University of California at Berkeley
Department of Physics
Physics 8A Fall 2002

Final examination, ~~section 1: Prof. Jacobsen~~
December 13, 12:30PM to 3:30PM

3 hours

You will be given three hours to work this exam. No books are permitted, but you may use a handwritten sheet of notes no larger than one standard sheet of paper.

Your description of the physics involved in a problem is worth significantly more than any numerical answer. Show all work, and take particular care to explain what you are doing.

Write your answers directly on the exam, and if you have to use the back of a sheet, make sure to put a note on the front. Do not use a blue book or scratch paper.

The multiple choice questions are worth one point each for a total of thirty-three points. The other questions are labeled with their point values. The exam total is one hundred fifty points.

NAME: PRACTICE FINAL EXAM

SID NUMBER: ______________________

DISCUSSION SECTION NUMBER: ______________________

DISCUSSION SECTION DAY/TIME: ______________________

Read the problems carefully.

Try to do all the problems.

If you get stuck, go on the next problem.

DON'T GIVE UP! Try to remain relaxed and work steadily.

Format of this year's final will be more like our midterms v = dx/dt a = dv/dt $x(t) = x_0+v_0t+1/2at^2$ $\sum \vec{F} = m\vec{a}$ $F_c = mv^2/r$

$F_k = \mu_k N$ W = Fx P = dW/dt $K = 1/2m\ v^2$ U = mgh

$\Delta K = K_f-K_i$ $\Delta U = U_f-U_i$ $W=\Delta U+\Delta K+\Delta E_{th}+\Delta E_{int}$

sin 45° = 0.707, cos 45° = 0.707, sin 30° = 0.500, cos 30° = 0.866

Rotational Inertias for radius R or length L:
sphere about axis: $(2/5)MR^2$ spherical shell about axis: $(2/3)MR^2$
disk about axis: $(1/2)MR^2$ hoop about axis: MR^2
rod about perpendicular at midpoint: $ML^2/12$

$$\frac{1}{2}\rho v^2 + yg\rho + P = \text{constant} \qquad F = \frac{GM_1M_2}{r^2} \quad \omega = \sqrt{\frac{k}{m}} \quad \omega = \sqrt{\frac{g}{l}} \quad \sum \vec{F} = m\vec{a}$$

Properties of water:

density	$= 1000\ kg / m^3$	heat of fusion	= 333 kJ/kg
Cp	= 4190 J / kg * K	heat of vaporization	= 2260 kJ/kg

$$\frac{\partial^2}{\partial t^2} f(t) + \omega^2 f(t) = 0 \qquad v^2 \frac{\partial^2}{\partial x^2} f(x,t) - \frac{\partial^2}{\partial t^2} f(x,t) = 0$$

$$Q = cm\Delta T = C\Delta T \qquad P = Q/t = kA\Delta T/L$$

$$p_1 V_1^\gamma = p_2 V_{21}^\gamma \qquad \int_{T_1}^{T_2} \frac{dt}{T} = \ln\frac{T_2}{T_1}$$

1) (25 points) Ideal Gas Cycle

A box contains n moles of ideal diatomic gas at pressure P_0 and temperature T_0. occupying volume V_0. One side of the box is a movable piston. The gas is then taken through the following process:

1) The gas is very rapidly doubled in volume to V_1=$2V_0$. This expansion is much faster than any heat-transfer process.
2) We slowly compress the gas back to the original volume, keeping the temperature constant
3) We slowly increase the pressure back to the original value, at constant volume

a) Sketch the process on a PV diagram, labeling corners and lines. Make sure that it's clear which lines correspond each of the three transformations in the process, and in which direction the system is moving.

a) Find the temperature T_1 and pressure P_1 after the first step in terms of T_0 and P_0. Explain your reasoning!

You may want to do the following three parts together. They've been separated to make the grading more reliable.

