Last Name:______________First Name________________Network-ID___________
Discussion Section:________Discussion TA Name:_____________________________

Instructions—
Turn off your cell phone and put it away.
Keep your calculator on your own desk. Calculators cannot be shared.
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*.

9. **At the end of the exam, turn in your exam booklet and scantron.** You must write your **name on the exam booklet**, and **your seat number** on the **scantron.** Submit both before you leave the room,

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 **110** 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.

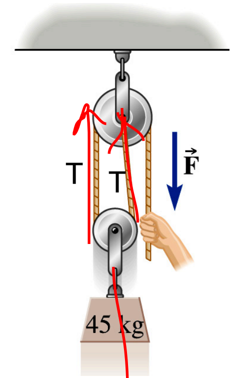
TF: *true-false questions, each worth 2 points.*
No partial credit.

(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 m/s^2 *downward and ignore any effects due to air resistance.*

1. Amelia is using the pulley system shown in the picture to hold a 45 kg mass stationary. The pulleys and the ropes can be considered massless and free to move without friction.

What is the magnitude of the force F provided by Amelia's hand necessary to keep the 45 kg mass stationary?



a. 221 N
b. 442 N
c. 662 N
d. 882 N
e. 1100 N

No acceleration in the vertical direction

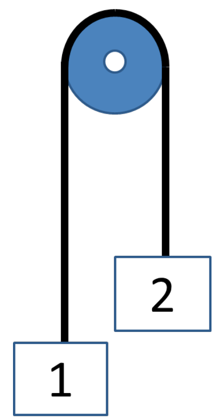
2T = 45g

T = |F| = 22.5g = 220.5 N.

gravity 45g

If you wish, you may assume the mass of the box2 to be m: then the downward acceleration a satisfies Newton's second law: ma = mg.

2. Two boxes are initially stationary and connected by a string over a frictionless pulley, as shown in the figure. At time t = 0, the string just above box 1 is cut so that box 2 drops downward due to gravitational acceleration. How long does it take for box 2 to drop by 1 meter?



a. 0.21 s
b. 0.45 s
c. 0. 85 s
d. 1.25 s
e. 1.56 s

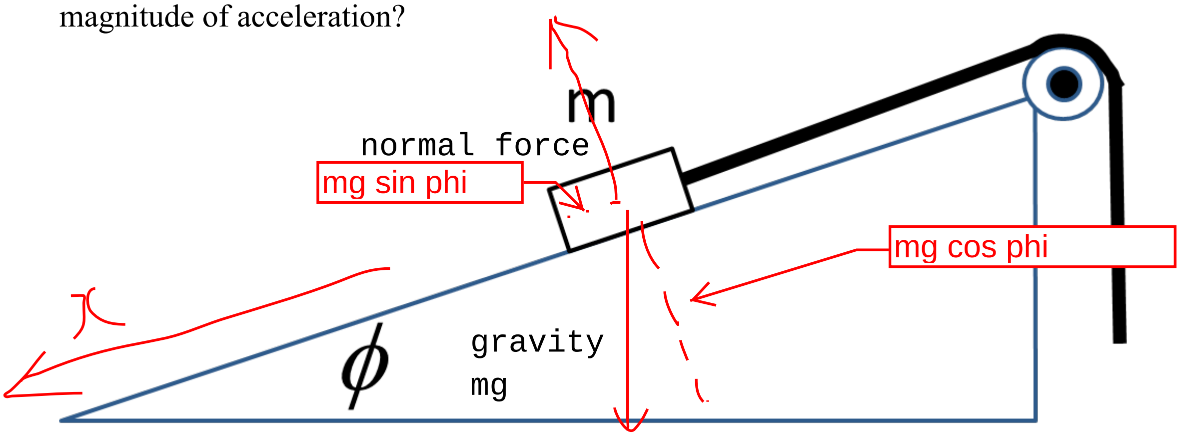
The acceleration of the box 2 downward is g:

1 = (1/2)g t^2

so

t = \sqrt{2/g} = 0.452 s

3. Paul is pulling on the rope to keep the block of mass m from sliding down a frictionless incline of angle ϕ from the horizontal, as shown in the picture. The wheel is frictionless. If the rope is let go, the block will slide down the incline. What would be the magnitude of acceleration?



