Name: Answer Key

PHYSICS 1050 Final Examination
University of Wyoming
4 May 2010

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Calculators are permitted but computers are not. No collaboration, consultation, or communication with other people (other than the administrator) is allowed by any means, including but not limited to verbal, written, or electronic methods. Sharing of materials, such as calculators, formula sheets, and notes cards, is prohibited.

If you have a question about the test, please raise your hand. If that does not get the administrator's attention, he will probably notice if you do "the wave."

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Part 1 (Exam 3): Recent Topics

Hollow Earth

1. (5 points) The Earth's core is made principally of iron, and its mass is about one-third (1/3) of the Earth's total mass. If alien invaders were to remove the Earth's core, how would your weight at the surface of the hollow Earth differ from what it is now? (Assume that the Earth's size does not change—the aliens are responsible miners.)

a. Your weight would be 1/3 of what it is now.
b. Your weight would be 2/3 of what it is now.
c. Your weight would be 4/3 of what it is now.
d. Your weight would be 1/9 of what it is now.
e. Your weight would be 4/9 of what it is now.
f. Your weight would be three times (3×) what it is now.
g. Your weight would be 3/2 of what it is now.
h. Your weight would be 9/4 of what it is now.
i. Your weight would be nine times (9×) what it is now.

Key idea: gravitational force = GMm/d^2. The Earth loses 1/3 its mass M, while your mass m and distance to the center of the Earth d remain the same.

Balloon and fur

2. (5 points) When a clean, dry rubber balloon is rubbed with clean, dry fur, the balloon and fur will stick together. Why?

a. Unbalanced charges in the balloon cause the opposite charges in the fur to move in opposite directions.
b. The balloon and fur attract gravitationally.
c. The balloon and fur have opposite magnetic fields.
d. The balloon and fur have opposite electric charges.
e. The balloon and fur have the same electric charge.

Electric charge was transferred between the two initially neutral objects. Their net charges became equal and opposite.

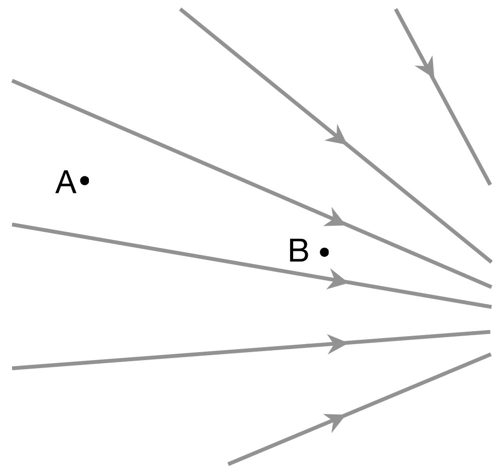
3. (5 points) Does the attraction between the balloon and the fur change with the distance between them?

a. Yes. Their attraction is weaker when they are farther apart.
b. Yes. Their attraction is stronger when they are farther apart.
c. No.

Key idea: Electrostatic force = kq_1q_2/d^2. As the distance d increases, the force gets weaker.

Electric field

4. (5 points) The diagram at right shows two points, A and B, in an electric field. The field is illustrated by field lines, shown as gray lines. Arrowheads on the field lines indicate the direction of the field. At which point is the *magnitude* of the electric field *greater*?



a. At point A.

b. At point B.

c. The magnitude is the same at both positions.

d. It is impossible to tell.

Key idea: Field line representation. The intensity of any type of field is greatest where field lines are closest together.

5. (5 points) The electric field described in the previous problem is created by a single point charge (an infinitesimally small object with an electric charge). The diagram does not show the location of the point charge. What is the *sign* of the charge that creates the field?

Key idea: Meaning of an electric field. An electric field is proportional to and in the direction of the force on a positive charge. Negative attracts positive. The "sink" charge is where the lines converge.

a. Positive (+).

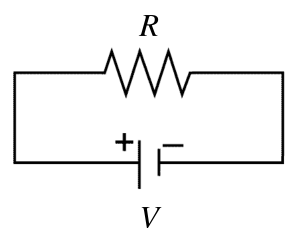
b. Negative (–).

c. The charge could be either positive or negative.

