University of California at Berkeley
Department of Physics
Physics 7B, Spring 1998

Final examination, section 2: Prof. Jacobsen
May 19, 8AM to 11AM

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 forty points. The individual parts of the four main questions are labeled with their point values, which total one hundred points. The exam total is one hundred sixty points.

$\varepsilon_0 = 8.85\ 10^{-12}$ F/m $\mu_0 = 1.26\ 10^{-6}$ H/m

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

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

NAME:______________________________

SID NUMBER: ______________________________

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DISCUSSION SECTION DAY/TIME:______________________

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Your grade posted by SID number ______________________

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I	
II	
III	
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Read the problems carefully.

Try to do all the problems.

If you get stuck, go on the the next problem.

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

1) 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

2) 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

3) 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

4) Two different samples have the same mass and temperature. Equal quanitites of heat are absorbed by each. Their final temperatures may be different because the samples hae different

a) thermal conductivities
b) coefficients of expansion
c) densities
d) volumes
e) heat capacities

5) Brownian motion of smoke particles in air is evidence of

a) thermal vibrations of the atoms in the smoke particles
b) air molecules are largely diatomic
c) the energy content of the illuminating light beam
d) the size distribution of the smoke particles
e) equipartition of energy between the smoke particles and the air molecules

6) The heat capacity at constant volume and the heat capacity at constant pressure have different values because:

a) heat increases the internal energy at constant volume but not at constant pressure
b) heat increases the internal energy at constant pressure but not at constant volume
c) the system does positive work at constant volume but not at constant pressure
d) the system does positive work at constant pressure but not at constant volume
e) the system does negative work at constant pressure but not at constant volume

7) 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) The heat absorbed by an ideal gas for an isothermal process equals:

a) the work done by the gas
b) the work done on the gas
c) the change in the internal energy of the gas
d) the negative of the change in internal energy of the gas
e) zero since the process is isothermal

9) When an ideal gas undergoes a quasi-static isothermal expansion:

a) the work done by the gas is the same as the heat absorbed
b) the work done by the environment is the same as the heat absorbed
c) the increase in internal energy is the same as the heat absorbed
d) the increase in internal energy is the same as the work done by the gas
e) the increase in internal energy is the same as the work done by the environment

10) 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

11) 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

12) A positively charged metal sphere A is brought into contact with an uncharged metal sphere B. As a result:

a) both spheres are positively charged
b) A is positively charged and B is neutral
c) A is positively charged and B is negatively charged
d) A is neutral and B is positively charged
e) A is neutral and B is negatively charged

13) The leaves of a positively charged electroscope diverge more when an object is brought near the knob of the electroscope. The object must be:

a) a conductor
b) an insulator
c) positively charged
d) negatively charged
e) uncharged

14) A certain physics textbook shows a region of space in which two electric field lines cross each other. We conclude that:

a) at least two point charges are present
b) an electrical conductor is present
c) an insulator is present
d) the field points in two directions at the same place
e) the author made a mistake

15) A hollow conductor is positively charged. A small uncharged metal ball is lowered by a silk thread through a small opening in the top of the conductor and allowed to touch its inner surface. After the ball is removed, it will have:

a) a positive charge
b) a negative charge
c) no appreciable charge
d) a charge whose sign depends on what part of the inner surface it touched
e) a charge whose sign depends on where the small hole is located in the conductor

16) The equipotential surfaces associated with an isolated point charge are:

a) radially outward from the charge
b) vertical planes
c) horizontal planes
d) concentric spheres centered at the charge
e) concentric cylinders with the charge on the axis.

17) The capacitance of a parallel plate capacitor can be increased by:

a) increasing the charge
b) decreasing the charge
c) increasing the plate separation
d) decreasing the plate separation
e) decreasing the plate area