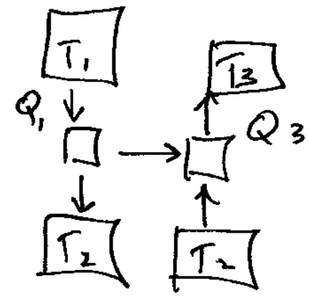
c) (8 points) For transformation 1, find the change in the gas's internal energy,
the work done by the gas,
the heat added to the gas
and the change in the gas's entropy, all in terms of n, R and T_0.

d) (8 points) For transformation 2, find the change in the gas's internal energy,
the work done by the gas,
the heat added to the gas
and the change in the gas's entropy, all in terms of n, R and T_0.

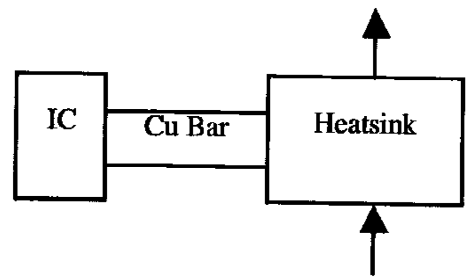
e) (8 points) For transformation 3, find the change in the gas's internal energy,
the work done by the gas,
the heat added to the gas
and the change in the gas's entropy, all in terms of n, R and T_0.

2) (12 points) Engine running a heat pump

A Carnot engine works between temperatures T_1 and T_2 to produce work. That work drives a Carnot heat pump that that move energy between the two temperatures T_2 and T_3. See the diagram at right. Find the efficiency of this system, defined as ratio $|Q_3|/|Q_1|$ in terms of the temperatures.



3) (15 points) Cooling a computer chip



An IC chip dissipates 2 watts of power. It has to be kept at $T_h = 35°$ C while running to work right, so this power must be removed by a cooling system. The chip is connected to a heatsink by a short copper bar. Thermal energy is conducted through this bar to a heatsink which is kept at a constant cooler temperature by flowing water.

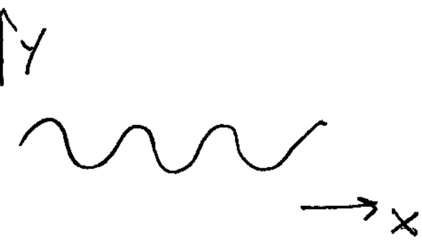
The length L of the copper bar is 5 mm. It has a square cross-section, 1mm on a side, so the area A is 10^{-6} m^2. The thermal conductivity of copper is 400 W/m.K. Information about water is on the front of the exam.

a) What temperature must the heatsink be for this to be a steady-state system? (Call this temperature Tc, and find it algebraically before calculating a value!)

b) Water flows into the heatsink at 3° C and is heated to 7°C as it passes through the heatsink. This absorbs the 2 watts of power coming from the chip, and keeps the heatsink at the temperature you found previously. How many grams of water need to be pumped through the heatsink per second to absorb this power?

c) You've just finished building this cooling system. Unfortunately, the chip designers have made a mistake, and the chip actually dissipates 4 watts. The chip still needs to be help at the right temperature, however, so they suggest you just double the water flow. Would that keep the chip at the desired temperature? (Note: this is a thermo question, not a question about fluid flow) Explain your reasoning, please.

4) (15 points) Wave motion on a rope



A sinusoidal wave is traveling to the <u>right</u> on an infinitely long, thick rope. Ignore the ends of the rope for now. The picture above is a snapshot of the wave at a particular time we'll call **t**=0. Note that the directions of the **x** and **y** axes are specified. The rope is under a tension **T**, is made of stuff with a density **ρ**, and has a radius **r**.

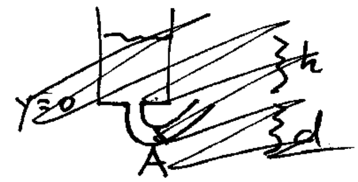
a) Write the equation describing this wave in terms of its amplitude y_m, frequency **ω** and wave velocity **v**. Please indicate on the diagram above where you consider the **x**=0 point to be.

