Last Name:______________First Name_________________Network-ID____________
Discussion Section:________Discussion TA Name:_____________________________

Instructions—
Turn off your cell phone and put it away.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil; do **not** use a mechanical pencil or a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner.

2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.

3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter “I” and the numeral “1” and for the letter “O” and the numeral “0”. **Do not** mark the hyphen circle at the bottom of any of these columns.

4. **This Exam Booklet is Version A**. Mark the **A** circle in the **TEST FORM** box at the bottom of the front side of your answer sheet.

5. Stop **now** and double-check that you have bubbled-in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.

6. Do **not** write in or mark any of the circles in the STUDENT NUMBER or SECTION boxes.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. (You need not fill in the COURSE or INSTRUCTOR lines.)

8. Sign **(DO NOT PRINT)** your name on the **STUDENT SIGNATURE** *line*.

Before starting work, check to make sure that your test booklet is complete. You should have 13 ***numbered pages*** *plus two Formula Sheets.*

*Academic Integrity—***Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

Exam Grading Policy—
The exam is worth a total of 125 points, and is composed of three types of questions:

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.
(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer, you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.
(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

TF: *true-false questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is 9.8 $\mathrm{m/s^2}$ *downward and ignore any effects due to air resistance.*

The following 2 questions concern the same physical situation:

A physics 101 student weighs 600N on Earth. She travels in her spaceship to mysterious planet X which has a radius r_X that is twice the radius of Earth, $r_X = 2r_E$. On the surface of planet X, she finds that she weighs 300N.

1. Relative to Earth's mass, m_E, what is the mass of planet X?

a. $0.25m_E$
b. $0.5m_E$
c. $1.0m_E$
d. $2.0m_E$
e. $4.0m_E$

```
Let M be her mass.  600 = G M m_E/r_E^2, and
300 = G Mm_X/r_X^2.  Taking the ratio, we get
2 = (m_E/m_X)(r_X/r_E)^2 = 4(m_E/m_X).  That is,
m_X = 2 m_E.
```

2. How does the acceleration due to gravity on planet X, g_X, compare to the acceleration due to gravity on Earth, g_E?

a. $g_X > g_E$
b. $g_X = g_E$
c. $g_X < g_E$

```
Mg_E = 600, Mg_X = 300, so g_X = g_E/2.
```

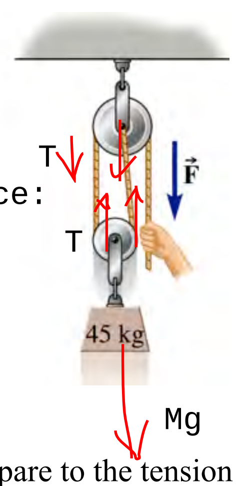
The following 2 questions concern the same physical situation:

Ralph is using the pulley system shown in the picture to hold a 45kg mass stationary.

3. What is the force exerted by the ceiling?

a. 222 N
b. 442 N
c. 662 N
d. 882 N
e. 1100 N

```
T = Mg/2 = F, so
3F = 3Mg/2 is the total force:
661.5 N.
```



4. How does the force provided by Ralph's hand, f_H, compare to the tension T in the rope?

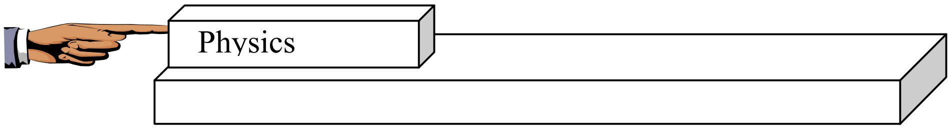
a. $f_H = T/3$
b. $f_H = T$
c. $f_H = 3T$

```
As noted above T = F = f_H.
```

This is due to the convention of the ideal pulley and the ideal rope that has no mass.

The following 2 questions concern the same physical situation:

A physics book of mass 2 kg is sitting atop a table with coefficient of static friction μ_s = 0.4 and coefficient of kinetic friction μ_k = 0.3. A person is pushing the book as shown in the figure.