18) A car battery is rated at 80 A • h. An ampere-hour is a unit of

a) power
b) energy
c) current
d) charge
e) force

19) Two wires are made of the same material and have the same length but different radii. The are joined end-to-end and a potential difference is maintained across the combination. Of the following the quantity that is the same for both wires is:

a) potential difference

b) current

c) current density

d) electric field

e) none of the above

20) It is better to send 10,000 kW of electric power long distances at 10,000 V rather than 220 V because

a) the resistance of the wires is less at high voltages

b) more current is transmitted at high voltages

c) there is less heating in the transmission wires

d) the insulation is more effective at high voltages

e) the "iR" drop along the wires is greater at high voltages

21) Two wires made of the same material have the same length but different diameter. They are connected in parallel to a battery. The quantity that is NOT the same for the wires is:

a) the end-to-end potential difference

b) the current

c) the current density

d) the electric field

e) the electron drift velocity

22) A charged capacitor is being discharged through a resistor. At the end of one time constantt the charge has been reduced by (1 - 1/e) = 63% of its initial value. At the end of two time constants the charge has been reduced by what fraction of its initial value?

a) 82%

b) 86%

c) 100%

d) between 90% and 100%

e) need to know more data to answer question

23) The magnetic force on a charged particle is in the direction of its velocity:

a) if it is moving in the direction of the field

b) if it is moving opposite to the direction of the field

c) if it is moving perpendicular to the field

d) if it is moving in some other direction

e) never

24) A current is clockwise around the outside edge of this page and a uniform magnetic field is directed parallel to the page, from left to right. If the magnetic force is the only force acting on the page, the page will turn so the right edge

a) moves to your right

b) moves to your left

c) moves toward you

d) moves away from you

e) does not move

25) Lines of magnetic field produced by a long thin straight wire carrying a current

a) are lines similar to those produce by a bar magnet

b) are in the direction of the current

c) are opposite to the direction of the current

d) leave the wire radially

e) are circles concentric with the wire

26) The magnetic field B inside a long solenoid is independent of:

a) the current

b) the core material

c) the spacing of the windings

d) the cross-sectional area

e) the direction of the current

27) The emf that appears in Faraday's law is:

a) around a conducting circuit

b) around the boundary of the surface used to compute the magnetic flux

c) throughout the surface used to compute the magnetic flux

d) perpendicular to the surface used to compute the magnetic flux

e) none of the above

28) A rectangular loop of wire with area S is placed perpendicular to a uniform magnetic field and then spun around one of its sides at frequency f. The maximum induced emf is

a) BSf

b) 4BSf

c) 2BSf

d) $2\pi BSf$

e) $4\pi BSf$

29) Gauss' law for magnetism tells us:

a) the net charge in any given volume

b) that the line integral of a magnetic field around any closed loop must vanish

c) the magnetic field of a current element

d) that magnetic monopoles do not exist

e) charges must be moving to produce magnetic fields

30) A bar magnet is broken in half. Each half is broken in half again, etc. The observation is that each piece has both a north and south pole. This is usually explained:

a) by Ampere's theory that all magnetic phenomena result from electric currents

b) by our inability to divide the magnet into small enough pieces

c) by Coulomb's law

d) by Lenz' law

e) by conservation of charge.

31) The energy of a magnetic dipole in an external magnetic field is least when

a) the dipole moment is parallel to the field
b) the dipole moment is antiparallel to the field
c) the dipole moment is perpendicular to the field
d) none of the above (the same energy is associated with all orientations)
e) none of the above (no energy is associated with the dipole-field interaction)

32) The most significant magnetic properties of materials stem from

a) particles with north poles
b) particles with south poles
c) motions of protons within nuclei
d) proton spin angular momentum
e) electron magnetic dipole moments

33) Of the three chief kinds of magnetic materials (diamagnetic, paramagnetic, and ferromagnetic) which are used to make permanent magnets?

a) only diamagnetic
b) only ferromagnetic
c) only paramagnetic
d) only paramagnetic and ferromagnetic
e) all three

34) An ordinary incandescent lamp is connected in series to a 100 volt AC source and a coil with many turns having a removable iron core. After the core is removed, the lamp will glow

a) less brightly than before
b) just as brightly as before
c) more brightly than before
d) depends on the ratio of L/R
e) depends on the rated wattage of the lamp

35) The stored energy in an inductor

a) depends, in sign, upon the direction of the current
b) depends on the rate of change of the current
c) is proportional to the square of the inductance
d) has units of J / H
e) none of the above

36) In a purely capacitive AC circuit the current

a) leads the voltage by 1/2 cycle
b) leads the voltage by 1/4 cycle
c) is in phase with the voltage
d) lags the voltage by 1/4 cycle
e) lags the voltage by 1/2 cycle

37) A resistor, an inductor, and a capacitor are connected in parallel to a sinusoidal seat of emf. Which of the following is true?

a) The currents in all branches are in phase.

b) The potential differences across all branches are in phase.

c) The current in the capacitor branch leads the current in the inductor branch by 1/4 cycle

d) The potential difference across the capacitor branch leads the potential difference across the inductor branch by 1/4 cycle.

e) The current in the capacitor branch lags the current in the inductor branch by 1/4 cycle.

