Physics 151 Roster No.:__________________________

Score:______17 pts. possible__________

SPRING 2003 Final Exam, Part A

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

Constants & Useful Data: $M_{\text{Earth}} = 5.97 \times 10^{24}$ kg $R_{\text{Earth}} = 6.38 \times 10^6$ m

$G = 6.67 \times 10^{-11}$ N·m²/kg² — $G = 6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2$ $R = 0.0821$ L·atm/(mol·K) = 8.315 J/(mol·K)
$N_A = 6.022 \times 10^{23}$ /mol $k_B = 1.38 \times 10^{-23}$ J/K
specific heat of water: c = 4186 J/(kg·˚C)
1 cal = 4.186 J $1\ \text{m}^3 = 1000$ L
1 atm = 1.013×10^5 Pa 0 ˚C = 273.15 K

(1 point each, unless otherwise specified)

1. Which ONE of the following is **NOT** a **scalar**?

A. frequency
B. temperature
C. impulse
D. mass
E. density
F. heat

2. In **freefall**, an object experiences which ONE of the following?

A. v = 0
B. v = 9.8 m/s
C. $a = 0$
D. $a = 9.8\ \text{m/s}^2$
E. $F_{\text{net}} = 0$
F. $F_{\text{net}} = 9.8$ N

3. Two projectiles of unknown masses are launched from the edge of a high vertical cliff: mass *A* is launched at an initial angle of 20˚ above the horizontal, and mass *B* at 20˚ below the horizontal. The ground far below the cliff is level. Neglect air resistance.

a. Which of the two masses strikes the ground **first**?

A. mass *A*
B. mass *B*
C. both strike at the same time
D. cannot tell without knowing the masses

b. Which of the two masses strikes the ground **farther** from the base of the cliff?

A. mass *A*
B. mass *B*
C. both strike at the same distance
D. cannot tell without knowing the masses

c. Which of the two masses strikes the ground with **greater final speed**? (*Hint*: Think carefully about this one.)

A. mass *A*
B. mass *B*
C. both strike with the same speed
D. cannot tell without knowing the masses

4. (3 pts. max) Two satellites are in circular orbits around the Earth, one orbiting at a distance of 3 R_E from the center of the Earth, and the other at a distance of 6 R_E. **TRUE or FALSE** (T/F):

a. ______ The closer satellite has a greater **speed** along its orbit than the farther satellite.

b. ______ The closer satellite has the same orbital **period** as the farther satellite.

c. ______ The closer satellite feels a greater **gravitational force** from the Earth than the farther satellite does.

d. ______ If the **mass of the Earth** suddenly (magically) doubled, the orbital periods of both satellites would remain unchanged.

5. For this entire problem, assume that you and your sweetheart each have a mass of 75 kg.

a. If the two of you are sitting 0.50 meters apart, what is the magnitude of the **gravitational force** between you?

A. 1.5×10^{-6} N
B. 1.5×10^{-4} N
C. 0.15 N
D. 1.5 N
E. 15 N
F. 1.5×10^{3} N

b. Suppose that your sweetheart is tired of waiting for gravity to attract you, and so ties a rope around you and directly applies a horizontal force of 250 N. If you remain at rest, then the **coefficient of static friction** between you and your seat must be *at least*:

A. 0.30
B. 0.34
C. 0.40
D. 0.45
E. 0.48
F. 0.60

c. With one big effort, your sweetheart finally overcomes your static friction and gets you sliding. With a new force (different than the force in part (b)), he or she is able to drag you horizontally with a *constant* speed of 0.50 m/s. If your coefficient of kinetic friction is 0.25, then your sweetheart's **power** output is:

A. 9.4 W
B. 19 W
C. 92 W
D. 190 W
E. 580 W
F. 3.4 kW

6. a. (2 pts.) On a frictionless horizontal surface, mass *A* traveling to the right at 3 v_0 overtakes and collides with an *identical* mass *B* traveling to the right at v_0. After the collision, mass *B*'s new velocity is 2.5 v_0. What is the **new velocity of mass *A***?

A. $-1.5\ v_0$
B. $-1.33\ v_0$
C. $-0.5\ v_0$
D. $0.5\ v_0$
E. $1.33\ v_0$
F. $1.5\ v_0$

b. The collision in part (a) was:

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

7. (2 pts.) A 50.-kg woman stands in high-heeled shoes. Each heel has an area of 0.50 cm^2 where it contacts the ground. Assuming that she leans back slightly so that all of her weight is momentarily borne on the two heel spikes (and none by the front of her shoes), what is the **pressure** each heel exerts on the ground?

