Physics 151 Roster No.:__________________________

Score:______23 pts. possible__________

SPRING 2004 Final Exam, Part A

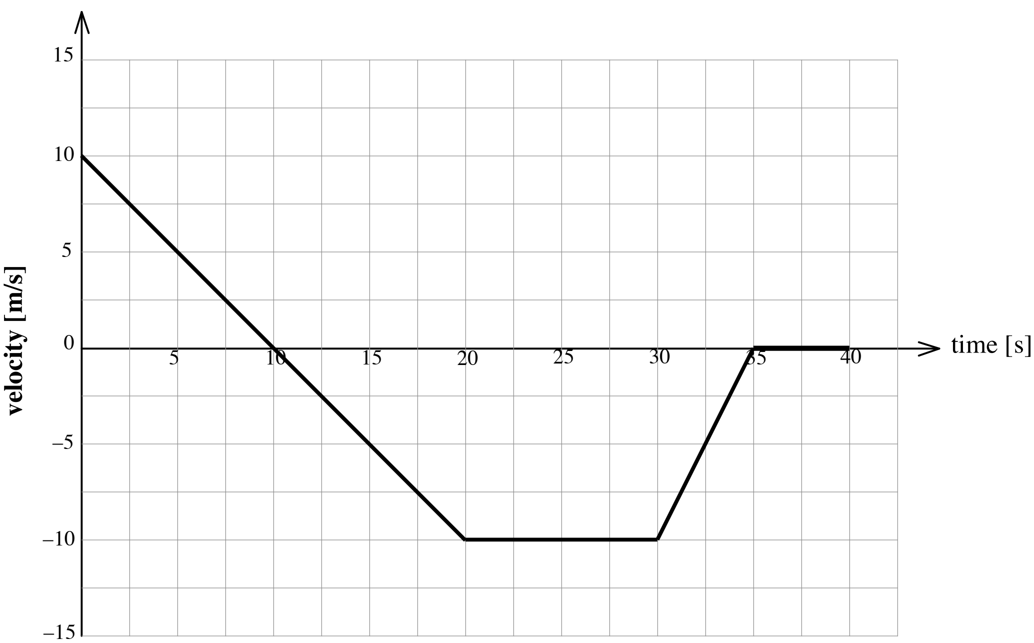
Exam time limit: 120 minutes. You may use calculators and both sides of 2 pages of notes, *handwritten only*. Closed book; no collaboration. For multiple choice questions, circle the one best answer or letter (unless more than one answer is asked for).

<u>*Physical constants:*</u>
$G = 6.673 \times 10^{-11}$ N·m²/kg² $g = 9.80$ m/s²

<u>*Useful conversions:*</u>
1 year = 3.156×10^7 s 1 m³ = 1000 L 1 atm = 1.013×10^5 Pa

1. (2 pts.) The Earth's volume, 1.1×10^{12} km³, is **equivalent** to:

A. 1.1×10^{15} L D. 1.1×10^{24} L
B. 1.1×10^{18} L E. 1.1×10^{27} L
C. 1.1×10^{21} L F. 1.1×10^{30} L



2. The graph above represents the *velocity* of a toy car, facing in the +*x*-direction, constrained to move only along the *x*-axis.

a. (2 pts.) During which time interval(s) is the car **moving backwards**? ***Circle ALL that apply:***

A. 0 to 10 s D. 30 to 35 s
B. 10 to 20 s E. 35 to 40 s
C. 20 to 30 s

b. (2 pts.) During which time interval(s) does the car have a **negative acceleration**? ***Circle ALL that apply:***

A. 0 to 10 s D. 30 to 35 s
B. 10 to 20 s E. 35 to 40 s
C. 20 to 30 s

c. (2 pts.) What is the car's **acceleration** at $t = 32$ s? __________
(Include proper sign and units. You do NOT need to show your work.)

d. (2 pts.) Suppose that $x = 0$ when $t = 0$. At what future **time** is the car's position again $\boldsymbol{x = 0}$?

A. $t = 5$ s D. $t = 20$ s
B. $t = 10$ s E. $t = 25$ s
C. $t = 15$ s F. $t = 35$ s

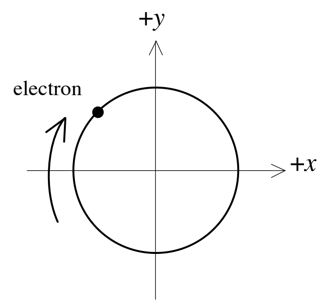
3. a. (1 pt.) A baseball is thrown straight up. (Ignore air resistance.) Taking the $+y$-direction to be upward, which **one** of the following is **TRUE** about the ball at the *top of its arc*?