38) The rms value of an AC current is

a) its peak value

b) the average value

c) that steady current which produces the same rate of heating in a resistor

d) that steady current which will charge a battery at the same rate

e) zero

39) A "step-down" transformer is used to:

a) increase the power

b) decrease the power

c) increase the voltage

d) decrease the voltage

e) change AC to DC

40) Displacement current exists wherever

a) there is a magnetic field

b) there is a moving charge

c) there is a changing magnetic field

d) there is an electric field

e) there is a changing electric field

I) The heat pump

The outside temperature in the Great Midwest can go as low as -40°C (-40°F). In this problem, you'll calculate what is needed to heat a small house to 20°C (68°F) on a day like that.

(8 points) The house has 4 outside walls, each 11 meters by 3 meters. Ignore the basement and roof. Assume the walls to be 0.1 meters thick and to have the thermal conductivity k of 0.06 W/m K.

How much heat must flow into the house (from a furnace or other heater) to keep its temperature constant? Make sure you specify units.

b) (4 points) If you didn't get part (a), call the required heat flow H.

In this part, we'll provide exactly that heat flow with an electric furnace. The furnace is connected to the 220 Volt power lines. What current does it draw while providung H? If electricity costs $0.15 per kilowatt/hour, what does it cost to run the furnace at the needed rate for a day?

c) (10 points) In the next three parts, a heat pump will be used to heat the house. A heat pump removes heat from the cold outside and "pumps" it to the hotter inside.

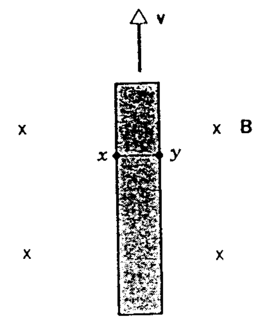
Assuming the heat pump is perfect from the thermodynamic point of view (e.g. no friction), how much mechanical power must be provided to make it move H? Make very sure that all your variables are clearly described; a picture will help.

d) (6 points) If you didn't get part (c), call the required mechanical power P_m.

The required mechanical power will be provided by an electrical motor. Assuming the motor is perfect from the thermodynamic point of view (e.g. no friction, so all the electrical power in becomes mechanical power out), what current does it draw? If electricity costs $0.15 per kilowatt/hour, what does it cost to run the heat pump motor at the needed rate for a day?

II HRK 34-39

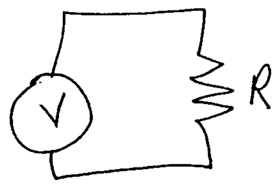
(12 points) A metal strip 6.5 cm long, 0.88 cm wide, and 0.76 mm thick moves with constant velocity v through a magnetic field B = 1.2 mT perpendicular to the strip, as shown in the figure. A potential difference of 3.9 μV is measured between points x and y across the strip. Calculate the speed v.



III Big electrical motors

The windings in big (much greater than a horsepower) electrical motors act like large inductors. In this problem, we examine some of the implications of that by examining the specific case of a 5kW electric motor used to run the fans in the lecture hall.

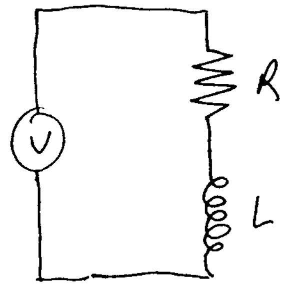
a) (6 points) An effective circuit for the motor and electric company is shown at right in the case where the inductance of the motor windings can be ignored. V is the 500 volt RMS 60 Hz power from the power company. R is the "effective resistance" of the motor; for this problem you can imagine that it is absorbing the 5kW of power that is being transferred to the fan blades.



