PHY131 Spring 2001; Final Exam
14 May, 8:00-10:30am

Remove everything from your work area, except this exam and your calculator. Have your student ID ready. Wait for the word "go" before turning this page and starting the exam. Use the paper provided for all work (use the back sides if necessary). Ask for empty sheets if you need more. Ask permission if you need to leave the room. Do not remove this exam from the room until the exam is over.

Do any 4 of the first 6 problems. Do all 4 of the last 4 problems. All problems are worth 20 points.

Remember to show units and a sensible number of significant figures.

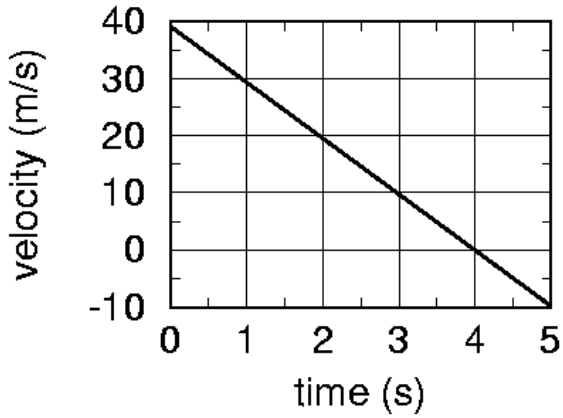
The grid below will be used by graders to record your scores.

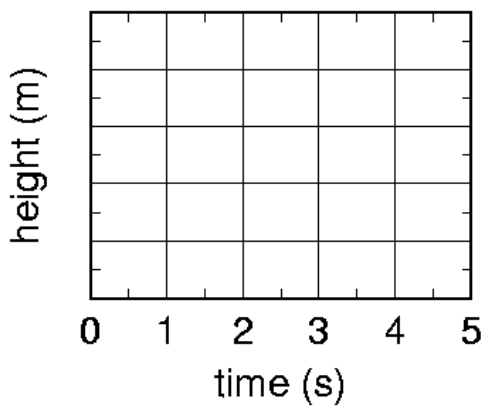
	grade	max
problem 1		20
problem 2		20
problem 3		20
problem 4		20
problem 5		20
problem 6		20
problem 7		20
problem 8		20
problem 9		20
problem 10		20
total		160

Possibly useful numbers

$G=6.67 \times 10^{-11}$ Nm^2/kg^2
$\sigma=5.67 \times 10^{-8}$ W/m^2K^4
Average atomic weight of air molecules = 28.2
$C(water)=4.186 \times 10^3$ J/kg^oC
$L_v(water)=2.256 \times 10^6$ J/kg
$L_f(water)=3.34 \times 10^5$ J/kg
1 amu = 1.66×10^{-27} kg

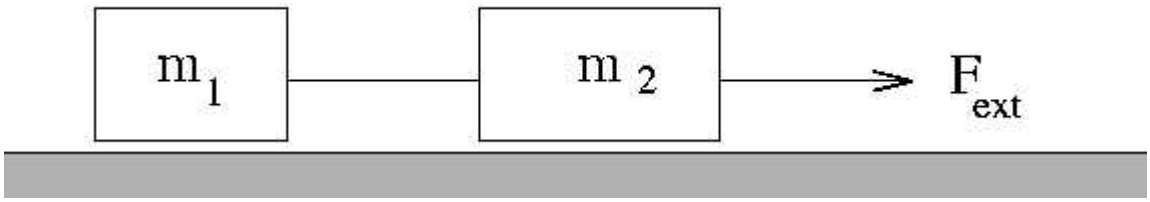
1. **(20 points)** An arrow (mass m=0.22 kg) is shot at an angle 45° above the horizontal. Its vertical velocity *versus* time is shown in the left-hand graph (only the first 5 seconds is shown.)





a. **(6 points)** At what time does the arrow hit the ground?
b. **(6 points)** What is the total horizontal displacement?
c. **(8 points)** Graph the vertical position (height) *versus* time on the right-hand graph above. Be sure to indicate the scale on the vertical axis.

2. (**20 points – show your work.**) Two masses, m_1=8.00 kg and m_2=14.00 kg, are coupled by a massless cord. They slide on a horizontal surface. An external force F_{ext}=24.0 N is applied to mass m_1 as shown.



