Answer Questions [12 points each]**
*[Show your work on separate pages – particularly if you wish to receive partial credit – a correct answer with no supporting equations/calculations will not be accepted.]*

8) A rope is stretched between supports 12 m apart; its tension is 52 N. If one end of the rope is tweaked, the resulting disturbance reaches the other end 0.45 s later.
a) What is the total mass of the rope?
b) Sketch the appearance of the standing waves in the rope with the three lowest frequencies.
c) What are the frequencies and wavelengths of the three lowest frequency standing waves in this rope?

9) A 200 g mass is attached to a spring of constant $k = 7.0\,N/m$ and cm set into oscillations with A=25 cm. [Ignore the effect of gravity when solving this problem]
Determine:
a) The frequency of oscillations (in Hertz)
b) The period of these oscillations.
c) The maximum velocity of the mass.
d) The maximum force on the mass.
e) The maximum and minimum energy stored in the spring over one cycle of oscillations.

10) We showed in class that the solar constant for Earth, (the amount of power reaching one square meter of Earth's upper atmosphere on the equator) is $S = 1400\,\frac{W}{m^2}$.

For Mars, the solar intensity is only $S:\ 600\,\frac{W}{m^2}$.

a) How far is Mars from the sun? (The Earth is $R_{ES} = 1.5\ \ 10^{11}\ m$ from the sun.)
[You don't need this answer to do part b – nor do you need part b to answer this!]

b) Using energy balance analysis (as from the homework problems about Venus and Pluto), calculate the average temperature of Mars. Ignore any greenhouse or atmospheric effects. Assume that the emissivity $\varepsilon$ .of Mars is 1, and that the efficiency of the absorption of solar radiation at Mars is also 1. Give your answer in $^{o}C$ and in $K$ .

11) Electrons are tiny but have a measurable mass $m_{ELECTRON} = 9.1 \ \ 10^{-31} \ kg$ . There is an attractive electric force between an electron and a proton of magnitude.

$$F_{ELECTRIC} = k \frac{q^2}{r^2}$$

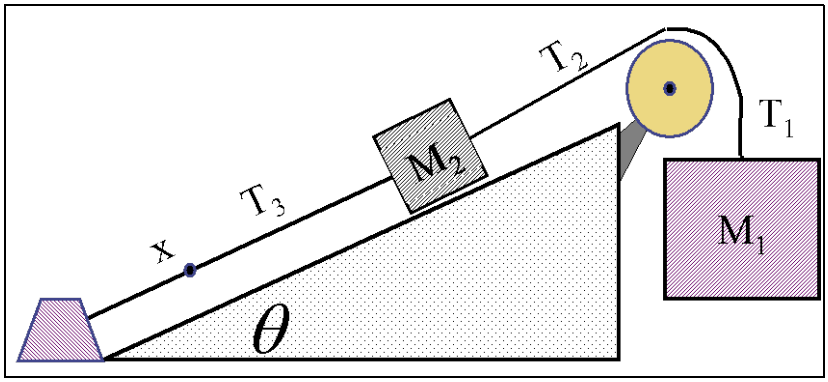
In the above formula, $k = 9.0 \ \ 10^{9} \ N - m^2 / C^2$, $q = 1.6 \ \ 10^{-19} \ C$ .

Although atoms are best described by quantum mechanics, it was originally thought by Niels Bohr that an electron orbiting a proton was exactly like a miniature solar system, in which the electron plays the role of Earth and the proton is like the sun. Approximately correct results can be derived based on the assumption that hydrogen is a miniature solar system with an electric instead of a gravitational attractive force. (While gravity does act in an atom, the force between an electron and a proton is so incredibly small compared to the electric force that it always ignored). Bohr determined that the smallest circular orbit of an electron about a proton is at a distance $a_0 = 5.3 \ \ 10^{-11} \ m$. ( $a_0$ is called the "Bohr Radius")

a) What is the magnitude of the force that is exerted on an electron orbiting at the Bohr radius?
b) What is the velocity of the electron in this orbit?
c) Assuming the electron begins at rest a distance of $a_0$ from the proton, how much energy would it take to remove the electron to infinity? (A chemist would say, "what is the ionization energy of hydrogen?")
Answer in Joules and electron-Volts (eV) (conversion factor is at top of exam).