Power in a resistor

6. (5 points) Different resistors are wired so that there are voltages across them. In which combination of resistance R and voltage V below does the resistor dissipate the most *power*?

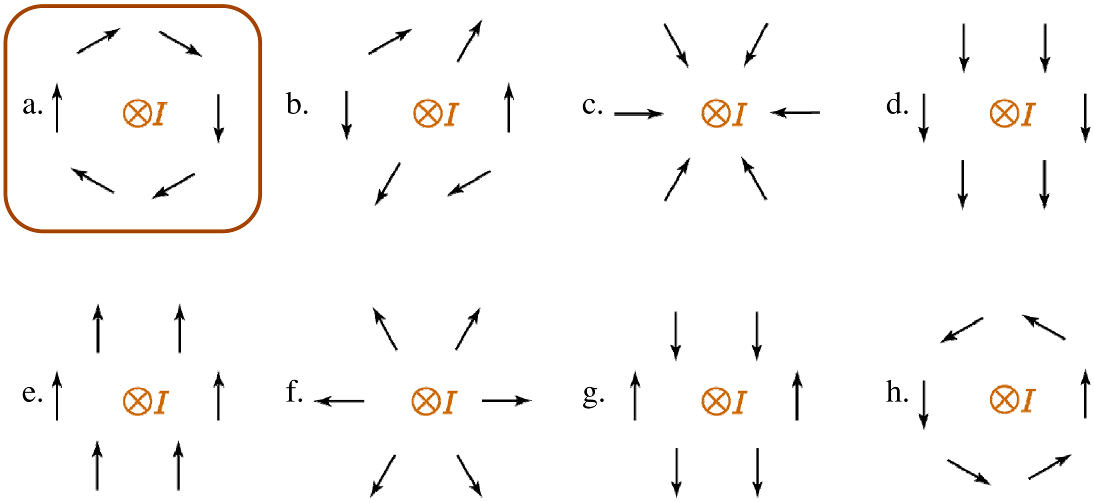
		I (A)	P (W)
a. $V = 5$ V,	$R = 5\ \Omega$.	1	5
b. $V = 10$ V,	$R = 10\ \Omega$.	1	10
c. $V = 5$ V,	$R = 10\ \Omega$.	0.5	2.5
d. $V = 2$ V,	$R = 1\ \Omega$.	2	2



Key ideas: $P = VI$ and $I = V/R$. Or, since you know V and R, you can also use $P = V^2/R$ directly.

Compasses and a wire

7. (5 points) An electric current flows along a straight wire into the page away from you (⊗). Six compasses are placed around the wire, in the positions shown. Their needles are free to turn. Which selection below shows how the compass needles will point? (Arrowheads indicate the north-seeking ends of the compass needles.)

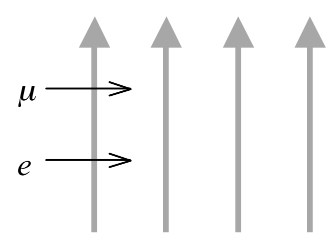


Key idea: Right-hand rule. When the thumb of your right hand points in the direction of the current, your fingers curl in the direction of the magnetic field.

Particle zoo

8. (5 points) In the mid-20th century, physicists discovered a particle now known as the *muon*. A muon's mass is about 207 times greater than an electron's mass, but a muon has exactly the same charge as an electron.

In the diagram at right, a muon (designated μ) and an electron (designated e) cross a magnetic field as shown. (The thick gray arrows represent magnetic field lines; the thin black arrows represent the particles' velocities.) Both the muon and the electron travel in the same direction with the same speed. How do the Lorentz forces on the two particles compare?



a. The Lorentz forces on both particles are *zero*.

b. The Loentz force on the *muon* is greater than the Lorentz force on the electron.

c. The Lorentz force on the *electron* is greater than the Lorentz force on the muon.

d. Both particles experience the *same* Lorentz force, which is not zero.

