Name: Answer Key

PHYSICS 1050 Test 2
University of Wyoming
27 March 2008

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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 and note cards, is prohibited.

If you have a question about the test, please raise your hand. If that does not get the administrator's attention, perhaps he will notice if you throw your chair at him.

Please do not open this test booklet until everyone has received a booklet and the test administrator has indicated for you to begin. While you are waiting, make sure that your name is written clearly at the top of this page and on your note card.

A

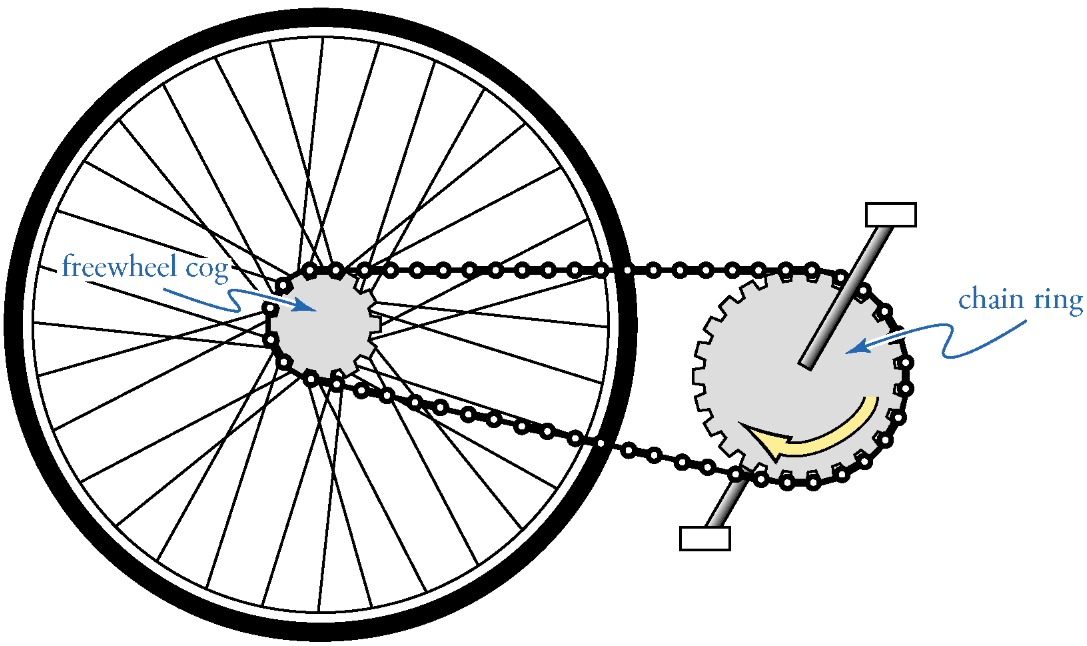
Scenario Problems

Four scenarios, 20 questions, 4 points each.

If choices are given, only one is correct. Please circle the correct choice. If a blank is provided, please enter your answer in the blank.

Scenario 1. Bicycle Power Train

In a standard bicycle, power is transferred from the pedals to the rear wheel by means of gears and a chain. The front gear, known as a "chain ring," has a larger radius than the rear gear, known as a "freewheel cog." The chain ensures that the rims of the chain ring and the freewheel cog move at exactly the same tangential speed. When the bicycle is being pedaled, the freewheel cog and the rear wheel rotate at exactly the same rotational frequency.



1. Which rotates with the greater *frequency*: the chain ring or the freewheel cog?

a. The chain ring.

b. The freewheel cog.

c. The chain ring and freewheel cog rotate with the same frequency.

The speeds are the same, but the chain ring has a greater circumference, that is, farther to travel. So it takes longer to complete one cycle.

2. Which has the greatest *angular momentum* about its axis of rotation: a point on the rim of the chain ring, or a point on the rim of the freewheel cog? Assume that the masses of the points are the same.

Angular momentum is r×mv. Mass *m* and speed *v* are the same for both gears; radius *r* is greatest for the chain ring.

a. A point on the rim of the chain ring.

b. A point on the rim of the freewheel cog.

c. The rims of the chain ring and freewheel cog have the same angular momentum.

3. Which experiences the greater *centripetal acceleration:* a point on the rim of the chain ring, or a point on the rim of the freewheel cog?

Same speed, but the cog reverses direction in a shorter distance ⇒ less time. Thus its acceleration is greater.

a. A point on the rim of the chain ring.

b. A point on the rim of the freewheel cog.

c. The rims of the chain ring and freewheel cog have the same centripetal acceleration.

4. The bicycle chain applies equal and opposite forces to the chain ring and the freewheel cog. These forces create torques on both gears. How does the magnitude of the torque on the chain ring about its axis compare to the *torque* on the freewheel cog about *its* axis?

a. The chain produces a larger torque on the chain ring than on the freewheel cog.

b. The chain produces a smaller torque on the chain ring than on the freewheel cog.

c. The chain produces torques of equal magnitude on the chain ring and freewheel cog.