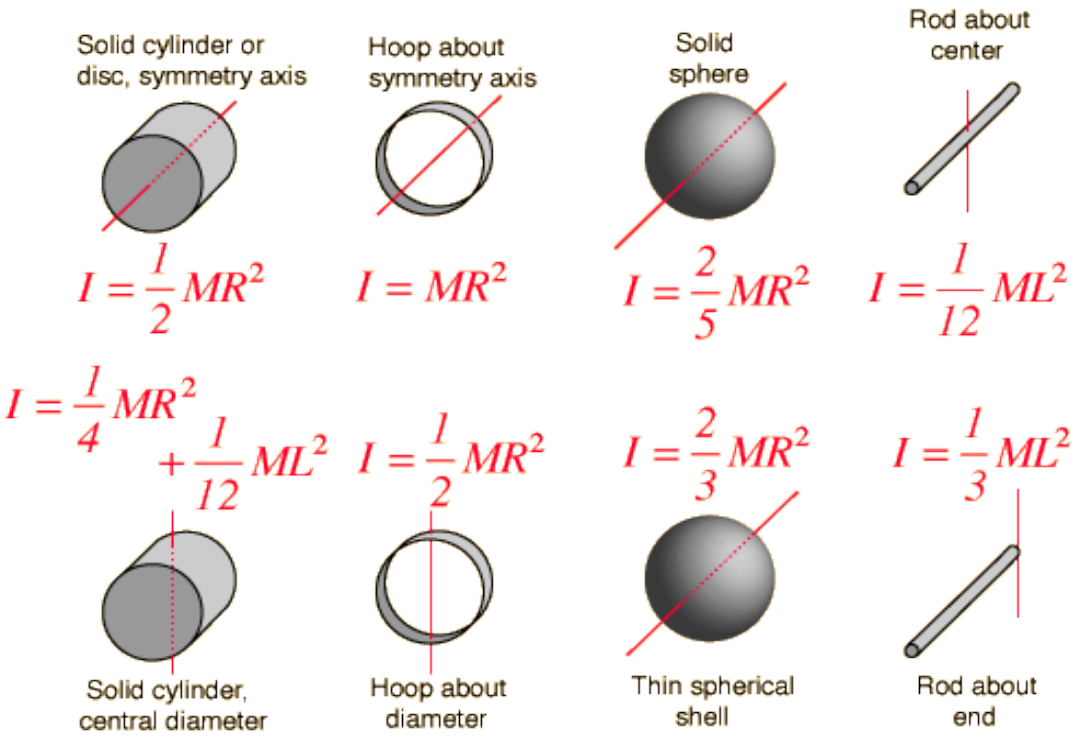
[If you actually know the ionization energy of Hydrogen, you'll see your answer comes out double the correct one. Extra credit for explaining why.]

12) Masses $M_1 \ \& \ M_2$ on a ramp are connected by rigid, massless ropes as shown. The coefficient of static friction between mass $M_2$ and the ramp is $\mu_S$ , and the coefficient of kinetic friction is $\mu_K$ .

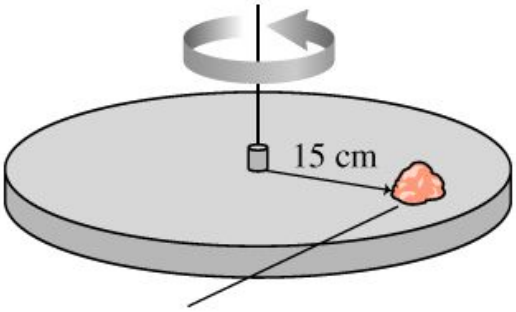



a) What are $T_1$, $T_2$, and $T_3$? (One or more of these may be equal).

b) The rope is cut at point 'X'. What are $a$, $T_1$, and $T_2$? (These may be equal).




13) A disk-shaped turntable has a mass of 2.0 kg and a radius of 20 cm. It is rotating at 1 revolution/second about a frictionless vertical axis. A wad of clay is tossed onto the turntable and sticks 15 cm from the rotation axis (see the figure). The clay hits with horizontal velocity component 13 m/s, at right angles to the turntable's radius, and in a direction that opposes the rotation. After the clay lands, the turntable has slowed to 0.9 rev/s.




a) Find the mass of the clay.
b) How much energy was lost during the collision of the clay with the turntable.
c) Even if you can't answer "b" numerically, explain in a sentence where the energy that was "lost" during this collision went (and if you can answer b, please also explain it!)