What value of R is required to absorb 5kW of power?

b) (4 points) In the same situation as (a), what is the current drawn from the power lines?

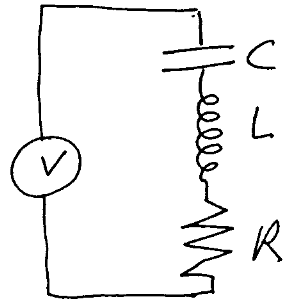
c) (8 points) An effective circuit for the motor and electric company is shown at right in the case where the inductance of the motor windings cannot be ignored. V and R are exactly as before. L is the inductance of the windings, which has been measured to be 0.2 Henry.



In this case, the resistor will be dissipating less than 5kW. How much power does it dissipate? (Note: you might want to do part d first)

d) (6 points) In the same situation as (c), what is the current drawn from the power lines?

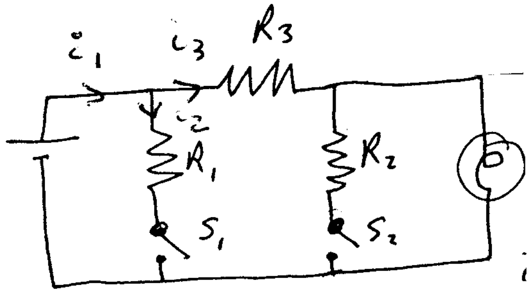
e) (8 points) We want to modify the circuit to get the power dissipation back up to 5kW, because we want the fan to move the air, but we cannot reduce the inductance. A possible circuit to do this is shown at right. V, L and R are the same as in part (c).



What value for the capacitor C will result in 5kW of power being dissipated in R?

f) (2 points) Is this a practical solution? (You might want to consider the size of the capacitor and the voltage across it)

IV DC circuits



All the resistors in the circuit to the right have values of 5 Ohms, as does the light bulb. The battery provides 25 volts. (You may want to do the parts of this problem in some other order, but if you do please make sure the grader can figure out your logic.)

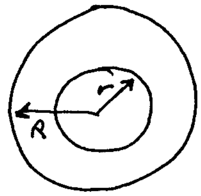
a) (8 points) With both switches closed, what is the current through the light bulb?

b) (4 points) When switch 1 is closed, is the bulb brighter or dimmer than when that switch is open? Assume switch 2 is closed. Make sure your logic is clear.

c) (4 points) When switch 2 is closed, is the bulb brighter or dimmer than when that switch is open? Assume switch 1 is closed. Make sure your logic is clear.

V The coaxial line

"Coaxial cable" is used to carry high frequency signals for radio, TV, etc. The drawing at right shows the basic layout. There is a central conductor of radius r, then an airgap, and then an outer conductor of radius R. You can ignore the thickness of the outer conductor. In a real cable, there needs to be little bits of plastic or something to keep the two conductors apart; ignore these here.



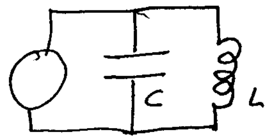
a) (6 points) Assume a charge density of λ Coloumbs/meter on the inner conductor, and $-\lambda$ on the outer. Find the direction and magnitude of the electric field in the space between the conductors and outside the cable. You will probably need a sketch to explain the direction.

b) (5 points) What is the capacitance C of a piece of this cable d meters long?

c) (6 points) Assume that there is a current I going into the page in the inner conductor, and the same current coming out of the page in the outer conductor. Find the direction and magnitude of the magnetic field in the space between the conductors, and outside the cable. You will probably need a sketch to explain the direction.

d) (5 points) What is the inductance L of a piece of this cable d meters long?

e) (5 points) If you put a short circuit at one end of a piece of cable of length d and connect to it at the other end, it works somewhat like an parallel LC "tank" circuit. The L and C values are the same as you found above.



What is the resonant frequency of the model circuit? (If you didn't get the earlier parts, just express it in terms of L and C)

f) (Just for fun, only 3 points, think about this last) If you instead think of the piece of cable as an "organ pipe" of length d, in which a wave can move at velocity c, what's the resonant frequency of the resulting standing wave? Compare it to the result to part (e), using for c the velocity of light.