Key idea: Lorentz force $F = qv \times B$. Both particles have the same charge and velocity, and traverse the same magnetic field.

9. (5 points) What is the *direction* of the Lorentz force on the electron described in the previous question?

a. Up (↑). b. Down (↓). c. Left (←).
d. Right (→). e. Into the page (⊗). f. Out of the page (•).
g. The Lorentz force on the electron has no direction, because it is *zero*.

Key idea: Lorentz force $F = qv \times B$. Since q is negative, qv is to the left. B is upward. The rules of vector cross products then dictate the direction of F.

Transformer

10. (5 points) In an electrical transformer, why does alternating current in the primary circuit cause current to flow in the secondary circuit?

a. Current in the primary circuit creates an electric field in the transformer core, causing electrons in the secondary circuit to move.

b. Alternating current in the primary circuit creates a changing magnetic field in the transformer core, which induces an electric potential in the secondary circuit.

c. The primary circuit charges a battery, which powers the secondary circuit.

d. The primary circuit and the secondary circuit are wired in series, so current that flows through the primary circuit then flows through the secondary circuit.

Key idea: Faraday's law. A changing magnetic flux within a loop produces an electric potential around the loop.

Light and x-rays

11. (10 points) Light and x-rays are both electromagnetic waves. Which of their properties do they share in common, and which of their properties are different? For each property listed below, identify whether it is the same or different for x-rays and light.

same	different	a. frequency
same	different	b. energy
same	different	c. speed in a vacuum
same	different	d. wavelength
same	different	e. relative directions of electric field, magnetic field, and velocity

Key idea: Electromagnetic waves. Light and x-rays are both electromagnetic waves; x-rays have shorter wavelengths. All electromagnetic waves have the same vacuum speed and the same relationship between their electric field, magnetic field, and velocity. They differ in wavelength, frequency, and energy; if any one of these quantities is known, the others are determined.

Nuclear reactions

12. (5 points) Choose the species that correctly completes this nuclear decay reaction.

$$^{14}\text{C} \rightarrow \_\_\_\_\_\_\_ + e^{-}$$

a. ^{10}N. b. ^{10}Be. c. ^{14}N. d. ^{14}B.

The daughter of beta decay has the same mass number as the parent (14), and is one higher in atomic number (6 + 1 = 7).

13. (5 points) Which nucleus listed below would be most likely to release energy by fission?

a. ^{55}Mn. b. ^{4}He. c. ^{251}Cf. d. ^{3}H.

Heavy nuclei are most likely to fission. Energy is released by producing iron-sized daughters.

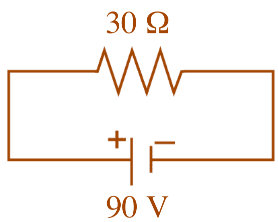
Constructed response questions

14. (15 points) Why are surfaces of equal electric potential always and everywhere perpendicular to electric field lines?

If the electric potential is the same at all points on a surface, that means that the electric field does not do any work on a charge moving along the surface. The only way this can always happen is if the field is perpendicular to the surface.

15. (15 points) Draw a diagram of an electrical circuit. Label each component with its value: the voltage of the voltage source and the resistance of each resistor.

- The circuit must contain exactly one voltage source, with a voltage of 90 V.
- The total current of the circuit (into and out of the voltage source) must be 3 A.
- The circuit may contain up to one 30-Ω resistor and up to one 45-Ω resistor. The resistors may be used alone, together in series, or together in parallel.



$V = 90$ V

$R = 30\ \Omega$

$I = V/R = 3$ A

16. (extra credit) In class, I sang, "Any charge to cross those lines feels a right-handed force."

a. (3 points) What is the formula for that force?

$F = qv \times B$. The Lorentz force F on a charge q is zero unless the charge crosses magnetic field lines B; that is, its velocity v cannot be purely parallel or anti-parallel to B.

