Physics 107: Ideas of Modern Physics

Exam 1
Sep. 28, 2005

Name______________________________________________________

ID #_________________________               Section #______________

On the Scantron sheet,
1) Fill in your name
2) Fill in your student ID # (not your social security #)
3) Fill in your section # (under ABC of special codes)

Fundamental constants:  
g= accel. of gravity on Earth = 10 m/s^2  
G= gravitational constant = 6.7x10^{-11} N·m^2/kg^2
1. A

2. The gravitational force exerted by the earth on 1 kg apple at the surface is
   
a. 0 N
   b. 0.5 N
   c. 1 N
   d. 5 N
   e. 10 N

   \[ \text{The gravitational force is} \]
   \[ mg = 1kg \times 10m/s^2 = 10 \text{ kg-m/s}^2 = 10N \]

3. In the graph to the right, which of the following is **negative**
   
   a. velocity but not acceleration
   b. acceleration but not velocity
   c. both velocity and acceleration
   d. neither velocity nor acceleration
   e. not enough information to answer the question.

   \[ The \ distance \ decreases \ with \ time \ so \ the \ velocity \ is \ negative. \ The \ velocity \ gets \ closer \ to \ zero \ as \ time \ increases, \ so \ the \ velocity \ is \ increasing. \ This \ means \ that \ the \ acceleration \ is \ positive \]

4. A Ferrari F50 can accelerate from 0 to 2.7 m/s (60 mph) in 3.8 sec. What is the average acceleration in terms of \( g \), the acceleration of gravity?
   
   a. 0.05 g
   b. 0.07 g
   c. 0.11 g
   d. 0.13 g
   e. 0.21 g

   \[ \text{Average acceleration} = \frac{2.7 \text{ m/s}}{3.8 \text{ s}} = 0.71 \text{ m/s}^2. \text{ Since the acceleration of gravity is} 10 \text{ m/s}^2, \text{ the acceleration is} 0.07g. \]

5. The inertia of an object best describes its
   
   a. speed
   b. velocity
   c. acceleration
   d. momentum
   e. mass

   \[ \text{Inertia is the property of an object by which it resists changes in its motion. That is, it resists being accelerated or decelerated to a different velocity. This is the mass of an object} (F=ma) \]
6. A 1 kg ball moving at 2 m/s on a table collides with a stationary 2 kg ball. After the collision, the 2 kg ball is moving to the right on the table at 1.5 m/s. After the collision, the 1 kg ball is

a. moving to the right at constant speed  
\[ \text{Before: } 1 \rightarrow 2 \text{ m/s} \]

b. moving to the left at constant speed  
\[ ? \rightarrow 2 \rightarrow 1.5 \text{ m/s} \]

c. accelerating to the right

d. accelerating to the left

e. stationary

Momentum conservation says that the total momentum before the collision is equal to the total momentum after the collision.

Before the collision, total momentum = \((1 \text{ kg}) \times (2 \text{ m/s}) + (2 \text{ kg}) \times (0 \text{ m/s}) = 2 \text{ kg-m/s} \)

After the collision, total momentum = \((1 \text{ kg}) \times (? \text{ m/s}) + (2 \text{ kg}) \times (1.5 \text{ m/s}) = 2 \text{ kg-m/s} \)

This says that the velocity must be negative (-1 m/s, i.e. opposite to the direction ball #2 is moving) to conserve momentum.

7. An 60 kg scientist has developed a jet pack with 1000 Newtons of thrust. If she uses it on earth, what is her acceleration upward?

a. 0 m/s²  
b. 3.2 m/s²  
c. 6.7 m/s²  
d. 10 m/s²  
e. 17 m/s²

Part of the jetpack thrust cancels the force of gravity, the rest will accelerate the scientist upward. The force of gravity on the scientist is \( mg = 60 \text{ kg} \times 10 \text{ m/s}² = 600 \text{ N} \). The remaining 1000N-600N=400N accelerates the scientist.

The acceleration is \( a = \frac{F}{m} = \frac{400 \text{ N}}{60 \text{ kg}} = 6.7 \text{ m/s}² \)

8. Conservation of momentum says that

a. The momentum of an object can never change.
b. The momentum of an object can never decrease.
c. Momentum can be transferred between objects, but does not disappear.
d. Momentum cannot be negative.
e. All of the above.
9. The figure at right shows an object in circular motion moving at constant speed. Which vector best describes the acceleration of the object at that point in its orbit?

- a. A
- b. B
- c. C
- d. D
- e. acceleration is zero

*The speed is constant, but the velocity continually changes direction. So the object is accelerating. The acceleration is directed toward the center.*

10. I lift a 5 kg bowling ball from the floor to above my head at a constant speed of 0.5 m/s. The instantaneous net force on the ball at any point during the motion is

- a. 0 N
- b. 2.5 N
- c. 10 N
- d. 12 N
- e. 50 N

*Since the ball is not accelerating (it moves at constant speed), the net force on the ball must be zero.*

11. In outer space there are two stationary rocks with different masses, related by \(M_{\text{big}} = 2M_{\text{small}}\). The same 10 Newton thrust is applied to each for 2 seconds and then shut off. The velocities when the thrust is turned off are related as:

