Name: Answer Key

PHYSICS 1050 Test 2
University of Wyoming
25 March 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 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 sneeze without covering your mouth.

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, on your note card, and on your formula sheet.

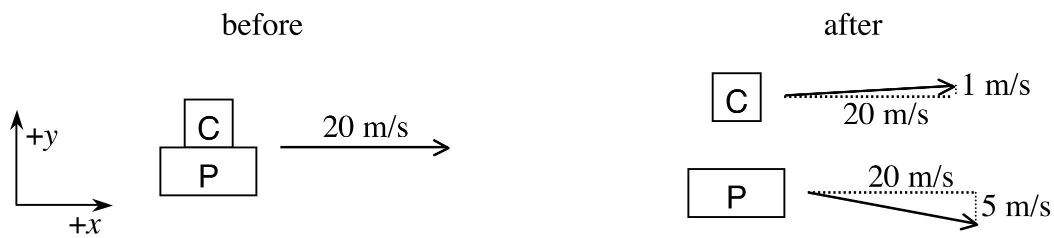
Scenario Problems

Five 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. 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 against the Chiron. After 4 s of pushing with a constant mutual force of 5,000 N, 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. On which craft was the most work done during the push-apart?

a. The most work was done on the Chiron.

b. The most work was done on the Polyphemus.

c. The same amount of work was done on each.

Key idea: Work = $F \cdot \Delta r$. The Polyphemus travels farther in the direction of the force while the force is applied to it.

2. Which craft had the greatest change in kinetic energy as a result of the push-apart?

a. The Chiron's kinetic energy changed the most.

b. The Polyphemus's kinetic energy changed the most.

c. The two crafts experienced the same change in kinetic energy.

Key idea: Work-energy theorem. The net work done on each craft is its change in *KE*.

3. What is the *sign* of the work done on the Polyphemus during the push-apart?

a. Positive (> 0) work was done on the Polyphemus.

b. Negative (< 0) work was done on the Polyphemus.

c. Zero (0) work was done on the Polyphemus.

Key idea: Dot product. The angle between F and Δr is less than 90°.

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

25,000 W ______ (5000 N)(5 m/s) = 25,000 W

Key idea: $P = F \cdot v$. The component of v in the direction of F is 5 m/s.

Scenario 2. Different Springs

Two different springs have different lengths when not stretched. Both springs double in length when the same tension is applied to them.

5. Which spring has the greater spring constant k?

a. The spring that is shorter when not stretched has the greater spring constant.

b. The spring that is longer when not stretched has the greater spring constant.

c. Both springs have the same spring constant.

d. Not enough information is given to compare the spring constants.

Key idea: $F = -kx$. The less the stretch under a given tension, the bigger the k.

6. If equal masses are attached to the ends of each of the two springs and set into oscillation, which will oscillate with the highest frequency?

a. The short spring will oscillate with the highest frequency.

b. The long spring will oscillate with the highest frequency.

c. The springs will oscillate with the same frequency.

d. Not enough information is given to compare the frequencies of oscillation.

Key idea: $T = 2\pi\sqrt{m/k}$. Higher k means shorter period $\Rightarrow$ higher frequency.

7. When the two springs are stretched to the same final tension, which spring has the most work done on it?

a. The spring that stretches the least has the most work done on it.

b. The spring that stretches the most has the most work done on it.

c. The two springs have the same amount of work done on them.

d. Not enough information is given to compare the amount of work done.

Key idea: work = $F \cdot \Delta r$. Both springs have the same force applied, so the one that stretches most has the most work done on it.

8. Different masses are attached to the ends of the two springs and set into oscillation. Both oscillate with the *same period*. How do the masses on the different springs compare?

a. The greatest mass is on the long spring.

b. The greatest mass is on the short spring.