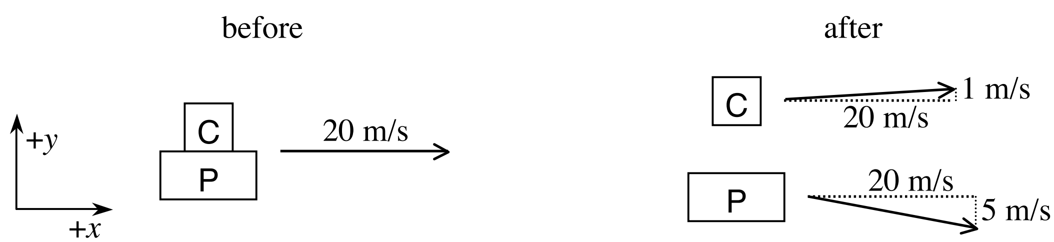
b. (2 points) In what way is the force "right-handed?"

$qv \times B$ is a vector cross product. The direction of that vector is given by the right-hand rule (one of the right-hand rules, that is).

Part 2 (Exam 4): Comprehensive

Detachment

Two docked spacecraft, the Chiron and the Polyphemus, drift in deep space at a constant velocity of 20 m/s in the direction of the *x*-axis. After their joint mission is complete, a piston on the Polyphemus pushes with a constant force of 5,000 N against the Chiron. After 4 s of pushing, they drift apart without any further forces acting on them. As they drift apart, the Chiron's *x*-component of velocity remains 20 m/s, while its *y*-component of velocity is 1 m/s; the Polyphemus's *x*-component of velocity also remains 20 m/s, while its *y*-component of velocity is –5 m/s.



1. (5 points) In what *direction* was the *net force* that acted on the Chiron?

a. In the +*x* direction.

b. In the –*x* direction.

c. In the +*y* direction.

d. In the –*y* direction.

e. In a combination of the +*x* and +*y* directions.

f. In a combination of the +x and –y directions.

Key ideas: Acceleration and Newton's second law. Net force is in the direction of acceleration; acceleration $a = \Delta v/\Delta t$ is in the direction of velocity change: +*y*.

2. (5 points) What was the *magnitude* of the Chiron's *acceleration* during the push-apart? (Don't forget the units!)

0.25 m/s²

Key ideas: Acceleration and Newton's second law. Constant force means constant acceleration; $a = \Delta v/\Delta t = (1 \text{ m/s})/(4 \text{ s}) = 0.25 \text{ m/s}^2$.

3. (5 points) How does the Chiron's *change* in *momentum* compare to the Polyphemus's change in momentum?

a. Their momentum changes were exactly equal.

b. Their momentum changes were exactly opposite.

c. The Chiron's momentum change had a greater magnitude.

d. The Chiron's momentum change had a smaller magnitude.

Key idea: Conservation of momentum. For the total momentum to not change, any change in one's momentum must be opposite the other's.

4. (5 points) How does the Chiron's *change* in *kinetic energy* compare to the Polyphemus's change in kinetic energy?

a. Their kinetic energy changes were exactly equal.

b. Their kinetic energy changes were exact negatives of each other.

c. The Chiron's kinetic energy change was greater than the Polyphemus's.

d. The Chiron's kinetic energy change was less than the Polyphemus's.

Key idea: work-energy theorem. Equal-magnitude forces were applied to each, but the Polyphemus's was over a greater distance.

5. (5 points) What was the *power* applied to the Chiron at the final instant of the push-apart? (Don't forget the units!)

5000 W

Key idea: Power = $F \cdot v$ (a vector dot product). F = 5000 N, and the component of v in the direction of F was 1 m/s.

Uniform circular motion

6. (5 points) When an object undergoes uniform circular motion (motion at a constant speed in a circular path), some of its properties change as it moves while other properties remain the same. Identify (by circling either "changes" or "constant") whether each of the five properties listed below changes or remains constant for an object in uniform circular motion.

changes	**constant**	a. magnitude of acceleration always v^2/r.
changes	constant	b. momentum magnitude constant, direction changes.
changes	constant	c. net force magnitude constant, direction changes.
changes	**constant**	d. kinetic energy constant speed and mass.
changes	**constant**	e. angular momentum (about the path's center) Though r and p change, $r \times p$ is constant. Their magnitudes are constant, and they are always perpendicular to each other.