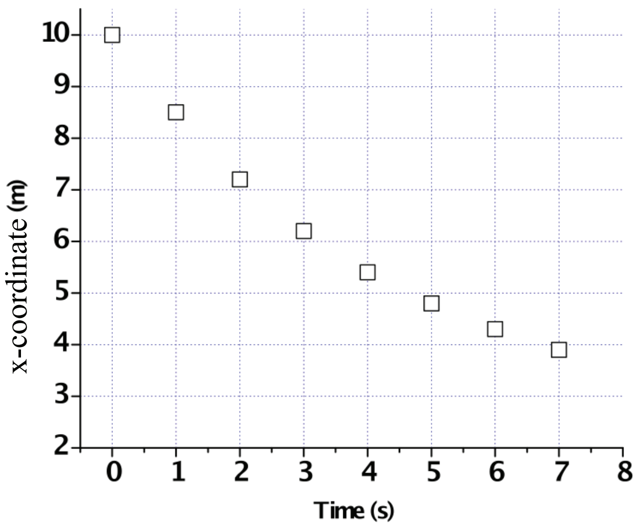
The equation of motion in the x direction reads

ma = mg sin phi.

a. g
b. g cosϕ
c. g sinϕ

The following 2 questions concern the same physical situation:

A cart is moving along the x-coordinate. It's x-coordinate as a function of time is measured every second and is shown below.



4. The average velocity between 0 and 7 seconds is:

a. negative
b. positive

The x-coordinate is decreasing, so the cart must be running against the x axis.

5. The average acceleration between 0 and 7 seconds is:

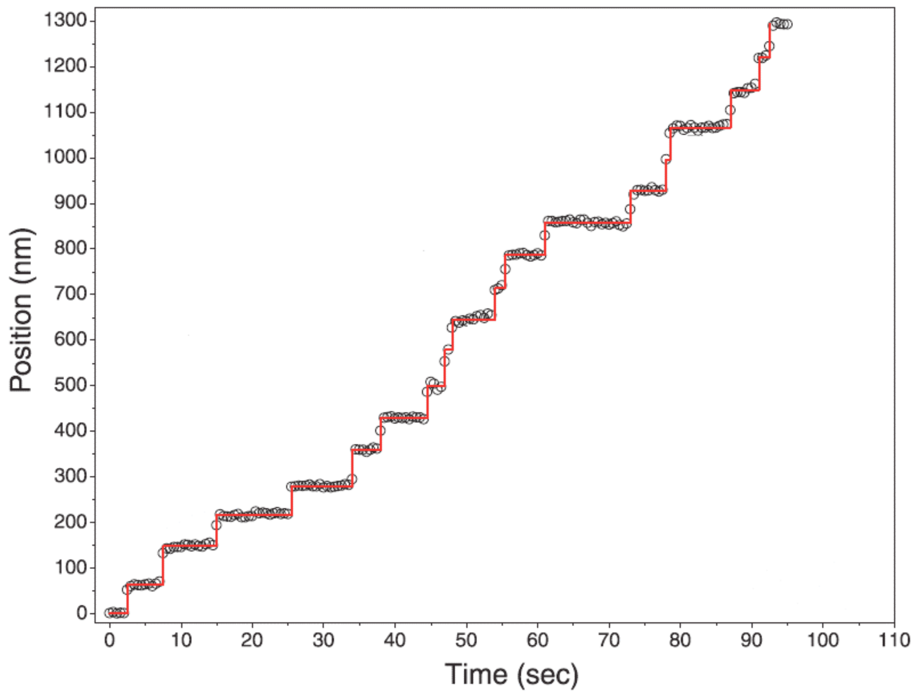
a. negative
b. positive

The negative velocity is decreasing its magnitude, so the acceleration must point in the positive direction.

This exam continues on the next page.