A. 2.4×10^{-5} atm
B. 0.0035 atm
C. 0.040 atm
D. 0.20 atm
E. 3.2 atm
F. 48 atm

8. An object whose volume is 2.5 L will **float** in water (ρ = 1000 kg/m^3) if its **mass** is…

A. less than 0.025 kg
B. less than 0.25 kg
C. less than 2.5 kg
D. less than 25 kg
E. less than 250 kg
F. any mass will float

Score:______17 pts. possible___________

SPRING 2003 Final Exam, Part B

9. Which ONE of the following is **TRUE** for a mass on an ideal spring?

A. The restoring force on the mass is greatest at $x = A$.
B. The acceleration of the mass is greatest at $x = 0$.
C. The velocity of the mass is greatest when its displacement is greatest.
D. The elastic potential energy is greatest when the speed of the mass is greatest.

10. An ideal, massless spring with a spring constant of 8.9 kg/s^2 is suspended vertically. If you gently hang a 250-g mass on the end of the spring, the spring will **stretch** by:

A. 19 cm D. 33 cm
B. 24 cm E. 36 cm
C. 28 cm F. 40. cm

11. Which ONE of the following could you do to **shorten the period** of a mass oscillating on a spring?

A. decrease the initial displacement D. decrease the stiffness of the spring
B. decrease the mass E. decrease the length of the spring
C. decrease the damping (friction) F. decrease the natural frequency

12. a. You have a 1.0-meter-long pendulum on Earth, and an identical 1.0-m pendulum on Mars. Each is pulled aside to an initial angle of 10° and released. If *g* on the surface of Mars is exactly 1/3 as large as that on Earth, then the **period** of the Mars pendulum will be **how many times** that of the Earth pendulum?

A. 9 D. $1/\sqrt{3}$ G. both have the same period
B. 3 E. 1/3
C. $\sqrt{3}$ F. 1/9

b. Neglecting air resistance, the Earth pendulum has a **period** equal to:

A. 0.63 s D. 1.3 s
B. 0.77 s E. 2.0 s
C. 0.98 s F. not enough information given

c. If the Earth pendulum is released from an initial angle of 5° instead of 10°, its **period** will become multiplied by a **factor** of:

A. 4 D. $1/\sqrt{2}$ G. it will have the same period as before
B. 2 E. 1/2
C. $\sqrt{2}$ F. 1/4

13. a. An ukulele string is fixed at both ends. On the string below, **sketch** its **2nd overtone**, indicating *all* nodes with heavy dots:

____

b. If the length of the ukulele string is 40.0 cm, and the speed of waves along the string is 704 m/s, what is the **frequency** of the **2nd overtone** you sketched above?

A. 1420 Hz D. 2180 Hz
B. 1720 Hz E. 2320 Hz
C. 1980 Hz F. 2640 Hz

c. (2 pts.) Which **TWO** of the following are TRUE about the **6th harmonic** of the same ukulele string?

A. It is a transverse wave. D. It lies outside the range of human hearing.
B. It has 6 nodes. E. Tightening the string will raise its frequency.
C. It has 7 antinodes. F. Tightening the string will increase its wavelength.

14. A typical male speaking voice has frequencies averaging around 200 Hz. If the speed of sound in air is 340 m/s, what is the **wavelength** of the sound waves?

A. 17 μm
B. 1.7 mm
C. 1.7 cm
D. 17 cm
E. 1.7 m
F. 17 km

15. a. You measure the pressure inside your car tire to be 322 kPa when it is "cold" at 25 ˚C. (Don't worry about "gauge pressure"; 322 kPa is the TOTAL pressure of the air inside the tire.) After a long drive at high speed, you measure the pressure again and find that it has risen to 343 kPa. Assuming that air is an ideal gas, and assuming that the tire's volume has remained constant, what is the new **temperature** of the air inside your car tire?

A. 28 ˚C
B. 35 ˚C
C. 44 ˚C
D. 68 ˚C
E. 80. ˚C
F. 103 ˚C

b. (2 pts.) Which **TWO** of the following are **TRUE** about the heating of the gas in the tire?

A. The gas inside the tire underwent an adiabatic process.
B. The gas inside the tire underwent an isothermal process.
C. The gas inside the tire underwent an isobaric process.
D. The work done by the gas on the tire is zero.
E. The internal energy of the gas inside the tire was unchanged.
F. The entropy of the gas inside the tire increased.

16. A car engine can be modeled as a heat engine with an input temperature of 500 ˚C (the temperature of the burning fuel in the cylinders) and an exhaust temperature of 85 ˚C. What is the ideal (maximum possible) **Carnot efficiency** of such a car engine? (Actual car engines fall far short of this efficiency.)