Vectors and Scalars

7. (3 points) From the choices below, select (by circling) *three* quantities that are *vectors*. (Do not select more than three! If you do, only the first three will count.)

a. Work.	b. Electric charge.	c. Time.
d. Electric field.	**e. Angular momentum.**	**f. Velocity.**
g. Force.	h. Heat.	**i. Impulse.**

(Of course, you should select only three of these.)

8. (2 points) From the choices below, select (by circling) *two* quantities that are *scalars*. (Do not select more than two! If you do, only the first two will count.)

a. Work.	b. Electric charge.	c. Time.
d. Electric field.	e. Angular momentum.	f. Velocity.
g. Force.	h. Heat.	i. Impulse.

(Of course, you should select only two of these.)

Conserved quantities

9. (5 points) Some physical quantities are conserved in all interactions, and others are not. Identify (by circling "always conserved" or "not always") whether each of the physical quantities listed below is always conserved or not.

always conserved	not always	a. angular momentum
always conserved	not always	b. momentum
always conserved	not always	c. total energy
always conserved	not always	d. entropy
always conserved	not always	e. temperature

Momentum, angular momentum, total energy, and charge are always conserved.

Heat transfer

10. (5 points) A student in physics lab places a hot block of metal into an insulated container of cool water. The metal block and the water have exactly the same mass, and the metal block is completely submerged in the water. When the metal block and the water reach the same final temperature, the temperature of the metal has decreased by 60 °C and the temperature of the water has increased by 6 °C. Why was the water's increase in temperature less than the metal's decrease in temperature?

a. The metal's specific heat was greater than the water's specific heat.

b. The water's specific heat was greater than the metal's specific heat.

c. The metal released more heat than the water absorbed.

d. The water absorbed more heat than the metal released.

The metal contacted only the water. It transferred heat only to the water; its energy loss was the water's energy gain. Water has a high specific heat; metals have low specific heat.

Temperature change is $\Delta T = q/(mc)$, where q is heat absorbed, m is mass, and c is specific heat. Here m was the same for the metal and water, and q's were equal and opposite. Thus, c's had to be different.

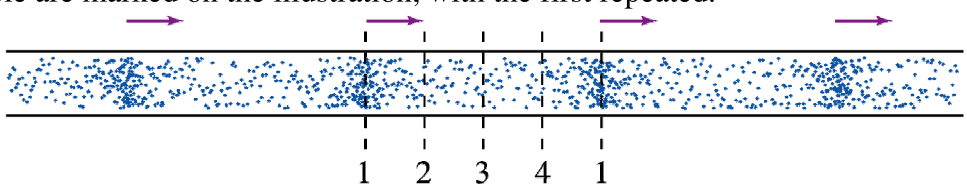
Interaction forces

11. (5 points) All forces are interactions between two objects. Match the forces listed below to the types of objects between which they act.

Force	Interacting Objects
friction	two masses
gravity	two charges
Lorentz	two nucleons
strong	two contacting surfaces
electrostatic	a charge and a magnet

Sound Waves

Longitudinal sound waves (pulses of condensations and rarefactions) travel to the right in an air-filled tube. The dots indicate the positions of the air molecules at one moment. The direction that the pulses travel is indicated by the arrows. Four evenly-spaced phases in a cycle are marked on the illustration, with the first repeated.



12. (5 points) What is the *direction* of the *net force* on the air molecules at phase 1? (Ignore the force of gravity.)

a. To the left.

b. To the right.

c. No direction : the net force is zero.

Key idea: *Net* force. Pressure pushes equally inward on both sides, for a grand total of nothing.

13. (5 points) At which phase is an air molecule's *acceleration* to the *left* the greatest?

a. At phase 1.

b. At phase 2.

c. At phase 3.