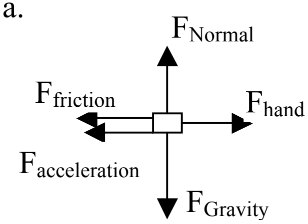
5. If the book is at rest, how hard can the person push on the book before it will start moving?

a. 2.0 N
b. 4.1 N
c. 5.7 N
d. 6.6 N
e. 7.8 N

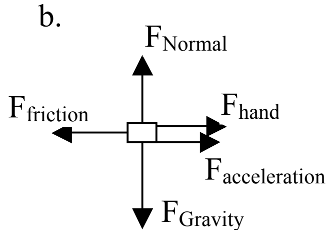
```
Max statistic friction is \mu_s N = \mu_s Mg
= 7.84 N.
```

6. If the book has an acceleration of 1 m/s^2, which of the following is a valid free body diagram for this situation? (Note: Ignore the length of the arrows; the direction is all that counts.)

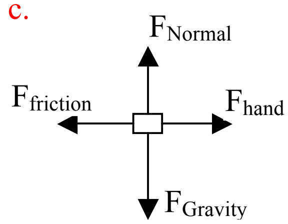
a.



b.

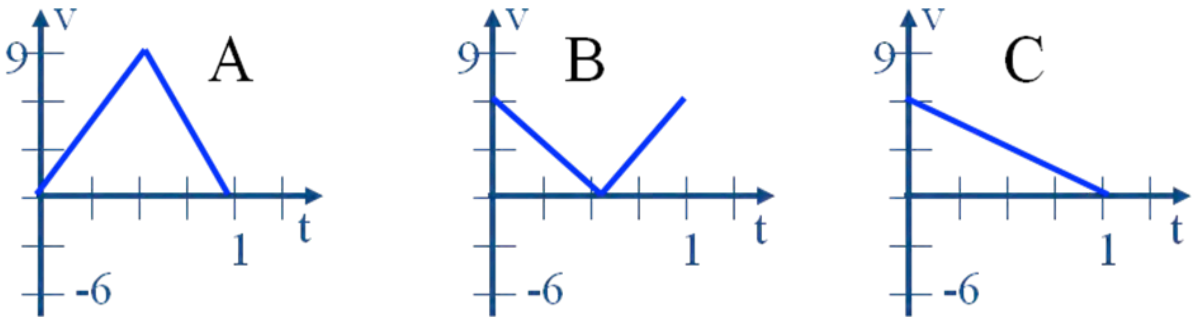


c.

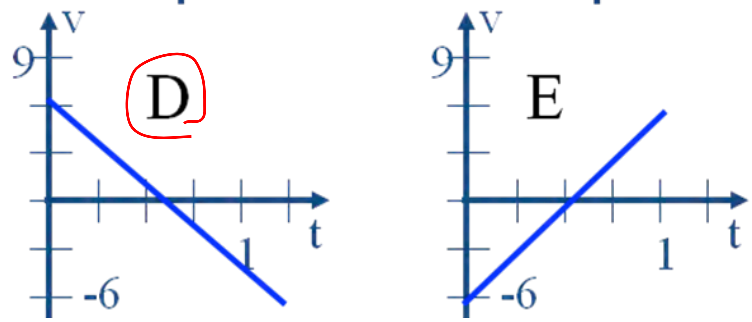



```
Notice that F_{acceleration} is the net force.
```

7. A ball is tossed directly upward to some height above the ground and falls back down. Positive direction is upward. Which of the following is the correct description of the ball's velocity versus time? D

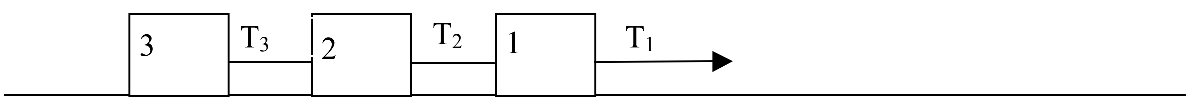


v = v_0 - gt



The following 2 questions concern the same physical situation:

Three boxes of equal mass, m, are connected to one another by strings as shown in the figure. They are pulled across a frictionless surface by tension T_1.