A. Its velocity is –9.8 m/s.
B. Its acceleration is zero.
C. Its weight is zero.
D. Its kinetic energy is zero.

b. (2 pts.) If the baseball in part (a) is thrown and caught at exactly the same vertical position, which **one or more** of the following are **TRUE** about the ball? ***Circle ALL that apply:***

A. Its final displacement and total distance traveled are equal.
B. Its time of ascent and time of descent are equal.
C. Its initial speed and final speed are equal.
D. Its acceleration during ascent and acceleration during descent are equal.

4. Early models of the atom supposed that electrons traveled in circular motion about the nucleus of each atom. Imagine that an electron ($m_e = 9.11 \times 10^{-31}$ kg) is moving in uniform circular motion in the xy-plane, at a radius of $r = 5.0 \times 10^{-11}$ m, and with speed v = 2.3×10^6 m/s, centered on a nucleus at the origin.



a. (2 pts.) **How many revolutions** does the electron complete in **one second**?

A. 7.3×10^5 D. 7.3×10^{11}
B. 7.3×10^7 E. 7.3×10^{13}
C. 7.3×10^9 F. 7.3×10^{15}

b. (2 pts.) The **centripetal force** acting on the electron is:

A. 1.4×10^{-8} N D. 6.6×10^{-8} N
B. 2.8×10^{-8} N E. 8.2×10^{-8} N
C. 4.2×10^{-8} N F. 9.6×10^{-8} N

c. (1 pt.) The **work** done by the centripetal force as the electron completes one orbit is: (*Hint:* Think carefully about the relative directions of the centripetal force vector and the displacement of the electron.)

A. zero D. 2.1×10^{-17} J
B. 4.4×10^{-18} J E. 2.6×10^{-17} J
C. 1.5×10^{-17} J F. 3.0×10^{-17} J

d. (2 pts.) If a_R denotes the magnitude of the electron's centripetal acceleration, and α is the electron's angular acceleration, then which **one** of the following is **TRUE**?

A. $\alpha = 0$ and $a_R = 0$
B. $\alpha = 0$ and a_R = constant (non-zero)
C. α = constant (non-zero) and $a_R = 0$
D. α = constant (non-zero) and a_R = constant (non-zero)

e. (2 pts.) The moment of inertia of the electron (a point mass) about the origin is simply MR^2. The electron's **angular momentum** about the nucleus is therefore: (This answer is a famous quantity in atomic physics, known as "h-bar"… but that's for PHYS 152.)

A. 1.0×10^{-30} kg·m²/s D. 1.0×10^{-33} kg·m²/s
B. 1.0×10^{-31} kg·m²/s E. 1.0×10^{-34} kg·m²/s
C. 1.0×10^{-32} kg·m²/s F. 1.0×10^{-35} kg·m²/s

f. (1 pt.) According to the diagram shown above, in which direction does the electron's **angular momentum vector** point?

A. into the page D. toward bottom of the page
B. out of the page E. to the right
C. toward top of the page F. to the left

Physics 151 Roster No.:___________________________

Score:______22 pts. possible____________

SPRING 2004 Final Exam, Part B

5. (2 pts.) **[watts × seconds ÷ newtons]** is equivalent to:

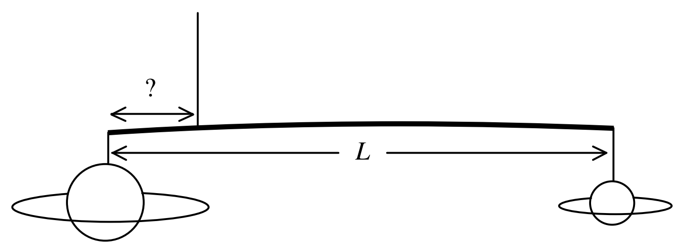
A. kg
B. m
C. m/s
D. kg·m/s
E. kg/s^2
F. $kg{\cdot}m^2$

6. (2 pts.) Which **one** of the following statements is **TRUE**?

A. For any given pair of materials, μ_s is always less than μ_k.
B. The magnitude of friction force depends on the area of contact between the two materials.
C. The magnitude of kinetic friction force depends on the relative speed between the two materials.
D. The direction of static friction force is always parallel to the surface of contact.