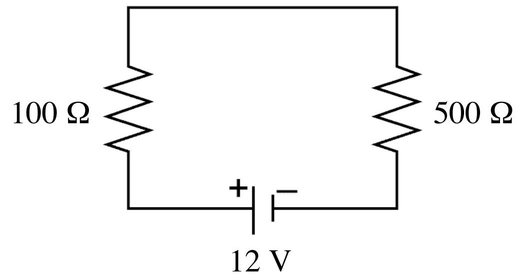
d. At phase 4.

e. Air molecules in this wave train *never* accelerate to the left.

Key ideas: Net force and Newton's second law. At phase 4, pressure to the right exceeds pressure to the left, for a leftward net force.

Circuit I

A 100-Ω resistor and a 500-Ω resistor are wired in series to a 12-V source, as shown.



14. (2 points) Through which resistor does the greatest *current* flow?

a. The greatest current flows through the 100-Ω resistor.

b. The greatest current flows through the 500-Ω resistor.

c. The current through both resistors is the same.

Key idea: Current in is current out. There is only one path, so the current is the same everywhere along it.

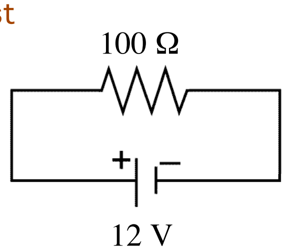
15. (2 points) Across which resistor is the *voltage drop* the greatest?

a. The voltage drop across the 100-Ω resistor is the greatest.

b. The voltage drop across the 500-Ω resistor is the greatest.

c. The voltage drops are the same across both resistors.

Key idea: $V = IR$. For the same current I, the voltage V must be greater across the larger resistance.



16. (1 point) How does the *total current* in the circuit above compare to the total current in the circuit to the right, which has a 12-V source and a single 100-Ω resistor?

a. The circuit with two resistors has more total current than the circuit with one resistor.

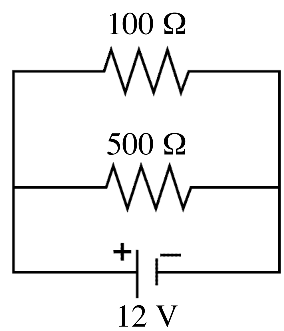
b. The circuit with one resistor has more total current than the circuit with two resistors.

c. Both circuits have the same total current.

Key idea: resistors in series divide the voltage. The total voltage around either circuit is 12 V. A moving charge encounters the resistance of every resistor it traverses. Resistors in series thus have more resistance than any one alone. There is more current in the circuit with less resistance.

Circuit II

A 100-Ω resistor and a 500-Ω resistor are wired in parallel to a 12-V source, as shown.



17. (2 points) Through which resistor does the greatest *current* flow?

a. The greatest current flows through the 100-Ω resistor.

b. The greatest current flows through the 500-Ω resistor.

c. The current through both resistors is the same.

Key idea: Ohm's law $I = V/R$. Voltage V is the same for both (see the next question), so I is greatest where R is least.

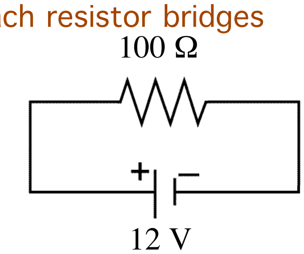
18. (2 points) Across which resistor is the *voltage drop* the greatest?

a. The voltage drop across the 100-Ω resistor is the greatest.

b. The voltage drop across the 500-Ω resistor is the greatest.

c. The voltage drops are the same across both resistors.

Key idea: Total voltage around any closed path is zero. Each resistor bridges the same 12-V source.



19. (1 point) How does the *total current* in the circuit above compare to the total current in the circuit to the right, which has a 12-V source and a single 100-Ω resistor?

a. The circuit with two resistors has more total current than the circuit with one resistor.