A. 17%
B. 32%
C. 44%
D. 48%
E. 54%
F. 59%

17. (2 pts. max) **TRUE or FALSE** (T/F):
For the phase diagram of an unknown substance, shown at right:

a. ______ This substance's boiling point at 3.0 atm pressure is 50 K.

b. ______ This substance *cannot* exist as a liquid at pressures below 0.5 atm.

c. ______ If kept in a chamber at 1.0 atm pressure and heated from 100 K to 250 K, the substance first melts then boils.

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Score:______21 pts. possible____________

SPRING 2003 Final Exam, Part C

Show your work on all free-response questions. Be sure to use **proper units** and **significant figures** in your final answers.

1. Suppose that you have a total volume of 70. L, and your overall density is 1.0×10^3 kg/m^3. The density of air at sea level is 1.29 kg/m^3.

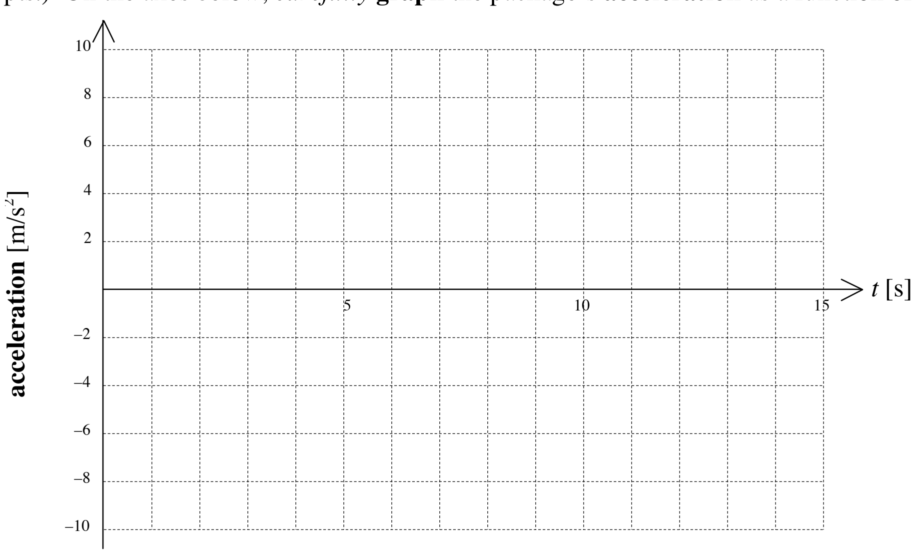
a. (3 pts.) Calculate the magnitude of your **weight**, in newtons. Show your work.

b. (4 pts.) Calculate the magnitude of the **buoyancy force** of air on you. What **percentage** is it of your true weight calculated in part (a)? (Your answer will be quite small… which is why it's not a big deal in everyday life.)

2. A 70.0-kg package is suspended from a helicopter by a rope. At time $t = 0$, the package is at rest on the ground, and the helicopter starts accelerating upward at 5.0 m/s^2. At $t = 6.00$ s, the rope suddenly breaks, and the package is free. The package eventually hits the ground at $t = 14.33$ s. Neglect air resistance.

a. (3 pts.) Calculate the magnitude of the **force of tension** in the rope during the first 6 seconds.

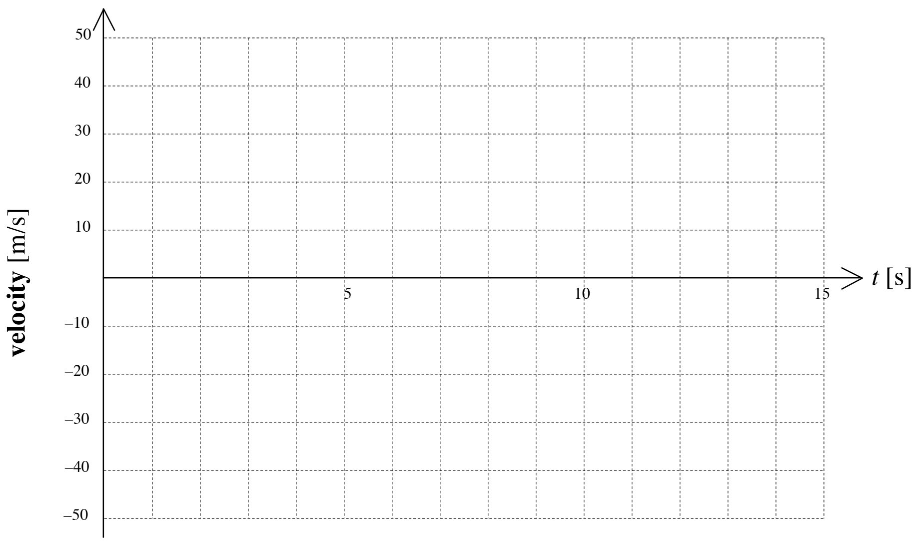
b. (2 pts.) On the axes below, *carefully* **graph** the package's **acceleration** as a function of time.