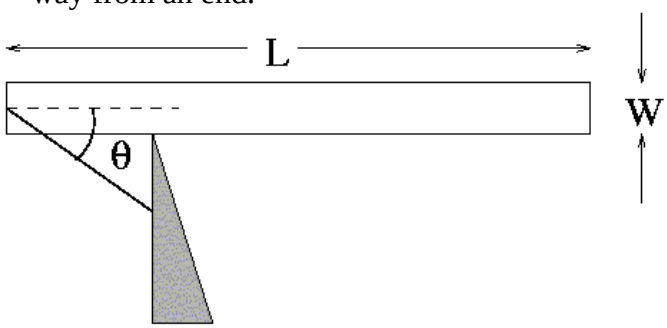
a. (**5 points**) Suppose there is no friction. Find the acceleration.
b. (**5 points**) Find the tension in the cord.
c. (**10 points**) Now suppose that there is friction, determined by a coefficient μ of kinetic friction which is the same for each mass. The system slides to the right at constant speed v=0.64 m/s. What is the coefficient of friction μ ?

3. **(20 points)** A duck (mass M=1.00 kg) flying **east** at 30.0 m/s is killed by an arrow of mass m=0.200 kg. After the hit, the duck and arrow are travelling **60° north of east** at 50.0 m/s.

a. **(10 points)** What direction was the arrow going just before the hit?

b. **(10 points)** What was the speed of the arrow just before the hit?

4. (20 points – show your work.) Shown below is a boom of length L=4.00 m and width W negligible. It is pivoted on a firm support at a distance 0.80 m from the end. The boom is uniform and has mass m=50.0 kg. A cable making an angle θ=30.0^o is attached to the left end and keeps the system in equilibrium. The moment of inertia is $I=52mL^2/300$ for a uniform bar around a point one fifth of the way from an end.

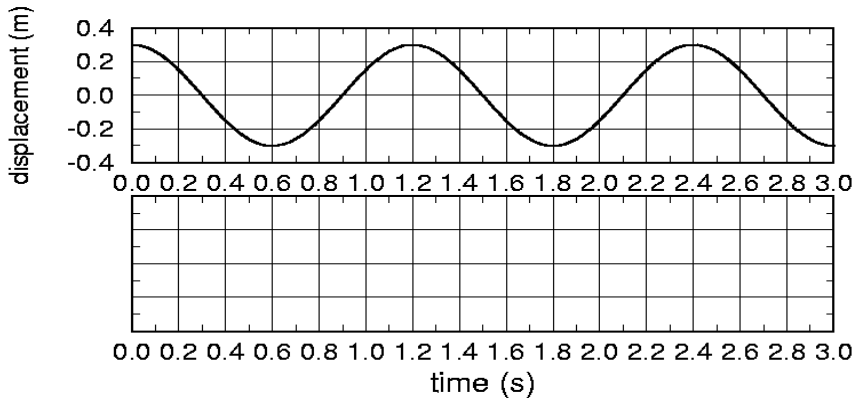


a. (7 points) How large is the tension T in the cable?

b. (8 points) Suddenly the cable snaps. What is the angular acceleration around the pivot point?

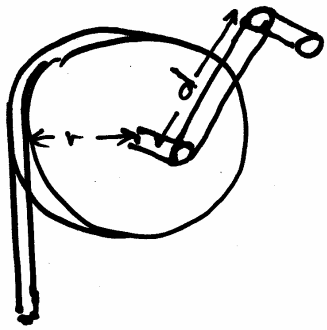
c. (5 points) What is the linear acceleration of the right hand end of the boom?

5. (**20 points – show your work unless the answer requires only simple inspection.**) The graph below shows a space-time history of a particle of mass 0.250 kg oscillating on a spring