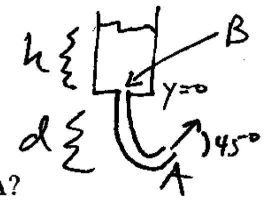
b) In what direction is energy moving? What is the power (e.g. energy flow in joules/second)?

c) Imagine putting a mark on the string at the **x**=0 point you indicated above. What is the velocity and position of that mark as a function of time? Both direction and magnitude must be specified.

5) (20 points) The simple fountain

A simple fountain is drawn at right. It consists of a can, kept full of water to a constant height **h** by an industrious grad student (not shown), and a hose. The hose has radius **r**, and droops down to a maximum depth d before turning upward at the point labeled "A". The tank is open to the air at the top, and the hose is open to the air at its end. Ignore friction, viscosity and all other defects; this is a problem about the idealized flows we've discussed in class. Note that the y=0 line has been labelled; please use that to simplify grading.





a) What is the velocity **v** of the water stream that emerges at point A?

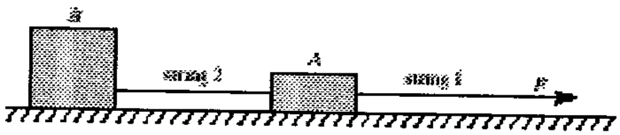
b) How much water flows out of the hose per second?

c) At point "B", how much water flows past in the hose each second?

d) What is the pressure at point B?

e) Sketch the path that the stream of water makes. Be sure to carefully indicate how high it goes and how far it goes.

6) (15 points) Two blocks



In the situation above, a person pulls a string attached to block A, which is in turn attached to another, heavier block B via a second string. Be sure to explain your answers.

a) Which block has the larger acceleration?

b) How does the force of string 1 on block A compare with the force of string 2 on block B?

c) How does the force of string 1 on block A compare with the force of string 2 on block A?

7) (15 points) Bicycle wheels and merry-go-rounds

Suppose you are standing on the center of a merry-go-round that is at rest. You are holding a rotating bicycle wheel over your head so that its rotation axis is pointing upward. The wheel is rotating counterclockwise when observed from above along your axis of rotation.

a) Suppose you now move the wheel so that its axis is horizontal. What happens to you? Specifically, are you and the merry-go-round turning? Which way?

b) What happens if you then point the axis of the wheel downward so that the wheel rotates clockwise as viewed from above? Specifically, are you and the merry-go-round turning? Which way? If you are turning in both parts (a) and (b), are you now turning faster/slower/same angular speed than you were in part (a)?

8) (1 point each, 33 total) Quick questions

8.1) A car accelerates from rest. In doing so the car gains a certain amount of momentum and Earth gains
a) more momentum.
b) the same amount of momentum.
c) less momentum.
d) The answer depends on the interaction between the two.

8.2) A person attempts to knock down a large wooden bowling pin by throwing a ball at it. The person has two balls of equal size and mass, one made of rubber and the other of putty. The rubber ball bounces back, while the ball of putty sticks to the pin. Which ball is most likely to topple the bowling pin?
a) the rubber ball
b) the ball of putty
c) makes no difference
d) need more information

8.3) An object hangs motionless from a spring. When the object is pulled down, the sum of the elastic potential energy of the spring and the gravitational potential energy of the object and Earth.
a) increases.
b) stays the same.
c) decreases.

8.4) A person swings on a swing. When the person sits still, the swing oscillates back and forth at its natural frequency. If, instead, two people sit on the swing, the natural frequency of the swing is
a) greater.
b) the same.
c) smaller.

8.5) A person swings on a swing. When the person sits still, the swing oscillates back and forth at its natural frequency. If, instead, the person stands on the swing, the natural frequency of the swing is
a) greater.
b) the same.
c) smaller.