Same force for both, but longer lever arm for the chain ring.

Scenario 2. Hydraulic Press

A hydraulic system consists of a narrow piston with a cross-sectional area of 10 cm^2 and a wider piston with a cross-sectional area of 50 cm^2. The fluid is incompressible, and the system has no leaks.

5. If a force of 50 N is applied to the narrow piston, what is the pressure increase inside the fluid?

____5____ N/cm $(50\text{ N})/(10\text{ cm}^2) = 5\text{ N/cm}^2$.

6. If the narrow piston is pushed 10 cm into its cylinder, how far is the wide piston pushed out of its cylinder?

____2____ cm   Same volume change: $(10\text{ cm}^2)(10\text{ cm}) = (50\text{ cm}^2)(2\text{ cm})$.
Same work: $(10\text{ cm})(F_1) = (2\text{ cm})(F_2) = (2\text{ cm})(5F_1)$

7. If a force of 500 N is applied to the wide cylinder, what is the force exerted by the hydraulic fluid on the narrow piston?

___100___ N Same pressure: (500 N)/(50 cm^2) = (100 N)/(10 cm^2)

8. If the pressure behind the narrow piston is 5000 Pa, what is the pressure behind the wide piston?

___5000___ Pa Same pressure.

Scenario 3. Cartesian Diver

One of the laboratory activities in this course involved an inverted test tube containing some air floating inside a water-filled plastic 2-L bottle. When the bottle was squeezed, the test tube sank to the bottom of the bottle. When the bottle was released, the test tube rose back to the top of the bottle.

9. Squeezing the bottle increased the pressure inside the bottle. How did the pressure increase in the water at the top of the bottle compare to the pressure increase at the bottom of the bottle?

a. The pressure increase at the top of the bottle was less than the pressure increase at the bottom of the bottle.

b. The pressure increase at the top of the bottle was greater than the pressure increase at the bottom of the bottle.

c. The pressure increase at the top of the bottle was the same as the pressure increase at the bottom of the bottle.

d. The location of the greatest pressure increase depended on where the bottle was squeezed.

Pascal's principle.

10. Was the *volume* of the diver (test tube + air inside it) greatest when it was floating at the top of the bottle or when it was sunk at the bottom of the bottle?

a. The volume of the diver was greatest when it was floating at the top of the bottle.

b. The volume of the diver was greatest when it was sunk at the bottom of the bottle.

c. The volume of the diver was the same at both locations.

Sunk when squeezed; greatest pressure when squeezed. Gas volume decreases when pressure increases.

11. Was the *mass* of the diver (test tube + air inside it) greatest when it was floating at the top of the bottle or when it was sunk at the bottom of the bottle?

a. The mass of the diver was greatest when it was floating at the top of the bottle.

b. The mass of the diver was greatest when it was sunk at the bottom of the bottle.

c. The mass of the diver was the same at both locations.

The amount of matter did not change.

12. Was the volume of water displaced by the diver (test tube + air inside it) greatest when the diver was floating at the top of the bottle or when it was sunk at the bottom of the bottle?

a. The diver displaced the greatest volume of water when it was floating at the top of the bottle.

b. The diver displaced the greatest volume of water when it was sunk at the bottom of the bottle.

c. The volume of water displaced was the same in both locations.

The volume of the test tube was constant; the volume of the air bubble was least when sunk at high pressure.

13. When was the *buoyancy force* acting on the diver the greatest?

a. The buoyancy force was greatest when the diver was floating at the top of the bottle.

b. The buoyancy force was greatest when the diver was sunk at the bottom of the bottle.

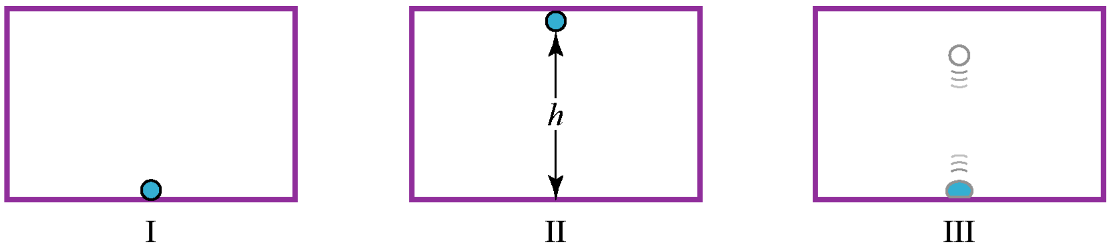
c. The buoyancy force was the same at both times.

Buoyancy equals weight of displaced fluid; the greatest volume, and hence weight, of fluid was displaced when the bubble was largest. Besides, the buoyancy *had* to be largest when the diver was floating!

Scenario 4. Ball in a Box

The three situations depicted below are instants from a sequence in time, not necessarily in order. They involve a rubber ball of mass *m* inside a rigid box. In situation I, the ball is at rest on the floor of the box. In situation II, the ball is at the very top of the box. In situation III, the ball is bouncing off the floor of the box, reaching a maximum height that is less than the full height *h* of the box.