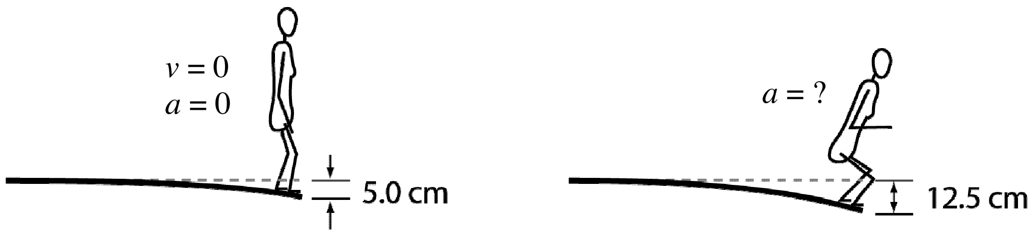
b. The circuit with one resistor has more total current than the circuit with two resistors.

c. Both circuits have the same total current.

Key idea: Each parallel path allows more current. The two-resistor circuit is the same as the one-resistor circuit, plus an additional path.

Constructed response questions

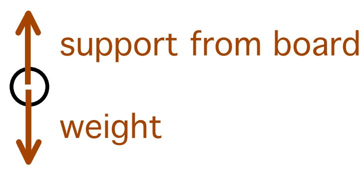
20. When a diver stands motionless on a diving board, her weight deflects it downward 5.0 cm from its unweighted position. When she jumps and lands back on the board, it deflects downward 12.5 cm from its unweighted position.



a. (2 points) Name the forces that act on the diver in both cases.

The diver's weight from her gravitational attraction to the Earth, and the upward support force from the board.

b. (4 points) Draw a force diagram for the diver showing the forces as vector arrows pointing away from the diver's center of mass.



c. (4 points) Give formulas for all the forces that act on the diver. Use variables for the quantities in the formulas: don't substitute in the quantities' numerical values. Identify each quantity in each formula in terms of this specific situation. (For example, "λ = wavelength of the sound waves emitted by the diving board.")

support from board: $F = -kx$

k = spring constant of diving board

x = upward flex of diving board

weight: $F = mg$

m = diver's mass

g = gravitational field

d. (5 points) What is the diver's *acceleration* when the board is deflected downward 12.5 cm? (Report both magnitude and direction. Don't forget the units!)

Key ideas: weight is constant, board's force is proportional to flex, $a = \sum F/m$, net force $\sum F = 0$ in the first case.

First case: board's upward force cancels the diver's weight mg. Second case: board's upward force is 12.5/5 = 2.5 times greater than in the first case, or 2.5 times the diver's weight. Total force then is $2.5\ mg - mg = 1.5\ mg$ upwards. Acceleration then is $1.5\ g$ upwards.

21. Wires carrying alternating electric current emit electromagnetic waves of the same frequency as the alternating current. The conversion of energy into the electromagnetic waves is greatest when the wire is about as long as the wavelength of the electromagnetic wave. So, a radio antenna works best if it is about as long as the radio waves it transmits. On the other hand, a circuit using alternating current at frequency f will "leak" power if it is about the same size as electromagnetic waves with frequency f.

In the United States, commercial electric power is generated and distributed at a frequency of 60 Hz.

a. (10 points) What is the *wavelength* of the electromagnetic waves emitted by power lines carrying this current? Report the wavelength in *kilometers* (1 km = 1000 m).

Key ideas: speed of light $c = 2.9979 \times 10^8$ m/s; any wave speed $c = \lambda f$.

$c = lf$, so $\lambda = c/f = (2.9979 \times 10^8 \text{ m/s})/(60/\text{s}) = 5 \times 10^6$ m

1 km = 1000 m, so $\lambda = 5 \times 10^3$ km = 5000 km

b. (5 points) What might this mean for distribution of electric power from one part of the United States to another? (The straight-line distance from Laramie to Salt Lake City is a little over 500 km.)

From one state to another, the distance is much less than a wavelength, so power losses by radiation will not be significant. Across the entire country, however, transmission at 60 Hz would give substantial leakage of power.

22. (5 points extra credit) When I sang, "Please allow me to introduce myself: I'm the law that tells your fate," what law was I personifying? Name it.

The second law of thermodynamics.