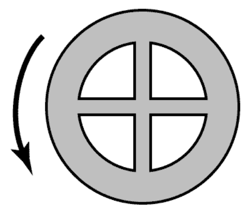
c. The two masses must be the same.

d. Not enough information is given to compare the masses.

Key idea: $T = 2\pi\sqrt{m/k}$. To achieve the same period, a spring with higher k must have a proportionally higher mass.

Scenario 3. Rotating Space Station

One proposed design for a space habitat with "artificial gravity" is a rotating ring with spokes. The station would rotate about its symmetry axis so that occupants would feel a centrifugal force pushing them to the rim of the rotating station. With the proper choice of rotational speed and radius of the station, the centrifugal force could be made the same as an occupant's weight on Earth.



9. If the station's period of rotation is doubled (made twice as long), what will happen to the "weight" of the occupants at the rim?

a. The occupants' weights will become less than half of what they were.

b. The occupants' weights will become half of what they were.

c. The occupants' weights will not change.

d. The occupants' weights will double.

e. The occupants' weights will more than double.

Key idea: Perceived "weight" is form the support force inward from the rim. This is the centripetal force $F = mv^2/r$. Halving v quarters F.

Suppose that the spokes of the station are actually hollow shafts that occupants can ascend and descend.

10. How will an occupant's "weight" depend on where he is in the shaft? Assume that the station's period of rotation remains constant.

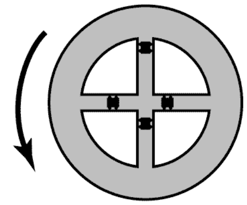
a. The occupant's "weight" will be greater the closer he is to the center of rotation.

b. The occupant's "weight" will be greater the farther he is from the center of rotation.

c. The occupant's "weight" will be the same at all locations.

Key idea: All parts rotate together, so speed v is proportional to radius r. The appropriate relation here is $a = 4\pi^2 f^2 r$.

Suppose that the spokes of the station are shafts along which elevator cars travel.



11. If an elevator car travels from the center of the station to the rim, would a passenger in the car feel a force tending to deflect her sideways?

a. Yes, deflecting her in the direction of rotation of the station.

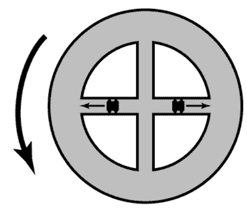
b. Yes, deflecting her opposite the direction of rotation of the station.

c. Yes, deflecting her parallel to the axis of rotation.

d. No, there would be no apparent sideways force.

Key idea: As she moves outward, the shaft presses into her. She will feel a "fictitious" Coriolis force pushing her opposite the direction of rotation.

12. Two elevators in opposite spokes travel in opposite directions at the same time so that the station's center of mass does not move. If the elevators travel outward from the center of the station to the rim, what happens to the *rotational speed* (frequency of rotation) of the entire station (including the elevator cars)? Assume that no external forces or engine adjustments are applied to the station.



a. The station's rotational speed increases.

b. The station's rotational speed does not change.

c. The station's rotational speed decreases.

Key idea: Conservation of angular momentum. $l = r \times p$. When r increases, p must decrease to compensate.

13. If the elevators travel outward from the center of the station to the rim as specified in the previous question, what happens to the *angular momentum* of the entire station (including the elevator cars)? Assume that no external forces or engine adjustments are applied to the station.

a. The station's angular momentum increases.

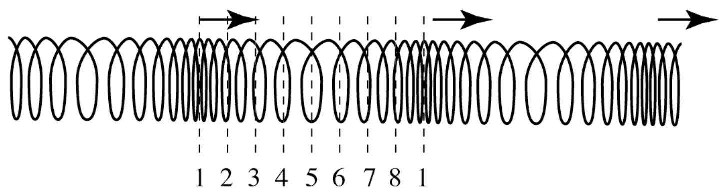
b. The station's angular momentum does not change.

c. The station's angular momentum decreases.

Key idea: Conservation of angular momentum. The station does not receive any torques from external objects.