8. Which of the three boxes has the largest net force acting on it?

a. box 1
b. box 2
c. box 3
d. boxes 1 and 3
e. all three boxes have the same net force acting on them.

All must have the same acceleration a, so ma is the net force on each block.

9. Which of the following is a valid expression for the acceleration of box 1?

a. $a = T_1/m$
b. $a = T_1/(2m)$
c. $a = T_1/(3m)$
d. $a = 2T_1/m$
e. $a = 3T_1/m$

The equation of motion reads 3ma = T_1.

The following 2 questions concern the same physical situation:

Professor Pitts pushes on a cart of mass 50 kg with a horizontal force F_{push}. There is no friction. The cart has an acceleration of 5 m/s^2.

10. Which of the following statements is true?

a. By Newton's third law, the cart applies an equal and opposite force of magnitude F_{push} on Professor Pitts.
b. The cart applies an opposite force on Professor Pitts, but it is smaller in magnitude than F_{push} because of the acceleration force.
c. The force the cart applies on Professor Pitts is responsible for the acceleration of the cart.
d. The cart applies no force on Professor Pitts, because it is not pushing back on him.
e. The cart applies an opposite force on Professor Pitts and it is larger in magnitude than F_{push}.

```
b, d and e violate the third law. c is nonsense.
```

11. Starting from rest, the cart is observed to be travelling at a velocity of 5 m/s after 1 s. What is the magnitude of F_{push}?

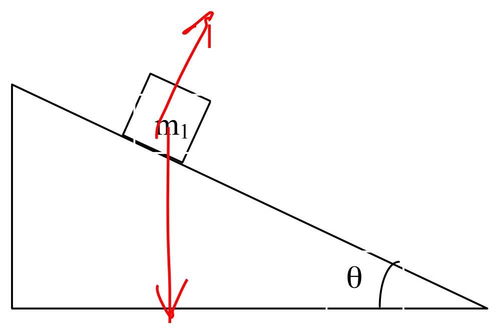
a. 1 N
b. 10 N
c. 100 N
d. 250 N
e. 980 N

```
We must assume that the force is constant.
The acceleration is 5 m/s^2, so F = 5 x 50 = 250 N.
```

This exam continues on the next page.

The following 3 questions concern the same physical situation:

A block of mass m_1 = 5 kg sits atop a frictionless incline which makes and angle θ = 25° as shown in the figure.



12. What is the acceleration of the block?

a. 1.1 m/s^2
b. 2.1 m/s^2
c. 4.1 m/s^2
d. 9.8 m/s^2
e. 11.1 m/s^2

```
The force parallel to the surface is responsible for
the acceleration.  Thus,
m_1 a = m_1 g sin \theta, or
a = g sin(25deg) = 4.14 m/s^2.
```

13. The normal force provided by the incline on mass m_1 and the weight of mass m_1 have the same magnitude.

a. TRUE
b. FALSE

```
The normal force N = m_1 g cos(25deg) \not equal
to m_1g.
```

14. A second block of mass m_2 = 10 kg is put on the incline next to mass m_1 and the two masses are released at the same moment. Which mass wins the race to the bottom of the incline?

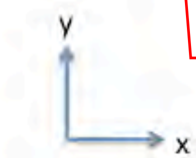
a. m_1 wins
b. m_2 wins
c. it's a tie, the two masses arrive at the same time.

```
As you can read from the result
of 12, the mass does not matter.
```