The box and ball do not receive any energy in any form (heat, work, etc.) from the surroundings, nor do they transfer any energy in any form to the surroundings.



14. Which of the three situations is the *latest* in time?

a. Situation I is the latest.
b. Situation II is the latest.
c. Situation III is the latest.
d. There is no way to tell the sequence of the situations.

That's how the sequence ends. The order is II → III → I.

15. In which of the three situations does the box + ball system have the highest *entropy*?

a. The system has the highest entropy in situation I.
b. The system has the highest entropy in situation II.
c. The system has the highest entropy in situation III.
d. There is no way to tell in which situation the system has the highest entropy.

Entropy increases with time. Here it is because the initial potential energy of the ball became random molecular vibrations (thermal energy).

16. When the ball bounces on the floor of the box, the box does not move. As a result, work is done on the ball, but not on the box, during each bounce. If the mass of the ball is 2 kg, the height *h* of the box is 5 m, the temperature of the ball in situation II is 10 °C, and the specific heat of the ball is 10 J/(kg °C)*, what is the temperature of the ball lying at rest on the bottom of the box in situation I?

___14.9___ °C q = work done = mgh

$\Delta T = q/(mc) = mgh/mc = gh/c = (9.8\ \text{N/kg})(5\ \text{m})/(10\ \text{J/kg}\,°\text{C}) = 4.9\,°\text{C}$

$T = 10\,°\text{C} + \Delta T = 14.9\,°\text{C}$

Scenario 5. Bungee

Amelia and Zelda have exactly the same mass. For Amelia's 21st birthday, they go bungee jumping.

In bungee jumping, a jumper jumps from a tall object with an elastic rope called a "bungee cord" tied around his or her ankles. The bungee cord is short enough to stop the jumper before hitting the ground. Since the bungee cord acts as a spring, the jumper oscillates up-and-down on the cord after jumping.

Both of the bungee cords used by Amelia and Zelda follow Hooke's law exactly. Both cords have exactly the same length when they are not stretched. However, the two cords are otherwise not the same. In particular, Amelia's cord stretches farther under Amelia's weight than Zelda's cord stretches under Zelda's weight.

Again, remember that Amelia and Zelda have exactly the same mass.

17. Which jumper's bungee cord has the larger Hooke's law spring constant *k*?

a. Amelia's cord has the larger *k*.

b. Zelda's cord has the larger *k*.

c. Both cords have the same spring constant *k*.

d. There is not enough information to know which cord has the larger *k*.

The spring constant *k* is the stiffness of the spring. Under the same tensions, the stiffer spring will not stretch as far as the softer spring.

* This is a *very* small specific heat, chosen to make the arithmetic easy.

18. Which jumper did the most *work* to stretch her cord to its maximum length?

a. Amelia did the most work on her cord.

b. Zelda did the most work on her cord.

c. Both did the same amount of work.

d. There is not enough information to rank the work done.

Each applied the same force (her weight), but Amelia's spring stretched the farthest. which means the most work done.

19. Which jumper's oscillation has the longest *period*?

a. Amelia's oscillation has the longest period.

b. Zelda's oscillation has the longest period.

c. Amelia's and Zelda's oscillations have the same period.

d. There is not enough information to rank their periods of oscillation.

Period is $2\pi\sqrt{m/k}$. Both jumpers have the same mass m, so the one with the smallest spring constant k has the longest period of oscillation.

20. At what point in an oscillation is a jumper's *upward acceleration* the *greatest*?

a. The upward acceleration is the greatest at the top of the oscillation.

b. The upward acceleration is greatest at the midpoint of the oscillation (the equilibrium point).

c. The upward acceleration is greatest at the bottom of the oscillation.

d. The acceleration is the same at all points in the oscillation.

At the bottom is where the spring is pushing upward the hardest.

Constructed Response

2 questions, 10 points each.

Please provide complete answers to each question. Show all work so that partial credit can be assigned.

21. Why do objects immersed in a fluid in a gravitational field experience an upward buoyancy force?

Pressure inside a fluid increases with depth, so the pressure pushing upward on the bottom of a submerged object is greater than the pressure pushing downward on its top.

22. Centripetal force is the net force on an object that travels at constant speed in a circular path. Over time, how does a centripetal force affect the momentum and kinetic energy of the object on which it acts?

Momentum:

The direction of the momentum constantly changes, though its magnitude stays constant. The momentum reverses twice each cycle.

Kinetic energy:

The kinetic energy remains constant, because the speed of the object is constant.

Extra credit

23. (5 points) In class, when I sang

“Limits to what can be
Are set by deep, deep symmetry,”

what “limits” was I referring to?

The “limits” are the three conservation laws: conservation of momentum, conservation of energy, and conservation of angular momentum. These conservation laws are a consequence of the three continuous symmetries of the laws of physics: uniformity, timelessness, and isotropy.