8.6) Imagine holding two bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is
a) larger
b) the same as
c) smaller
than the force required to hold brick A in place.

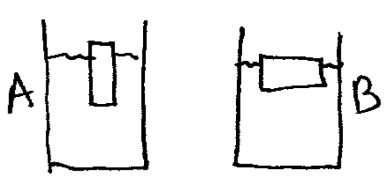
8.7) Two cups are filled to the same level with water. One of the two cups has plastic balls floating in it. Which of the two cups weighs more?
a) The cup without plastic balls.
b) The cup with plastic balls.
c) The two weigh the same.

8.8) Consider an object that floats in water but sinks in oil. When the object floats in water, half of it is submerged. If we slowly pour oil on top of the water so it completely covers the object, the object
a) moves up.
b) stays in the same place.
c) moves down.

8.9) Two hoses, one of 20-mm diameter, the other of 15-mm diameter are connected one behind the other to a faucet. At the open end of the hose, the flow of water measures 10 liters per minute. Through which pipe does the water flow faster?
a) the 20-mm hose
b) the 15-mm hose
c) The flow rate is the same in both cases.
d) The answer depends on which of the two hoses comes first in the flow.

8.10) Water waves in the sea are observed to have a wavelength of 1000 m and a frequency of 0.07 Hz. The velocity of these waves is:
a) 0.0007 m/s
b) 7 m/s
c) 70 m/s
d) 700 m/s
e) none of these

8.11) Two identical blocks of ice float in water as shown. Then:



a) block A displaces a greater volume of water since the pressure acts on a small bottom area
b) block B displaces a greater volume of water since the pressure is less on the bottom
c) the two blocks displace equal volumes of water since they have the same weight
d) the density of block A is less than that of block B
e) the density of block A is more than that of block B

8.12) A string of length 50 cm is held fixed at both ends. This string CANNOT be made to vibrate with a wavelength of
a) 200 cm
b) 100 cm
c) 50 cm
d) 33.3 cm
e) 25 cm

8.13) In simple harmonic motion, the restoring force must be proportional to the
a) amplitude
b) displacement
c) frequency
d) displacement squared
e) velocity

8.14) Let F1 be the magnitude of the gravitational force exerted on the sun by the earth and F2 be the magnitude of the force exerted on the earth by the sun. Then
a) F1 is much greater than F2
b) F1 is slightly greater than F2
c) F1 is equal to F2
d) F1 is slightly less than F2
e) F1 is much less than F2

8.15) A sinusoidal force with a given amplitude is applied to an oscillator. At resonance the amplitude of the oscillation is limited by
a) the damping force
b) the initial velocity
c) the initial amplitude
d) the force of gravity
e) none of the above

8.16) In simple harmonic motion, the magnitude of the acceleration is greatest when the
a) velocity is maximum
b) displacement is zero
c) force is zero
d) displacement is maximum
e) none of these

8.17) A force acting on a particle is conservative if
a) its work equals the change in kinetic energy of the particle
b) it obeys Newton's second law
c) it obeys Newton's third law
d) its work depends on the end points of the motion, not on the path between them
e) it is not a frictional force

8.18) A compact car and a large truck collide head on and stick together. Which vehicle undergoes the larger acceleration during the collision?
a) car
b) truck
c) Both experience the same acceleration.
d) Can't tell without knowing the final velocity of combined mass.

8.19) A figure skater stands on one spot on the ice (assumed frictionless) and spins around with her arms extended. When she pulls in her arms, she reduces her rotational inertia and her angular speed increases so that her angular momentum is conserved. Compared to her initial rotational kinetic energy, her rotational kinetic energy after she has pulled in her arms must be
a) the same.
b) larger because she's rotating faster.
c) smaller because her rotational inertia is smaller.