Scenario 4. Waves in a Coil Spring

Longitudinal compression waves (pulses of condensations and rarefactions) travel to the right along a coil spring, as illustrated. The direction that the pulses travel is indicated by the arrows. Eight evenly-spaced phases in a cycle are marked on the illustration, with the first repeated.



14. In the phase marked 1, what is the acceleration of the spring coil at that position?

a. Backward (to the left ←), at maximum magnitude.

b. Backward (to the left ←), at intermediate magnitude.

c. Zero.

d. Forward (to the right →), at intermediate magnitude.

e. Forward (to the right →), at maximum magnitude.

Key idea: Acceleration is from low to high tension (high to low compression). At 1, tension is even on both sides, for zero net force.

15. In which phase does the coil accelerate *to the left* (←) the most strongly?

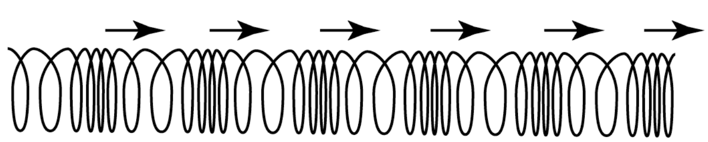
a. In phase 1. b. In phase 2. c. In phase 3. d. In phase 4.

e. In phase 5. f. In phase 6. g. In phase 7. h. In phase 8.

i. The coils do not accelerate to the left in any of the phases.

Key idea: Acceleration is from low to high tension (high to low compression). At 7, tension is most unbalanced to the left. (Choices f and h receive 3 points.)

16. Another spring has pulses traveling through it with less distance between them, as illustrated below. Identify if each of the combinations of changes listed below could result in these shorter waves. (Circle "True" if those changes could result in the shorter waves below; "False" if not.) Each answer is worth 1 point.



True False a. Same period, faster wave speed.

True False b. Shorter period, same wave speed.

True False c. Same period, slower wave speed.

True False d. Longer period, same wave speed.

Key idea: $u = \lambda/T$. Here we see a decreased $\lambda = uT$. If u stays the same, T must decrease. If T stays the same, u must decrease.

Scenario 5. Prince Rupert drops

"Prince Rupert drops" are made by heating the end of a glass rod with a torch, and allowing the globs of molten glass to fall into water. (The cooled drops have very interesting mechanical properties with which we won't concern ourselves in this course.)

17. After the glass drops have been in the water for a long time, how will the final temperatures of the glass drops and the water compare?

a. The glass drops' final temperature will be higher than the water's final temperature.

b. The glass drops' final temperature will be lower than the water's final temperature.

c. The glass and the water will come to the same final temperature.

d. There is insufficient information to compare the final temperatures.

Key idea: heat flows from high to low temperature. The heat flow only stops when the temperatures are equal. (This maximizes entropy.)

18. The system is perfectly insulated so that no heat centers the system from the surroundings and no heat enters the surroundings from the system. What is the relationship between ΔT_w, the change in temperature of the water, and ΔT_g, the change in temperature of the glass drops? In the formulas below, c_w is the specific heat of water, c_g is the specific heat of glass, m_w is the mass of water, and m_g is the mass of glass.

a. $\frac{\Delta T_w}{\Delta T_g} = -\frac{c_w m_w}{c_g m_g}$

b. $\frac{\Delta T_w}{\Delta T_g} = -\frac{c_w m_g}{c_g m_w}$

c. $\frac{\Delta T_w}{\Delta T_g} = -\frac{c_g m_w}{c_w m_g}$

d. $\frac{\Delta T_w}{\Delta T_g} = -\frac{c_g m_g}{c_w m_w}$

e. $\frac{\Delta T_w}{\Delta T_g} = -\frac{c_g}{c_w}$

f. $\frac{\Delta T_w}{\Delta T_g} = -\frac{c_w}{c_g}$

g. $\frac{\Delta T_w}{\Delta T_g} = -\frac{m_g}{m_w}$

h. $\frac{\Delta T_w}{\Delta T_g} = -\frac{m_w}{m_g}$

Key idea: $\Delta T = q/(cm)$. The glass and water have opposite heat inputs:

$\Delta T_g = -q/(c_g m_g)$ and

$\Delta T_w = q/(c_w m_w)$, so

$\Delta T_w/\Delta T_g = -(c_g m_g)/(c_w m_w)$.