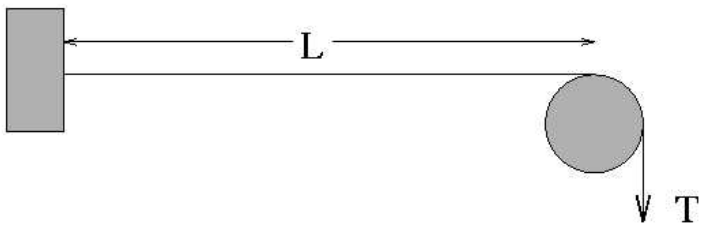
a. (**3 points**) What is the frequency in Hertz?
b. (**3 points**) What is the velocity at t=0.30 s?
c. (**2 points**) What is the acceleration at t=0.30 s?
d. (**2 points**) What is the velocity at t=0.60 s?
e. (**2 points**) What is the force at t=0.9 s?
f. **(2 points)** What is the spring constant?
g. (**3 points**) How much energy does the oscillator have?
h. **(3 points)** on the blank graph provided, draw the graph of $v(t)$, the velocity of the oscillator. Be sure to label and indicate the scale on the axis.

6. (20 points) A cylindrical wheel (mass m=1.20 kg, radius r=0.30 m, moment of inertia $I=mr^2/2$) is turned using a crank of negligible mass and length d=0.50 m. The angular acceleration α is 1.6 rad/s^2. Friction can be neglected.



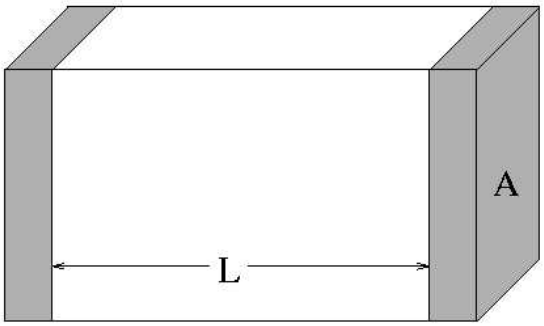
(a) **(5 points)** What is the minimum force F which must be applied to the crank?
(b) **(5 points)** If there is a massless rope attached as shown, and if the system starts from rest, how long does it take for 15.0 m of rope to be wrapped?
(c) **(5 points)** Suppose a bucket of mass M=3.5 kg is attached to the rope, and the angular acceleration α is still 1.6 rad/s^2. What is the tension in the rope?
(d) **(5 points)** What is now the minimum force F?

7. **(20 points)** The string shown below has mass m=0.0150 kg and length L=1.80 m. A standing wave, the 2nd harmonic (or 1st overtone) is excited with amplitude A=0.0250 m at a frequency f= 30.0 Hz.



a. **(4 points)** What is the wavelength?
b. **(4 points)** What is the wave velocity of the string?
c. **(4 points)** What is the tension T on the string?
d. **(4 points)** What is the maximum displacement of a piece of string at a distance 0.30 m from the left end?
e. **(4 points)** What is the maximum velocity of a piece of string at this position?

8. **(20 points)** The vertical parallel walls shown below have area A=1.200m^2 and are separated by a distance L=0.400m. The left wall is held at temperature T=40.0^{o}C and the right wall at temperature T=10°C. How much heat is transferred in an hour if:



a. **(10 points)** The space is filled with cork with thermal conductivity κ=0.040 W/mK.
b. **(10 points)** The space is empty ("filled" with vacuum.) The walls have emissivity e=0.45.

9. **(20 points)** 1.20 kg of water at 100°C and at one atmosphere pressure is turned to steam at 100°C and at one atmosphere pressure. (H_2O has atomic mass 18.)

   a. **(4 points)** How much heat was added?
   b. **(4 points)** How much ice (at 0°C) would this amount of heat melt (to water at 0°C)?
   c. **(4 points)** What is the volume of the resulting steam?
   d. **(4 points)** How much work was done by the "system" (that is, the H_2O)?
   e. **(4 points)** How much did the internal energy U of the H_2O increase?

10. **(20 Points)** One (1.00) kg of (monatomic) neon (Ne, atomic mass M=20.2) is in a box of volume V_1=0.800 m^3. It is an ideal gas to good approximation. The temperature is 20.0^{o}C.

a. **(4 Points)** How many atoms are there?
b. **(4 Points)** What is their total kinetic energy?
c. **(3 Points)** The gas expands into a volume V_2=1.200 m^3 without changing the temperature. How much work was done by the gas?
d. **(3 Points)** How much heat was absorbed by the gas?
e. **(3 Points)** The gas now expands adiabatically to a volume V_3=1.600 m^3. What is the temperature?
f. **(3 Points)** How much heat was absorbed during the expansion from V_2 to V_3?