7. (2 pts.) Your instructor wants to hang two toy planets from either end of a rod of length *L* as part of a Solar System mobile sculpture for a baby crib. (Okay, who am I kidding… it's not for any baby, it's for *me*.) If one planet has a mass 5 times greater than the other (and the rod's mass is negligible), at what **position** along the rod should I suspend it so that it will be *balanced*?

A. at distance L/16 from the heavier planet
B. at distance L/√6 from the heavier planet
C. at distance L/√5 from the heavier planet
D. at distance L/6 from the heavier planet
E. at distance L/5 from the heavier planet
F. at distance L/4 from the heavier planet



8. (2 pts.) Suppose that there are two *actual* planets like those in the previous question, with relative masses of *M* and 5*M*, separated by distance *L*, and initially at rest in outer space (but without the rod and strings). Which **one** of the following statements is **TRUE**?

A. The gravitational force of 5*M* on *M* is five times greater than the force of *M* on 5*M*.
B. If both masses were doubled, the gravitational forces between the two planets would become four times greater.
C. If *L* were doubled, the gravitational forces between the two planets would become half as great.
D. Once released from rest, the two planets would fall toward each other with constant speed.

9. a. (2 pts.) Many museums, like the Smithsonian and Griffith Park Observatory, have very long Foucault Pendulums swinging on display (in order to demonstrate the rotation of the Earth, but don't worry about that here). These pendulums are often 3 or 4 stories tall. Suppose that a 12-kg metal bob is hung at the end of a 14-meter-long (massless) cable. When the pendulum is released from an initial angular displacement of 5.0°, what is the pendulum's resulting **period** of oscillation?

A. 3.8 s
B. 7.5 s
C. 15 s
D. 28 s
E. 56 s
F. 110 s

b. (1 pt.) Which **one** of the following could you do to a pendulum to **increase** the time it takes to complete each swing?

A. Increase its initial angular displacement to a larger angle
B. Increase the mass of the bob
C. Increase the length of the cable
D. Increase (slightly) the damping (friction) on the pendulum

10. Every key on a piano produces sound by striking its own particular string with a hammer, causing the string (fixed at both ends) to vibrate. The note we hear is the fundamental oscillation. The highest note on a piano has a frequency of 4096 Hz, while the lowest note is 27 Hz.

a. (2 pts.) The highest key (4096 Hz) strikes a string only 13 cm long. Suppose, hypothetically, that all strings on a piano were tightened to the same tension, and were made of wire of the same thickness. Such similar strings should all have the same wave velocity. If their only difference were their length, **how long** would the string be for the **lowest** (27 Hz) key? (Your answer will be absurdly long for a piano.)

A. 8.3 m
B. 10. m
C. 13 m
D. 17 m
E. 20. m
F. 24 m

b. (2 pts.) Instead, piano makers want to limit the maximum length of strings to approx. 1 meter for upright and baby-grand pianos. What should they do to further **lower the pitch** of the strings for the low keys?

A. Increase tension and use thicker strings
B. Increase tension and use thinner strings
C. Decrease tension and use thicker strings
D. Decrease tension and use thinner strings

c. (1 pt.) A piano tuner is able to tune strings by listening simultaneously to the piano note and a tuning fork, and listening for any beat that may result. If a tuning fork with a standard frequency of 256 Hz is struck at the same time as an out-of-tune piano string at 252 Hz, what **beat frequency** would result?

A. 0.00391 Hz
B. 0.25 Hz
C. 4 Hz
D. 254 Hz
E. 258 Hz
F. 508 Hz

11. (6 pts.) **Match** each phenomenon on the left to the most relevant law or principle from the right column that it illustrates. *Use each letter NO MORE THAN ONCE, or not at all:*

_____ Faster airflow speed over an airplane wing than under it results in less air pressure above it and greater air pressure below it

_____ Planets tend to move fastest in their orbits when they are at closest approach to the sun, and slowest when they are farthest

_____ A mother pushes her child on a playground swing with the same timing as the natural period of the child-swing system; the amplitude of the child's oscillations grows steadily

_____ A floating 350-gram ball displaces 350 g of water

_____ When I push on a wall, it pushes back on me with exactly the same magnitude of force, but in the opposite direction