The following 3 questions concern the same physical situation:

A cellular motor protein called myosin V can carry cargos and move on a straight cellular track called actin filament. Researchers in the Physics Department at the University of Illinois measured the position of a single myosin V molecule along an actin filament a function of time as shown below.



6. What is the magnitude of the average velocity between 0 second and 70 second? 1 nm is 10^{-9} m.

a. 1.5 nm/s
b. 2.7 nm/s
c. 5.9 nm/s
d. 7.4 nm/s
e. 12.1 nm/s

Roughly, 850/70 = 12.1 nm/s

7. What is the instantaneous velocity at time 30 s?

a. 0 nm/s
b. – 40 nm/s
c. + 40 nm/s
d. – 400 nm/s
e. + 400 nm/s

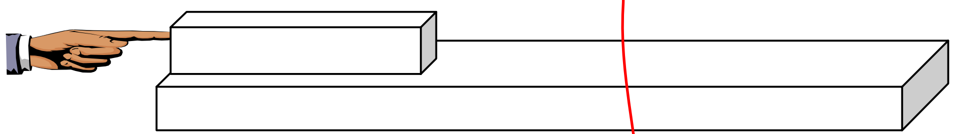
8. Is the molecule experiencing constant acceleration?

a. Yes
b. No

The velocity is not constant!

The following 2 questions concern the same physical situation:

A steel block of mass 3 kg is sitting atop a horizontal table with coefficient of static friction $\mu_s = 0.35$ and coefficient of kinetic friction $\mu_k = 0.25$. Professor Ha is pushing the book as shown in the figure.



9. If the block is at rest, how hard can he push on the block before it will start moving?

a. 2.0 N
b. 4.1 N
c. 5.7 N
d. 7.4 N
e. 10.3 N

```
This asks the max static friction force:
     f_max = \mu_s normal force = \mu_s mg
           = 0.35 x 3 x 9.8 = 10.29 N.
```

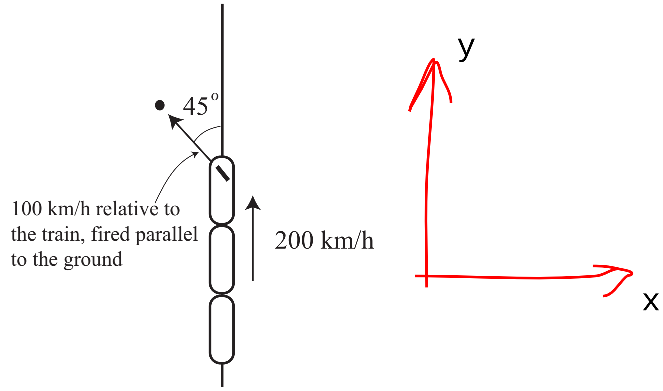
10. Once the book is traveling at 4 m/s, he stops pushing. How much farther does the book move before coming to rest?

a. 3.3 m
b. 2.3 m
c. 1.8 m
d. 1.5 m
e. 1.2 m

```
Now, there is no acceleration except from the kinetic
friction
     \mu_k mg
Therefore, the equation of motion read
     ma = - \mu_k mg   that is, a = - \mu_k g = -2.45 m/s^2
Then, use
     v^2 = v_0^2 + 2 a Delta x
or
     0 = 4^2 - 2 x 2.45 (Delta x).
Hence, (Delta x) = 3.27 m.
```

This exam continues on the next page.

The next problem refers to this diagram:



11. A train is moving to north at the speed of 200 km/hour (see figure). A person on the train shoots a toy cannon and the speed of the projectile leaving the toy cannon is 100 km/hour. If the toy cannon was facing toward 45 degrees to the left relative to the front of the train, what is the speed of the projectile relative to the ground?