- a. \(v_{\text{big}} = 2v_{\text{small}}\)
- b. \(v_{\text{small}} = 2v_{\text{big}}\)
- c. \(v_{\text{big}} = 4v_{\text{small}}\)
- d. \(v_{\text{small}} = 4v_{\text{big}}\)
- e. \(v_{\text{big}} = v_{\text{small}}\)

An applied force changes the momentum of an object. The momentum=mass\times velocity of each object was changed by the same amount. So the velocity of the small rock changes twice as much as the velocity of the big rock.
12. The acceleration of gravity on the moon is 6 times smaller than on earth. Identical apples are dropped from the same height on the Earth and the moon. Which of the following approximate answers best describes the velocity of the apple as it hits the moon’s surface?

a. The same as the apple on Earth.
b. 3 times less than the apple on Earth.
**c. 2.5 times less than the apple on Earth.**
d. 6 times less than the apple on Earth.
e. 36 times less than the apple on Earth.

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The potential energy of the rock (=mgh) is converted into kinetic energy = (1/2)mv^2 during the fall. The velocity when the rock has fallen a distance h is then v^2=2mgh. Since m and h are the same, and g is smaller on the moon by a factor of 6, v^2 is smaller by a factor of 6. v is then smaller by a factor 2.4495~2.5.

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13. A racer floors his dragster from a stop at time=0, so that a constant force is applied to it for the entire race. Which of the following statements is true?

a. Its speed is constant after a short time.
b. Its speed increases proportional to time.
**c. Its speed increases proportional to time squared.**
d. Its speed increases proportional to the square root of time.
e. Its speed varies chaotically.

Constant force means constant acceleration. So the velocity increases by the same amount every second. Since the velocity is originally zero, it is then proportional to time.

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14. An object is moving to the right in a straight line at a constant speed. Which one of the following statements best describes forces acting on it?

a. No forces are acting on the object.
b. A larger number of forces are acting on the object to the right than to the left.
c. The net force acting on the object is to the right.
d. Just one force is acting on the object.
**e. No net force is acting on the object.**

Since the object is moving at constant speed, its acceleration is zero. If the acceleration is zero, then there is no net force acting on the object (F=ma).
15. Which of the following is not a system that can show chaotic behavior.

   a. Dripping water faucet.
   b. The weather.
   c. A driven pendulum.
   d. A fire hose.
   e. They can all show chaotic behavior.

16. Hoover dam produces electrical power from water dropping a vertical distance of 200 meters. This water flows at a rate 20,000 gal/sec (=750,000 kg/s). Assuming that energy of the falling water is converted entirely to electrical power, what is the power output of the dam?

   a. 7.5 million watts
   b. 40 million
   c. 750 million watts
   d. 1500 million watts
   e. 3000 million watts

The potential energy of the water is converted into kinetic energy during the fall, which drives the turbines to produce electrical power. The rate is (750,000 kg/s)×(10 m/s²)(200 m)=1,500,000,000 Watts = 1500 million watts (Hoover dam is actually rated at 2000 megawatts)

17. In class, a brave physics professor did not flinch when a bowling ball pendulum swung to within millimeters of his nose, because it swung back exactly to its release position. This illustrated the

   a. conservation of energy
   b. principle of superposition
   c. conservation of momentum
   d. principle of inertia
   e. stupidity of the professor
18. In outer space, an astronaut applies a 5 Newton force to a 2 kg object for 5 meters. How much work did the astronaut do?

- a. 10 Joules
- **b. 25 Joules**
- c. 50 Joules
- d. 100 Joules
- e. 250 Joules

\[
\text{Work} = \text{Force} \times \text{Distance} = (5 \text{ N}) \times (5 \text{ meters}) = 25 \text{ Joules}
\]

19. Two people use ropes to pull identical sofas up to their neighboring 5th floor apartments. One pulls up the sofa gradually in 100 seconds. The other pulls theirs up quickly in 20 seconds. The power output and the work done of the quick puller compares to that of the slow puller as

- a. Work same, Power same
- **b. Work same, Power greater**
- c. Work greater, Power same
- d. Work greater, Power greater
- e. none of the above.

Both do the same work, because the work done is equal to the change in potential energy. But the quick puller does that work in a shorter amount of time, so the power output is larger.

20. Two stones of different masses are released from rest at the same height, but one of them one second after the other. Which of the following is true?

- a. The difference in their speeds are constant.
- **b. They hit the ground one second apart.**
- c. There is a constant distance between them.
- d. The difference in their accelerations increase as they fall.
- e. All of the above.

The falling times of the stones are the same. Since they are released one second apart, they will hit one second apart. Their accelerations are both g. Their spatial separation increases as they fall. Also, as Seth pointed out to me, since they both accelerate at g, the speeds both increase linearly in time as \((\text{accel}) \times \text{(time)}\), and so the difference is their speeds is also constant! I didn’t notice this when I made up the exam.

21. Two people standing still on roller blades start throwing a ball back and forth. After a couple of throws, they are (ignoring friction)

- a. standing still at their initial locations.
- b. standing still farther from each other.
- c. standing still closer together.
- d. moving toward each other.
- **e. moving away from each other.**

Both when the roller blader catches or throws the ball, the force exerted by the ball on the roller blader is in the same direction - directed away from the other roller blader. The roller blader is accelerated for the duration of the force, so that he ends up with a net velocity away from the other roller blader.