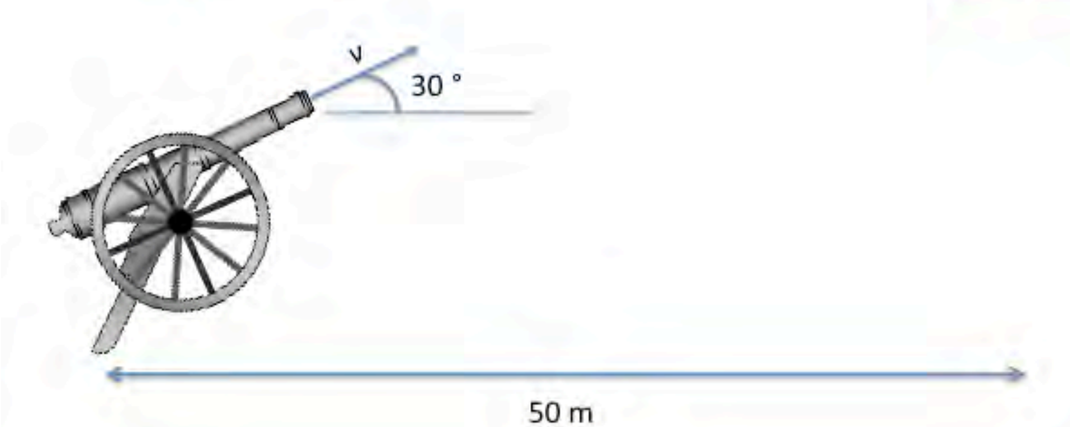
The following 2 questions concern the same physical situation:

Never do this!

You are trying to shoot a monkey hanging on a tree branch using a toy cannon. You aim directly at the monkey and fire the cannon with a speed v and at an angle of 30° relative to the x direction. At the same time, the monkey lets go of the tree branch and fall toward the ground due to gravitational force. We ignore air resistance in this problem. The distance between the cannon and the tree is 50 m in the x direction.



What is the key issue?



15. The cannon ball hits the monkey 2 seconds later after the shot was fired. What was the initial speed of the cannon ball *v*?

a. 28.9 m/s
b. 25.3 m/s
c. 22.1 m/s
d. 20.0 m/s
e. 18.9 m/s

Let (v_x, v_y) be the initial velocity. Then, the x-component (the horizontal component) of the velocity stays constant, so 50/v_x =2 s. That is, v_x = 25 m/s. We know v_x = v\cos(30deg),so v = 25/(\sqrt{3}/2) = 28.86 m/s.

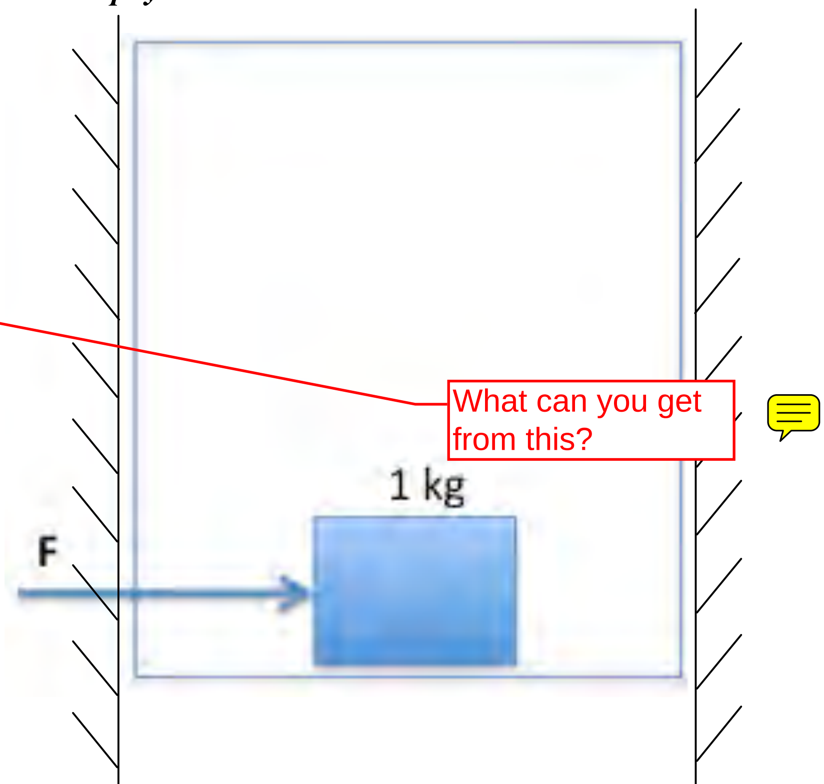
16. What is the distance over which the monkey dropped before it got hit by the cannon ball?

a. 9.8 m
b. 19.6 m
c. 25.4 m

The monkey falls freely with zero initial velocity, so y = (1/2)gt^2 = 4.9 \times 4 = 19.6 m.