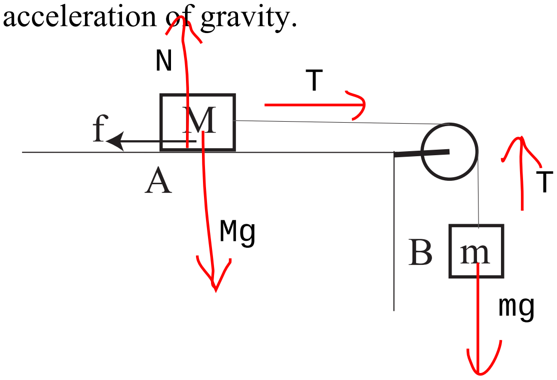
a. 137 km/hr
b. 200 km/hour
c. 223 km/hour
d. 280 km/hour
e. 300 km/hour

```
To answer the question `mechanically,' let us introduce
the coordinate system as shown above.
the train velocity against ground V = (0, 200) km/h
the projectile velocity relative to the train
     v = (-100 sin(45deg), 100 cos(45deg))
          = (-70.7, 70.7) km/h
The velocity of the projectile relative to the ground
     = V + v = (-70.7, 270.7) km/h.
We need the speed: \sqrt{70.7^2 + 270.7^2} = 279.8 km/h.
```

This exam continues on the next page.

The following 2 questions concern the same physical situation:

Consider two Blocks, Block A = mass M, and Block B= mass m, connected with a weightless string through a weightless and frictionless pulley as shown in the figure. Block A is on a table which is horizontal. The coefficient of static friction between Block A and the table is $\mu_s = 3/5$. Let g be the acceleration of gravity.



12. Assume that m= M/3 and that the masses are static. What is the friction force f on Block A from the table?

a. f = Mg/5
b. f = Mg/3
c. f = 3Mg/5
d. f = 2Mg/3
e. f = Mg

Everything is stationary, so T = mg = f.
\mu_s Mg is the MAXIMUM and NOT the ACTUAL friction force.

13. Suppose the mass m of Block B is increased to be a very large value (say, m = 1000M). The blocks start to move and the kinetic friction between Block A and the table is $\mu_k = 1/5$. What is the acceleration of Block A?

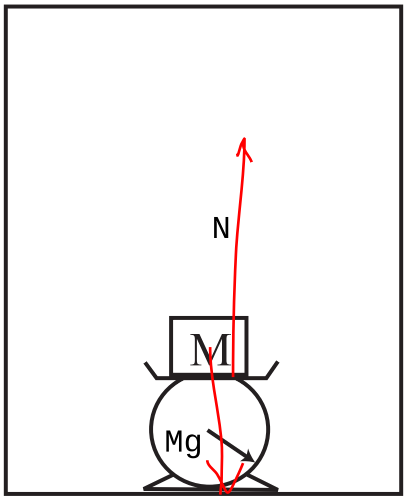
a. the acceleration is much smaller than g.
b. the acceleration is almost g.
c. the acceleration is much larger than g.

Since B is very large, A does not matter. It is just a free fall problem of B.
A is pulled by B, and must move together.

This exam continues on the next page.

The following 3 questions concern the same physical situation:

A box of mass M is sitting on a scale in an elevator. Initially, the elevator is stationary (is not moving relative to the earth). Let g be the acceleration of gravity.




```
The upward acceleration a satisfies
     Ma = N - Mg,
so
     N = M(a + g)
The scale is a device to measure the force
pushing down the tray.  The Action-Reaction
principle tells us that the magnitude of N
is measured by the scale as N/g (the mass
needed on the tray to produce this force
as a gravitational force).
```

14. When the elevator starts to move, the reading of the scale becomes 1.1 times M (that is, 1.1M). What can you say about the motion of the elevator immediately after it starts to move?

a. The elevator is going upward.
b. The elevator is going downward.
c. Not enough information to tell the direction.

```
N = 1.1Mg, so a = g/10 > 0.
This means the velocity is also
positive (upward).
```

15. Let us be quantitative. What is the magnitude of the acceleration "a" of the elevator?

a. $|a| = g/20$
b. $|a| = g/10$
c. $|a| = g/7$
d. $|a| = g/4$
e. $|a| = g/3$

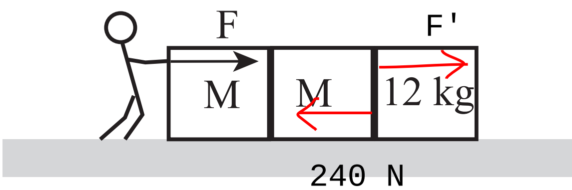
16. Suppose the elevator is initially moving at a constant velocity. Then, you feel the elevator starts to accelerate. You observe that the reading of the scale becomes 1.3 times M (i.e. 1.3M). Which of the following statements is true about the motion of the elevator before the acceleration starts?

```
Now, the velocity after small time dt is
v_0 + a dt. Although a = 0.3 g > 0, we
cannot tell the sign of v_0.
```

a. The elevator is going upward.
b. The elevator is going downward.
c. There is not enough information to tell the direction.