_____ When a train approaches, its whistle sounds higher-pitched than when it leaves

A. Archimedes's Principle
B. Bernoulli's Principle
C. Doppler Effect
D. Kepler's 2^{nd} Law
E. Newton's 1^{st} Law of Motion
F. Newton's 2^{nd} Law of Motion
G. Newton's 3^{rd} Law of Motion
H. Newton's Law of Universal Gravitation
I. Pascal's Principle
J. Resonance

Physics 151 Roster No.:__________________________

Score:______25 pts. possible____________

SPRING 2004 Final Exam, Part C

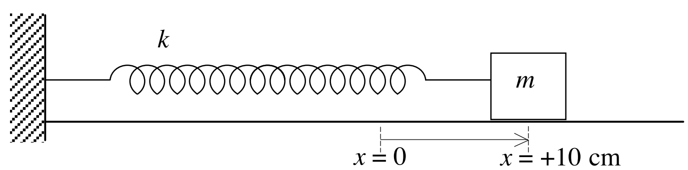
Exam time limit: 2 hours. You may use calculators and both sides of 2 sheets of notes, *handwritten only*. Closed book; no collaboration. Show your work on all free-response questions. Be sure to use **proper units** and **significant figures** in your final answers.

1. You give a friend a 15-liter, helium-filled balloon for her birthday. (Possibly useful densities: $\rho_{He} = 0.179\ \text{kg/m}^3$, and $\rho_{air} = 1.29\ \text{kg/m}^3$.)

a. (5 pts.) Calculate the **buoyancy force** acting on the balloon by the surrounding air.

b. (3 pts.) If $m_{balloon} = 7.5$ g (mass of balloon plus enclosed helium), what is the **minimum mass** of the birthday card you should hang from the balloon to prevent the balloon from rising when released? (Assume the card has negligible additional volume.)

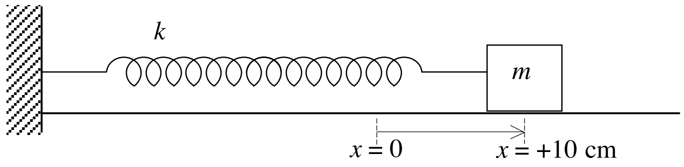
2. A mass $m = 0.50$ kg is attached to an ideal, massless spring ($k = 8.8$ N/m), as shown below. For parts (a)–(d), the surface is frictionless.



a. (4 pts.) The mass is initially pulled aside to a displacement of $x = +10.$ cm. How much **force** must be applied to the right in order to hold m stationary at that position?

The mass is then released and allowed to oscillate freely.

2 (repeated):

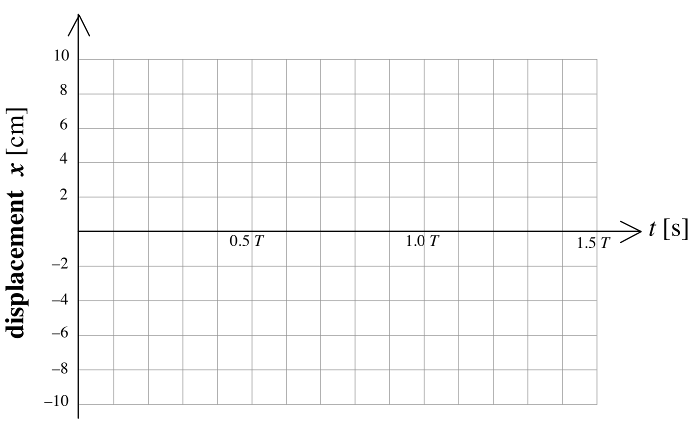


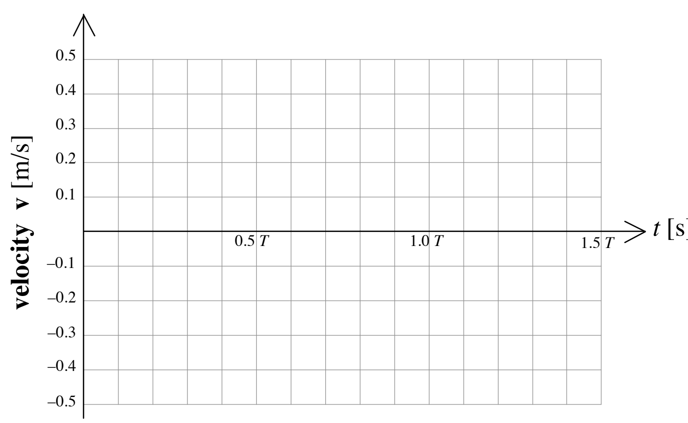
A mass m = 0.50 kg is attached to an ideal, massless spring (k = 8.8 N/m), as shown above. For parts (a)–(d), the surface is frictionless. The mass is initially pulled aside to a displacement of x = +10. cm. The mass is then released and allowed to oscillate freely.

