Name (printed): ______________________________________________
Recitation Instructor: _________________________      Section #_______

INSTRUCTIONS:

This exam contains 25 multiple-choice questions plus 2 extra credit questions, each worth 4 points. Choose one answer only for each question. Choose the best answer to each question. Answer all questions.

Allowed material: Before turning over this page, put away all materials except for pens, pencils, erasers, rulers and your calculator. There is a formula sheet attached at the end of the exam. Other copies of the formula sheet are not allowed.

Calculator: In general, any calculator, including calculators that perform graphing, is permitted. Electronic devices that can store large amounts of text, data or equations (like laptops, palmtops, pocket computers, PDA or e-book readers) are NOT permitted. Wireless devices are NOT permitted. If you are unsure whether or not your calculator is allowed for the exam, ask your TA.

How to fill in the bubble sheet:
Use a number 2 pencil. Do NOT use ink. If you did not bring a pencil, ask for one. You will continue to use the same bubble sheet that you already used for the first midterm exam. Bubble answers 55-81 on the bubble sheet for this exam.

Please turn over your bubble sheet when you are not writing on it.

If you need to change any entry, you must completely erase your previous entry. Also, circle your answers on this exam. Before handing in your exam, be sure that your answers on your bubble sheet are what you intend them to be. You may also copy down your answers on a piece of paper to take with you and compare with the posted answers. You may use the table at the end of the exam for this.

When you are finished with the exam, place all exam materials, including the bubble sheet, and the exam itself, in your folder and return the folder to your recitation instructor.

No cell phone calls allowed. Either turn off your cell phone or leave it at home. Anyone answering a cell phone must hand in their work; their exam is over.

Best of luck,

Drs. Kai-Ming Ho, Eli Rosenberg, and Kerry Whisnant
55) A test rocket is fired straight up from rest with a net acceleration of 20.0 m/s$^2$. After 4.00 seconds the motor turns off, but the rocket continues to coast upward with no appreciable air resistance. What maximum elevation does the rocket reach, in m? You may assume that the acceleration of gravity remains constant.

A) 320
B) 160
C) 327
D) 408
E) 487

56) A 0.60 kg rock is swung in a circular path in a vertical plane on a 0.30 m length string. At the top of the path, the angular velocity is 12.0 rad/s. What is the tension in the string, in N, at that point?

A) 5.9
B) 15
C) 20
D) 26
E) 32

57) Tom and Jerry throw identical rocks off a tall building at the same time. The ground near the building is flat. Tom throws his rock straight downward. Jerry throws his rock at an initial angle 30° below the horizontal. Jerry throws the rock with a speed twice that of Tom’s rock. If air resistance is negligible, which rock hits the ground first?

A) Tom’s rock
B) Jerry’s rock
C) They hit at the same time
D) It is impossible to determine without more information
E) It depends on the height of the building
58) A series of weights connected by very light cords are given an upward acceleration of 4.00 m/s² by a pulling force \( P \), as shown in the figure. \( A \), \( B \), and \( C \) are the tensions in the connecting cords. What is the SMALLEST of the three tensions, \( A \), \( B \), and \( C \), in N?

A) 483  
B) 196  
C) 621  
D) 276  
E) 80.0

59) A 2.0 kg box sits on an incline that makes an angle of 20° with respect to the horizontal (see figure). The coefficient of static friction between the incline and the box is \( \mu_s = 0.30 \). What is the horizontal force, \( F \), required to start the box moving up the incline, in N?

A) 12  
B) 15  
C) 20  
D) 26  
E) 32
60) A 2000-kg car is initially moving with speed 30.0 m/s. The driver slams on his brakes and skids for 5.00 s. If the coefficient of kinetic friction between the tires and the road is 0.400, how much work was done by friction in slowing down the car, in J?

A) $\text{-}7.92\times10^5$
B) $\text{-}3.96\times10^4$
C) $\text{-}2.38\times10^6$
D) $\text{-}3.17\times10^5$
E) 0

61) Swimmers at a water park have the choice of two frictionless water slides. Both slides have the same vertical height, but one slide is straight and the other is curved (see figure). How does the speed $v_1$ of a swimmer reaching the end of slide 1 compare with $v_2$, the speed of a swimmer reaching the end of slide 2?