The following 2 questions concern the same physical situation:

There is a box with a total mass of 1 kg sitting on the floor of an elevator located in the middle of a vertical shaft. The elevator is free to move upward or downward. When the elevator is at rest, it takes a horizontal force of 4 N to make the box start to slide.



17. The elevator is now moving vertically (without friction). It takes 5 N of horizontal force to make the box start to slide. What can you say about the direction of elevator's motion?

a. It is going up.
b. It is going down.
c. Not enough information is given to determine in which direction the elevator is moving.

The info in the problem tells us that there is an acceleration upward, but this could be realized by accelerating upward motion, or decelerating the downward motion.

18. Now the elevator is accelerating vertically upward by 3 m/s^2. What is the minimum horizontal force on the box required to make the box start to slide?

a. 5.22 N
b. 4.6 N
c. 4 N
d. 3.4 N
e. 2.78 N

If we know the normal force N from the floor acting on the box, the needed minimum horizontal force is given by
F = \mu_s N.
To obtain N, let us set us the equation of motion:
Ma= N - Mg, where M = 1 kg, a = 3 m/s^2, so N = 12.8 N.
We need \mu_s, which must be computed from the data given for a stationary case with N = Mg = 9.8 N. Thus,
\mu_s = 4/9.8 = 0.408. F = 5.22 N.

The following 2 questions concern the same physical situation:

An airplane is flying ***due east relative to the air*** at a speed of 200 m/s.

19. The wind is blowing at 30 m/s toward the east relative to the ground. (With the wind), it takes 1.5 hours to fly from point A to point B, where point B is due east of point A. Under this condition, how long will it take to fly from point B to point A?

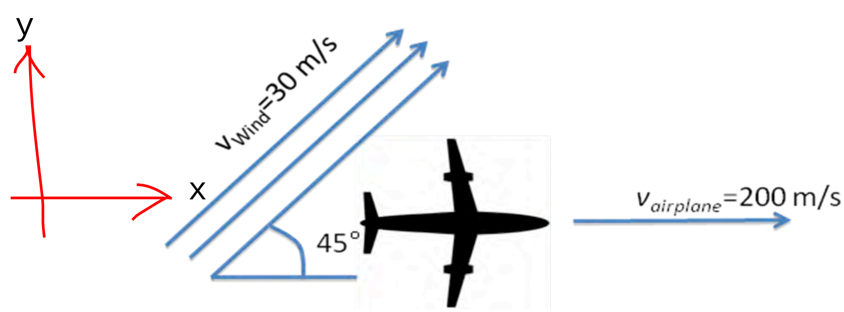
a. 1.3 hour
b. 2.0 hour
c. 1.7 hour
d. 1.85 hour
e. 1.6 hour

Let W = 30 m/s be the wind velocity (this is a 1D problem!), and U = 200 m/s be the speed of the airplane relative to the air. Let the distance between A and B be L.

When the plane flies from A to B with the wind, the speed of the plane relative to the ground is U + W, so L/(200 + 30) = 1.5 (hrs). When the plane flies from B to A against the wind, the speed of the plane relative to the ground is U - W, so we need t = L/(200 - 30). Thus, t/1.5 = 230/170, so t = 2.029 hrs.