19. We know that when the hot glass contacts the cool water, the glass's temperature decreases and the water's temperature increases. We also know that the process will not go in reverse: if lumps of glass sit in water, thermal energy will *not* spontaneously flow into the glass from the water, heating it until it melts. If this reverse process *did* occur, however, how would the total entropy of the universe change as a result?

a. The total entropy of the universe would increase in the reverse process.

b. The total entropy of the universe would decrease in the reverse process.

c. The reverse process would have no effect on the total entropy of the universe.

Key idea: Actual processes increase entropy. The forward process occurs because it increases entropy. The reverse process would decrease entropy.

20. Some of the liquid water is allowed to evaporate, and the resulting water vapor remains in the insulated container with the remaining liquid water and the glass drops. How will the final temperature of the liquid water in this case compare to what its final temperature would be if none of it evaporated?

a. The liquid water would have a higher final temperature if some were to evaporate.

b. The final temperature of the liquid water would be the same in both cases.

c. The liquid water would have a lower final temperature if some were to evaporate.

Key idea: Evaporation is a cooling process. Vapor has a higher *PE* than liquid. Evaporating molecules convert *KE* to *PE*.

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. 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. What is the diver's *acceleration* when the board is deflected downward 12.5 cm? (Report both magnitude and direction.)

Key ideas: $F = -kx$ and $\Sigma F = ma$.

While the diver is on the board, the two forces acting on her are gravity (downward with magnitude mg) and the force of the springy diving board (upward with magnitude $-kx$.) So the net force is $\Sigma F = -mg - kx$ and her acceleration is $a = -(mg + kx)/m = -kx/m - g$.

When $x = x_1 = -5.0$ cm, $a = 0$. Thus $kx_1 = -mg$. When x is more downward than x_1, the upward spring force $-kx$ will be proportionally greater. At $x_2 = -12.5$ cm, the board's flex is 2.5 times that of x_1, so the force it applies is $2.5mg$.

The net force is thus $\Sigma F = -mg + 2.5mg = 1.5mg$ upward. The acceleration is then $1.5g$ upward.

You can also explicitly find k and substitute it into the force expression at x_2:

$$kx_1 = -mg$$
$$k = -mg/x_1$$

Then

$a = -kx_2/m - g = -(-mg/x_1)x_2/m - g = g(x_2/x_1) - g = g\,(x_2-x_1)/x_1$

So, $a = g(12.5 - 5.0)\text{cm}/(5.0\ \text{cm}) = 1.5g$ upward.

22. In Scenario 3, “Rotating Space Station,” *why* would occupants of the rotating space station feel weight? What force or forces actually act on them, and what objects exert these forces? Answer these questions from the perspective of a frame of reference that does *not* rotate.

Key idea: Uniform circular motion involves acceleration toward the center of the circular path.

The force pushing the occupants toward the center is the “support” from the floor of the station, which is its rim. That is the only force. it is unbalanced: there is no other force acting on the occupants. They all are accelerating toward the center of the station.

Extra credit

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

“I see straight shootin’, and side with Newton
While paths are curved in your rotating reference frame,”

I was referring to behavior of objects moving in rotating reference frames. Give a specific example of this behavior.

Key idea: This couplet describes the Coriolis force.

Examples include the curved paths you saw the balls take when you played catch on the rotating carousel; the rotation of a Foucault pendulum; the spiraling of cyclonic storms; and the veering of ballistic trajectories on Earth.