A) $v_1 = v_2$
B) $v_1 > v_2$
C) $v_1 < v_2$
D) It can’t be determined without knowing the curvature of slide 2
E) It can’t be determined without knowing the relative mass of the swimmers
62) A 2000-kg car moves eastward with speed 65 mph. It hits a 6000-kg truck that is traveling at 20 mph towards the northeast. They bounce off of each other, with the truck heading directly to the east at 15 mph after the collision. What is the direction of the car after the collision?

A) 11° south of east
B) 11° north of east
C) directly east
D) 34° north of east
E) 4.0° north of east

63) A tire is rolling along a road, without slipping, with a velocity $v$. A piece of tape is attached to the tire. When the tape is opposite the road (at the top of the tire), its velocity with respect to the road is

A) undeterminable without knowing the radius of the tire
B) 0
C) $v$
D) $1.5v$
E) $2v$

64) A dentist's drill has an initial angular speed of $2.15 \times 10^4$ rad/s. It undergoes constant angular acceleration for 2.50 s and reaches an angular speed of $6.75 \times 10^4$ rad/s. How many revolutions does the drill bit make during this period?

A) $8.55 \times 10^3$
B) $1.77 \times 10^4$
C) $3.54 \times 10^4$
D) $1.11 \times 10^5$
E) $2.23 \times 10^5$
65) A uniform 300-kg beam, 6.00 m long, is freely pivoted at P, as shown in the figure. The beam is supported in a horizontal position by a light strut, 5.00 m long, which is freely pivoted at Q and is loosely pinned to the beam at R. A load of mass is suspended from the end of the beam at S. A maximum compression of 23,000 N in the strut is permitted, due to safety. The maximum mass $M$ of the load is what value, in kg?

A) 554  
B) 789  
C) 1020  
D) 1090  
E) 1320

66) The Eiffel Tower, constructed in 1889, is a lattice work structure made of iron. On a 22° C day the tower is 301 m high. How much smaller, in cm, is the tower on a day when the temperature is only 0.0° C? The coefficient of linear expansion of iron is $1.2 \times 10^{-5}$/K.

A) 14  
B) 4.4  
C) $3.0 \times 10^{-2}$  
D) $1.1 \times 10^{2}$  
E) 8.0
67) A 1.50 m long tube closed at one end is filled with air. The speed of sound in air is 343 m/s. Which one of the following is a resonant frequency of this tube, in Hz?

A) 114  
B)  76  
C) 143  
D) 286  
E) 229

68) A 100 g block of a metal at 20.00° C is placed into an insulated container with 400 g of water at a temperature of 0.00° C. The temperature of the metal and the water ends up at 2.00° C. What is the specific heat of this metal, in J/kg-K? The specific heat of water is 4.19x10³ J/kg-K.

A) 1.16x10²  
B) 9.32x10²  
C) 1.86x10³  
D) 2.36x10⁴  
E) 1.51x10⁵

69) Water near the surface of a tropical ocean has a temperature of 25° C. Water 700 m below the surface has a temperature of 7° C. What is the maximum efficiency of a heat engine which uses the warm water as a hot reservoir and the cool water as cold reservoir?

A) 94%  
B) Not enough information is given to know  
C) 72%  
D) 28%  
E) 6.0%
70) A pendulum consists of a massive bob suspended from the ceiling by a massless string. To double the period of the pendulum, you should

A) Quadruple the length of the string
B) Double the length of the string
C) Double the mass of the pendulum bob
D) Halve the length of the string
E) Halve the mass of the pendulum bob

71) A transverse wave is described by \( y(x, t) = (2.0 \text{ cm}) \sin[(3.2 \text{ m}^{-1})(x - (4.3 \text{ m/s})t)] \)

What is the frequency of the wave, in Hz?