20. Now the wind has changed its direction and is blowing towards the northeast direction. (See picture.) The wind has a speed of v_{wind} = 30 m/s (as before). The airplane is flying due east relative to the air at a speed of $v_{airplane}$ = 200 m/s. What is the speed of the airplane relative to the ground?

a. 173 m/s
b. 180 m/s
c. 202 m/s
d. 222 m/s
e. 231 m/s

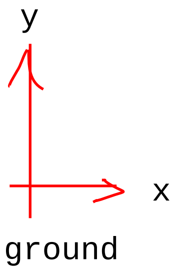


Let us choose the coordinate system as above. Then, the wind velocity relative to the ground is 30(1/\sqrt{2}, 1/\sqrt{2}). Let the velocity of the plane relative to the ground be (V, W). Then,
(V, W) - (21.2, 21.2) = (200,0). Therefore,
(V, W) = (221.2, 21.2). Therefore, the speed is \sqrt{V^2 + W^2} = 222.2 m/s.

This exam continues on the next page.

The following 2 questions concern the same physical situation:

You are flying on an airplane flying due east at a speed of 50 m/s and at an altitude of 1,000 m, and drop an apple of 0.1 kg in mass. Ignore air resistance for this problem. And there is no wind.



21. What is the speed of the apple when it hits the ground?

What is the key point?

a. 149 m/s
b. 86 m/s
c. 140 m/s
d. 50 m/s
e. 177 m/s

Let us choose the coordinate system shown to the left. The initial velocity of the apple is (50, 0) m/s. Let the final velocity be (v_x, v_y). Then, v_x = 50.
For the vertical direction, we use
v_y^2 = 2 g x 1000. Therefore, v_y = 140 m/s. Therefore, |(v_x, v_y)| = \sqrt{50^2 + 140^2} = 148.7 m/s.

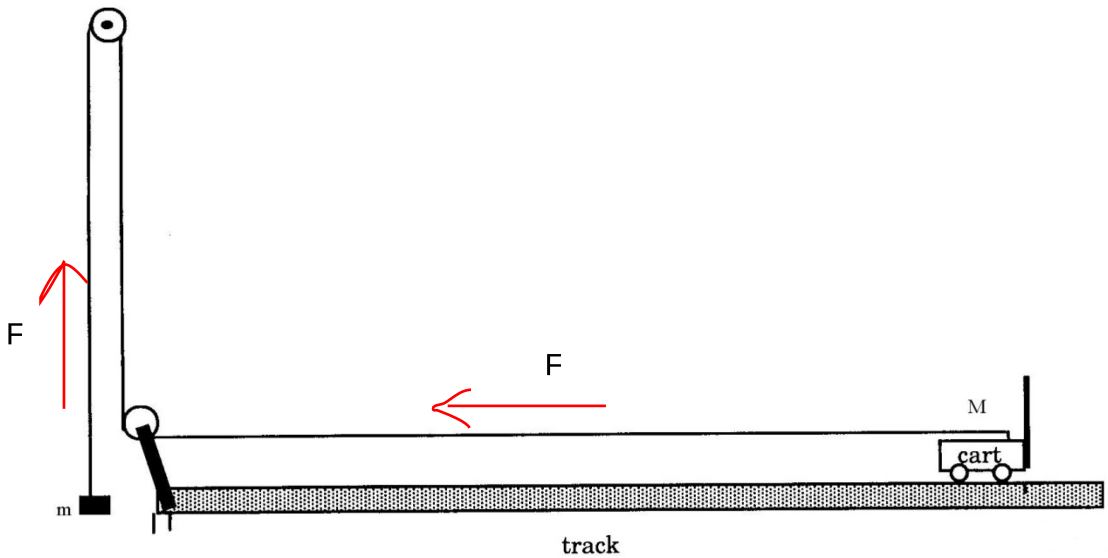
22. How long does it take the apple to reach the ground?

a. 2.9 s
b. 9.8 s
c. 11.8 s
d. 14.3 s
e. 21.7 s

This is a free fall problem with zero initial velocity. Therefore, 1000 = (1/2) gt^2, or t = 14.28 s is the solution.

This exam continues on the next page.