b. (3 pts.) Find the **period** of the resulting oscillations.

c. (4 pts.) Find the **maximum speed, in [m/s]**, of the mass during oscillations.

d. (4 pts.) If t = 0 when the mass is released, sketch the mass's **displacement** in [cm] and **velocity** in [m/s] over the first 1.5 periods, using the graphs provided:





e. (2 pts.) Suppose that instead of a frictionless surface, there exists some μ between the mass and the surface. Which one or more of the following quantities would **decrease** over time? ***Circle ALL that apply:***

A. amplitude of oscillations
B. period of oscillations
C. frequency of oscillations
D. maximum velocity of mass
E. total mechanical energy of system (KE + PE)

Physics 151 Roster No.:________________________

Score:_____30 pts. possible__________

SPRING 2004 Final Exam, Part D

3. On a level, frictionless air-hockey table, two pucks (plastic discs) of *unequal mass* collide: puck *A* (m_A = 0.10 kg) traveling in the +*x*-direction collides exactly head-on with puck *B* (m_B = 0.30 kg), which is initially at rest. After the collision, puck *B* leaves in the +*x*-direction at 5.0 m/s, and puck *A* rebounds in the –*x*-direction at 3.0 m/s.

a. (6 pts.) What was the initial **velocity of puck *A*** before the collision? Show your work.

b. (1 pt.) The collision described above was:

A. **elastic**
B. **inelastic**

c. (6 pts.) The tabletop is 1.2 meters above the (level) floor. Suppose that the railing around the edge of the table is removed, so that puck *B* travels horizontally off the edge of the table at 5.0 m/s. At what **horizontal distance** from the table edge does the puck land on the floor? (Ignore air resistance.) Show your work clearly.

d. (1 pt.) In part (c), if the less massive puck *A* had left the table edge at the same speed instead of puck *B*, how would your **answer to part (c) change**?

A. greater distance B. no change C. shorter distance

e. (1 pt.) If puck *B* had been dropped **from rest** from a height 1.2 m above the floor…

A. it would have taken a *longer period of time* to land than it did in part (c)
B. it would have taken the *same period of time* to land as it did in part (c)
C. it would have taken a *shorter period of time* to land than it did in part (c)

4. Air is gently blown through a cylindrical cardboard tube with *two open ends*, creating standing-wave modes in the tube. The tube's length is 2.70 m, its diameter is 24.0 cm, and the speed of sound waves in air is 330. m/s.

a. (4 pts.) **Sketch** the tube's modes of oscillation (for displacement of the air) for the **first two harmonics**, denoting *all nodes with heavy dots*:

1st harmonic:

2nd harmonic:

b. (1 pt.) What is the **wavelength** of the **fundamental**?

A. 1.35 m
B. 1.80 m
C. 2.03 m
D. 2.70 m
E. 4.05 m
F. 5.40 m

c. (1 pt.) What is the **wavelength** of the **1st overtone**?

A. 1.35 m
B. 1.80 m
C. 2.03 m
D. 2.70 m
E. 4.05 m
F. 5.40 m

d. (4 pts.) Calculate the **frequencies**, f_1 and f_2, of both of the harmonics that you sketched. Show your work.

e. (1 pt.) Do your frequencies in part (d) lie within the range of **human hearing**?

A. Yes
B. No, they are too high.
C. No, they are too low.

f. (1 pt. each) *Individually*, how would each of the following changes affect the **frequency of the fundamental** compared to its value for the original tube?

i. Shortening the length of the tube by 10%:

A. raises f_1 by 10%
B. no change in f_1
C. lowers f_1 by 10%

ii. Increasing the diameter of the tube by 10%:

A. raises f_1 by 10%
B. no change in f_1
C. lowers f_1 by 10%

iii. Going to a mountaintop where the speed of sound in air is 10% slower:

A. raises f_1 by 10%
B. no change in f_1
C. lowers f_1 by 10%

g. (1 pt.) The standing sound waves generated inside the tube are:

A. **transverse**
B. **longitudinal**