A) 2.0
B) 2.2
C) 3.2
D) 4.3
E) 1.3

72) A Carnot engine takes heat in from a reservoir at 100°C and discards heat to a reservoir at 10°C. If the engine does 140 J of work per cycle, how much heat does it take in from the hot reservoir per cycle, in J?

A) 140
B) 156
C) 185
D) 580
E) 1080
73) The average speed of a molecule in a particular sample of an ideal monatomic gas is 380 m/s. If the gas is in a 1.20-m³ container at STP, what is the total mass of the gas, in kg?

A) 1.68
B) 2.14
C) 2.52
D) 3.26
E) 5.79

74) For the $pV$ diagram shown, what is the work done by the gas for one cycle (abca), in L-atm? Process bc is isothermal.

A) $-0.30$
B) $-0.25$
C) 0
D) 0.25
E) 0.30
75) When an ideal gas is allowed to expand isothermally from volume $V_1$ to a larger volume $V_2$, the gas does an amount of work equal to $W_{12}$.

If the same ideal gas is allowed to expand adiabatically from volume $V_1$ to the same larger volume $V_2$, the gas does an amount of work that is

A) greater than $W_{12}$  
B) equal to $W_{12}$  
C) less than $W_{12}$  
D) either A, B, or C, depending on the ratio $V_2/V_1$  
E) either A, B, or C, depending on the final temperature

76) You have 1.00 mol of an ideal monatomic gas and 1.00 mol of an ideal diatomic gas whose molecules can rotate. The gases are in identical fixed containers and initially both gases are at the same temperature. If the same amount of heat flows into each gas, which gas will undergo the greatest increase in temperature?

A) The monatomic gas  
B) The diatomic gas  
C) They have the same increase in temperature  
D) The answer depends on the molar masses on the gases  
E) The answer depends on the value of the initial temperature

77) A stationary siren emits sound of frequency 1000 Hz and wavelength 0.343 m. An observer who is moving toward the siren will measure a frequency $f$ and wavelength $\lambda$ for this sound such that

A) $f > 1000$ Hz and $\lambda > 0.343$ m  
B) $f > 1000$ Hz and $\lambda < 0.343$ m  
C) $f > 1000$ Hz and $\lambda = 0.343$ m  
D) $f = 1000$ Hz and $\lambda > 0.343$ m  
E) $f = 1000$ Hz and $\lambda < 0.343$ m
78) The side \( L \) of a square is measured with an ordinary plastic ruler. The result, along with the estimated uncertainty, is:

\[ L = 50.0 \pm 0.5 \text{ mm} \]

Which of the following is the area of the square with the corresponding propagated uncertainty?

A. 2500 \( \pm \) 0.3 mm\(^2\)
B. 2500 \( \pm \) 0.5 mm\(^2\)
C. 2500 \( \pm \) 1 mm\(^2\)
D. 2500 \( \pm \) 2 mm\(^2\)
E. 2500 \( \pm \) 50 mm\(^2\)

79) A 300-g mass oscillates at the end of vertical spring. The vertical position of the object is measured with a motion detector. The data is shown in the figure below:

Use the data to estimate the spring constant \( k \) of the spring.

A. 14 N/m
B. 33 N/m
C. 62 N/m
D. 95 N/m
E. 120 N/m
80) A cart is pulled by a string on a track. The motion of the cart is monitored with a motion detector like the ones used in the labs, and the tension in the string is measured by a force probe mounted on the cart (see figure below). Using the data of position versus time produced by the motion detector, our software can compute numerical derivatives of position, so we also have velocity and acceleration as a function of time.

Shown below is a graph showing the tension in the string versus the acceleration of the cart. Based on this data, what is the mass of the cart + force probe system?

A. 1.2 kg  
B. 2.6 kg  
C. 3.2 kg  
D. 3.8 kg  
E. 4.4 kg
81) A flask containing air from the room is closed with a tightly-fitting rubber stop. The system is then slowly cooled down by placing it in a cold bath. Both the temperature and the pressure inside the flask are measured throughout the process. Which of the following graphs is closest to the graph you will obtain with that data?