The following 2 questions concern the same physical situation:

There are three boxes on a frictionless horizontal surface as illustrated in the following figure. The masses of the two left boxes are M (identical) and the mass of the rightmost box is 12 kg. A person pushes the leftmost box to the right with a force F. Consequently, all the boxes are accelerated to the right.



17. The rightmost box of mass 12 kg pushes the middle box with a force whose magnitude is 240 N. What is the magnitude of the force the middle box exerts on the rightmost box?

a. 12 kg
b. 24 kg
c. 120 N
d. 240 N
e. 480 N

The action-reaction principle tells that the force F' that is exerted on the 12 kg box by the middle box must be identical to 240 N.

18. The magnitude of F is 540 N. What is the value of M?

a. M = 2.0 kg
b. M = 4.0 kg
c. M = 4.5 kg
d. M = 6.5 kg
e. M = 7.5 kg

Let a be the acceleration of the boxes (all are the same).

$(2M + 12)a = F = 540,$

$2M\,a = 540 - 240 = 300$ (see the figure above)

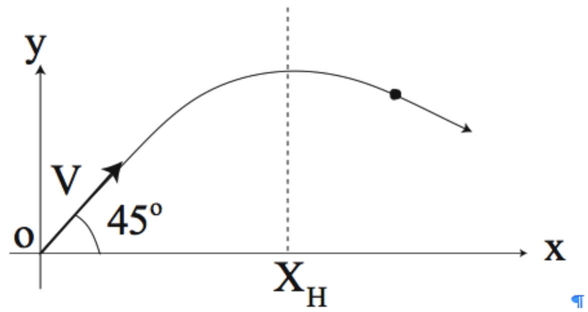
Or if you could answer 17 correctly, $12a = 240$.

In any case, getting a first is the easiest: a = 20 m/s^2.

Therefore, $M = 300/40 = 7.5$ kg.

This exam continues on the next page.

19. A ball of mass m is thrown with initial velocity that makes a 45 degree with the horizontal, with initial speed V. The coordinates of the starting point are (0, 0) as illustrated below. What is the x-coordinate X_H of the highest point the ball can reach? (g is the usual acceleration of gravity near the Earth's surface.)



This is a 2D kinematics question, so x and y directions may be considered separately. Let the initial velocity be (v, u).
y-direction v_y(t) = v - g t.
At the highest point, v_y = 0, so v/g is the time required to reach the highest point.
The x-component stays constant, so X_H = uv/g.
Now, u = v = V/\sqrt{2}, so X_H = V^2/2g.
the

a. $X_H = V^2/2g$
b. $X_H = V^2/g$
c. $X_H = 2V/g$
d. $X_H = V/g$
e. $X_H = V/2g$

20. You are going at constant speed, but not constant direction. Therefore the force acting on you is zero. Is this true or false?

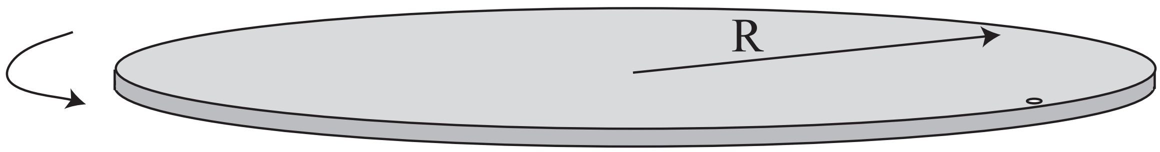
Not constant direction implies not constant velocity. That is, it is an accelerated motion. Any acceleration requires non-zero force.

a. True
b. False

This exam continues on the next page.