23. The following question refers to the drawing below, which is similar to that used in the labs. The cart and pulley are frictionless. The cart starts to move.



Which is the appropriate relationship between force pulling the cart (F), the mass of the cart (M), the mass of the weight (m), and acceleration of the cart (a)?

a. F = mg = Ma
b. F= (m+M)g = ma
c. F= (m+M)g = Ma
d. F = M= Ma
e. F= mMg/(m+M) = Ma

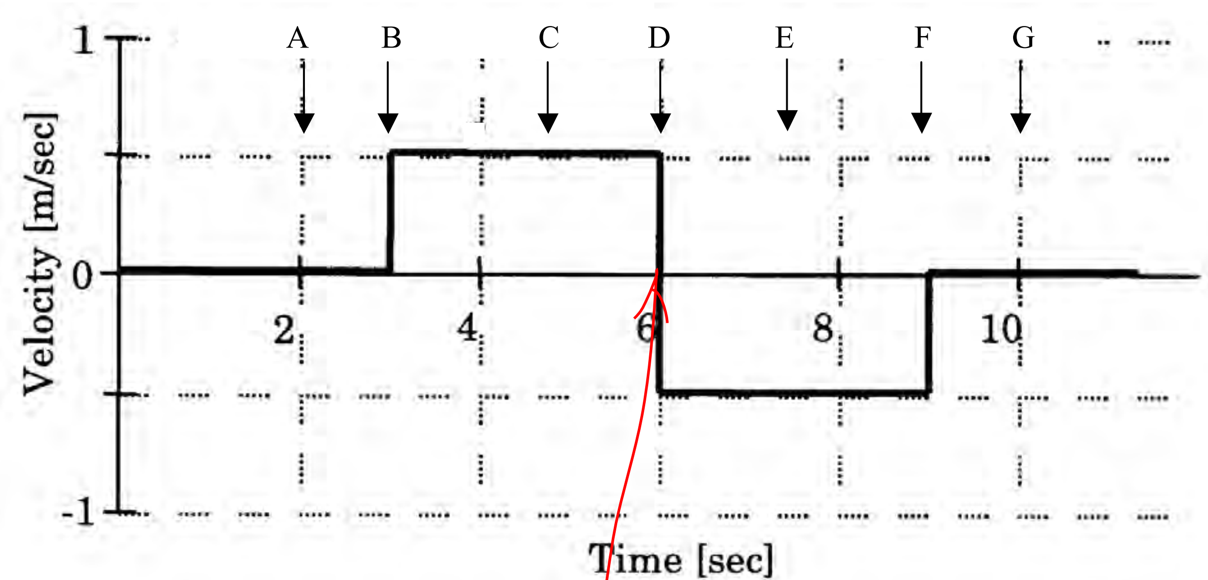
Obviously, F = Ma. (F cannot be equal to ma because of gravity.)
Let us write down the equations of motion for m and M. The magnitude a of the acceleration of m downward and that of M leftward are identical.

$$ma = mg - F,$$
$$Ma = F.$$

Therefore, we immediately obtain $a = mg/(m + M)$. This implies that $F = mMg/(m + M)$.

This exam continues on the next page.

The next three questions refer to this diagram.



The above diagram is a graph of Mary walking on a runway. The detector is at zero position and velocity. The direction away from the detector is positive. Note: in reality, a person may not be able to exactly reproduce this.

24. Where is Mary accelerating?

a. B, D, F
b. A, C, E, G
c. D

```
This happens when the velocity changes.
The slope is the acceleration.  That is why the
above diagram cannot be reproduced exactly.
```

25. What is Mary's velocity at the moment she changes direction?

a. Infinity
b. Negative infinity
c. 0

26. What is the difference in the person's motion comparing points B and D?

a. In B she is moving towards the detector while in D she is moving away from the detector.
b. No difference.
c. In B she is rapidly speeding up, till the point where she is moving away from the detector at constant speed, whereas in D she is rapidly changing direction until she is going at a constant speed walking towards the detector.

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version, and network-ID?