8.20) An object moves in a circle at constant speed. The work done by the centripetal force is zero because:
a) there is no friction
b) the displacement for each revolution is zero
c) the average force for each revolution is zero
d) the magnitude of the acceleration is zero
e) the centripetal force is perpendicular to the velocity

8.21) We may apply conservation of energy to a cylinder rolling down an incline without slipping, thus saying no work is done by friction, because
a) there is no friction present
b) the angular velocity of the center of mass about the point of contact is zero
c) the coefficient of kinetic friction is zero
d) the linear velocity of the point of contact (relative to the surface) is zero
e) the coefficients of static and kinetic friction are equal in this case

8.22) If two objects are in thermal equilibrium with each other
a) They cannot be undergoing an elastic collision
b) They cannot have different pressures
c) They cannot be at different temperatures
d) They cannot be falling in the earth's gravitational field
e) They cannot be moving

8.23) During a slow isothermal expansion of a gas
a) the pressure remains constant
b) heat is added
c) work is added
d) no heat enters or leaves
e) the volume remains constant

8.24) A balloon is filled with cold air and placed in a warm room. It is NOT in thermal equilibrium with the air of the room until
a) it sinks to the floor
b) it rises to the ceiling
c) it starts to contract
d) it stops expanding
e) none of the above

8.25) The specific heat of a diatomic gas is greater than the specific heat of a monatomic gas because
a) the diatomic gas does more positive work when heat is absorbed
b) the monatomic gas does more positive work when heat is absorbed
c) the energy absorbed by the diatomic gas is split among more degrees of freedom
d) the pressure is greater in the diatomic gas
e) a monatomic gas cannot hold as much heat

8.26) Inside a room at a uniform comfortable temperature, metallic objects generally feel cooler to the touch than wooden objects do. This is because:
a) a given mass of wood contains more heat than the same mass of metal
b) metal conducts heat better than wood
c) heat tends to flow from metal to wood
d) the equilibrium temperature of metal in the room is lower than that of wood
e) the human body, being organic, resembles wood more closely than it resembles metal

8.27) An inventor suggests that a house might be heated by using a refrigerator to draw heat from the earth and reject heat into the house. He claims that the heat supplied to the house can exceed the work required to run the refrigerator. This:
a) is impossible by first law
b) is impossible by second law
c) would only work if the earth and the house were at the same temperature
d) is impossible since heat flows from the (hot) house to the (cold) earth
e) is possible

8.28) According to the kinetic theory of gases, the pressure of a gas is due to:
a) average kinetic energy of the molecules
b) change of kinetic energy of the molecules as they strike the wall
c) change of momentum of molecules as they strike the wall
d) force of repulsion between the molecules
e) rms speed of the molecules

8.29) The change in entropy is zero for:
a) all adiabatic processes
b) reversible isobaric processes
c) reversible processes during which no work is done
d) reversible isothermal processes
e) reversible adiabatic processes

8.30) An ideal gas expands into a vacuum in a rigid vessel. As a result there is
a) a change in phase
b) a decrease in the internal energy
c) a change in the temperature
d) an increase in pressure
e) a change in entropy

8.31) In a reversible process the system
a) is close to equilibrium states throughout, except at the beginning and end
b) is close to equilibrium states only at the beginning and end
c) might never be close to any equilibrium state
d) is always close to equilibrium states
e) is none of the above

8.32) A heat engine that in each cycle does positive work and rejects heat, with no heat input, would violate
a) Newton's second law
b) the zeroth law of thermodynamics
c) the first law of thermodynamics
d) the second law of thermodynamics
e) the third law of thermodynamics

8.33) A reversible heat engine and an irreversible heat engine both operate between the same high temperature and low temperature reservoirs. They absorb the same heat from the high temperature reservoir. The irreversible engine:
a) does more work
b) rejects more heat to the low temperature reservoir
c) has the greater efficiency
d) has the same efficiency as the reversible engine
e) cannot absorb the same heat from the high temperature reservoir without violating hte second law