The following 2 questions concern the same physical situation:

A small coin of mass M is just inside the edge of a rotating horizontal circular stage of radius R as illustrated below. The coefficient of static friction between the coin and the stage floor is μ_s.

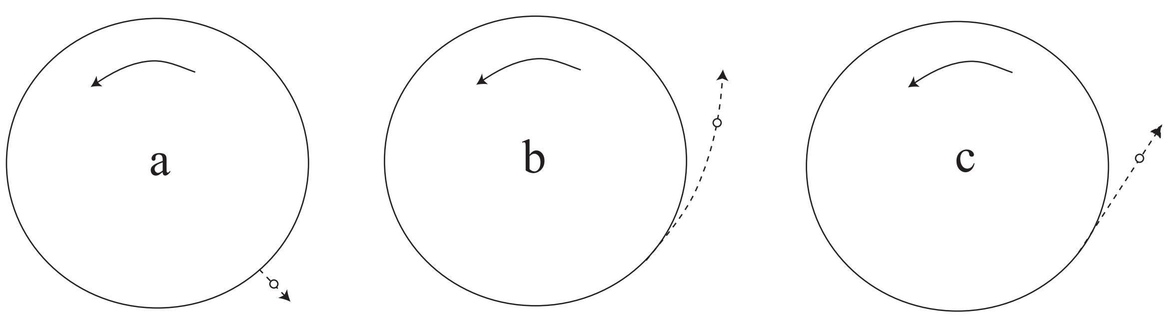


21. What is the angular speed ω of the circular stage beyond which the coin cannot stay on the edge of the stage?

a. $\omega = \sqrt{M\mu_s/R}$
b. $\omega = \sqrt{Mg/R}$
c. $\omega = \sqrt{\mu_s g/MR}$
d. $\omega = \sqrt{\mu_s gR}$
e. $\omega = \sqrt{\mu_s g/R}$

```
Let f be the static friction force.  This provides
the centripetal force needed by the coin to make an
accelerated motion.  The equation of motion in the
radial direction reads
     MR omega^2 = f, which cannot exceed \mu_s Mg
Therefore, the largest omega satisfies
     omega^2 = \mu_s g/R.
```

22. The angular speed exceeds the limit obtained in the preceding problem, and the coin falls off the stage. Choose the right trajectory immediately after the coin leaves the stage from the following top view sketches observed by a stationary person. The choices are "a", "b", or "c".



a. a
b. b
c. c

```
Newton's first law! b is impossible without external forces.
The coin does not have any velocity component radially, so a
is out of question.
```

The following description corresponds to the next 2 questions:

A cart is pushed up a ramp with force F in the presence of friction. At some point the force is suddenly turned off. It reaches some height, then rolls down. (Our sign convention is the positive direction is up.)

23. The velocity is:

impossible

a. $v > 0$ on the way up, zero at the top, and then $v > 0$ on the way down.
b. $v > 0$ on the way up, zero at the top, and then $v < 0$ on the way down.
c. $v < 0$ on the way up, zero at the top, and then $v < 0$ on the way down.

impossible

24. The acceleration is:

a. $a > 0$ on the way up, zero at the top, and then $a > 0$ on the way down.
b. $a > 0$ on the way up, zero at the top, and then $a < 0$ on the way down.
c. $a < 0$ on the way up, zero at the top, and then $a < 0$ on the way down.
d. $a < 0$ at all times but of greater magnitude when going up than coming down.
e. $a < 0$ at all times but of greater magnitude when going down than coming up.

The acceleration is always due to some force external to the cart.
There are two forces: gravitational force F_G and friction f.
The total force that determines the acceleration of the cart is F_G + f:

$$m a = F_G + f.$$

F_G is always negative and constant.
When the cart goes up, f is negative.
When the cart comes down, f is against downward motion, so positive.
However, it cannot stop the cart, so F_G + f < 0.
Thus, always, a < 0, but its magnitude is larger when it goes up.

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