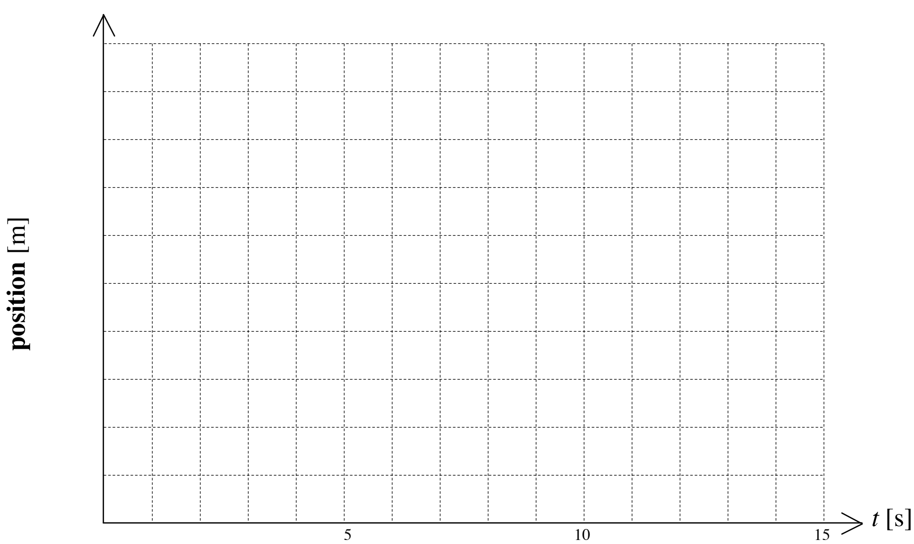
(**2. repeated:** A 70.0-kg package is suspended from a helicopter by a rope. At time $t = 0$, the package is at rest on the ground, and the helicopter starts accelerating upward at 5.0 m/s^2. At $t = 6.00$ s, the rope suddenly breaks, and the package is free. The package eventually hits the ground at $t = 14.33$ s. Neglect air resistance.)

c. (5 pts.) What is the package's **final velocity** as it hits the ground? (Let the $+y$-direction be upward.) Show all work.

d. (2 pts.) On the axes below, *carefully* **graph** the package's **velocity** as a function of time.



e. (2 pts.) On the axes below, *qualitatively* **graph** the package's vertical **position** as a function of time. (Let $y = 0$ at the ground, and let the $+y$-direction be upward.) The *overall shapes* of the graph from $t = 0$ to 6 s, and again from $t = 6$ to 14.33 s, are all you need to have correct; the exact values of y are NOT needed.



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Score:______25 pts. possible___________

SPRING 2003 Final Exam, Part D

3. A 75-gram rubber ball is thrown vertically downward against a horizontal surface.
a. (4 pts.) After bouncing, the ball reaches a maximum height of 4.0 meters. Neglecting air resistance, what is the **speed** of the ball immediately after bouncing off the surface? State your assumptions/show your work.

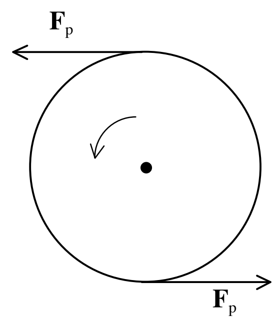
b. (3 pts.) If the ball originally strikes the surface at 15 m/s, how many **joules** of the ball's kinetic energy are **lost** during the bounce?

c. (1 pt.) The ball's bounce is:

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

d. (4 pts.) If the specific heat of the rubber is 1800 J/(kg·˚C), and if all of the lost kinetic energy is absorbed by the molecules of the ball, by how much does the **temperature** of the ball increase? (Your answer should be less than 1 ˚C.)

4. Two children push tangentially counterclockwise on the edge of a 1.8-meter-radius merry-go-round to accelerate it from rest. Each child pushes continuously with a constant force of $F_p = 120$ N.



a. (4 pts.) Calculate the magnitude of the **total torque** on the merry-go-round. (Use proper units on your final answer.)

b. (5 pts.) Suppose that $I = 320$ kg·m^2 for the merry-go-round. After 3.5 s of being pushed with constant torque, what is the **period** of rotation of the merry-go-round?

c. (3 pts.) How much **total work** did the children do during the same 3.5 s? State your assumptions/show your work.

d. (1 pt.) According to the diagram shown above, in which direction does the merry-go-round's **angular momentum vector** point?

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