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 11 ***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 123 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.*

The following 3 questions concern related physical situations:

and with zero initial velocity (the problem incomplete)

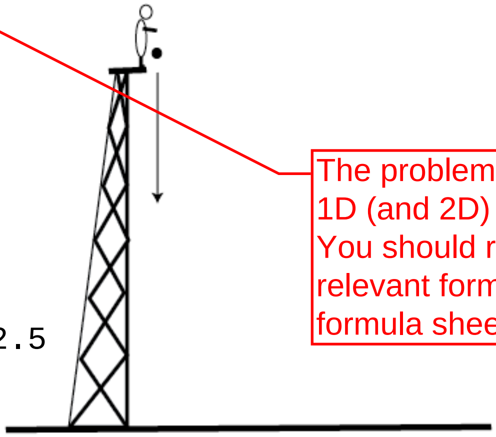
From the top of a tower it takes 3.5 seconds for a ball to fall freely to the ground (see the figure).

This implies 0=h -(1/2)gt^2 or h = 4.9 x 3.5^2 = 60.025 m

1. From the top of the tower, you throw the ball vertically downward to the ground. The ball reaches the ground 2.5 seconds later. What is the initial speed of the ball?

a. 7.4 m/s
b. 9.6 m/s
c. 10.7 m/s
d. 11.8 m/s
e. 12.9 m/s

```
0 = h -v_0 x 2.5
     -(1/2) g 2.5^2,
so
v_0 = (60 - 4.9x2.5^2)/2.5
     = 11.76 m/s
```



The problems are about 1D (and 2D) kinematics. You should recall 3 relevant formulas on the formula sheet.

2. If you perform the same experiment on the planet with the acceleration of gravity being 10.5 m/s^2, how long does it take for the ball to fall freely to the ground (with the initial velocity being zero) and same initial height?

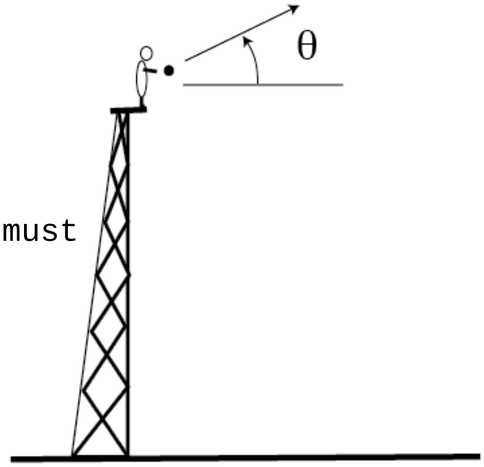
a. 2.5 s
b. 2.7 s
c. 3.2 s
d. 3.4 s
e. 3.6 s

```
h = (1/2) gt^2 implies that t is proportional to 1/\sqrt{g}.
Therefore,
t(on planet) = 3.5 \sqrt{9.8/10.5} = 3.38 s.
```

3. Let us return to the earth. From the top of the tower as above the ball is thrown with an initial velocity that makes an angle θ from the horizontal direction (see Figure). This time it takes 3.6 seconds for the ball to reach the horizontal ground. What can we say about the angle θ ?

a. θ is positive (upward).
b. θ is negative (downward).
c. Not enough information.

Since it takes longer than 3.5 s, there must have been a positive component in the y direction of the initial velocity.



Since we have to discuss the acceleration, use Newton's second law to be quantitative.

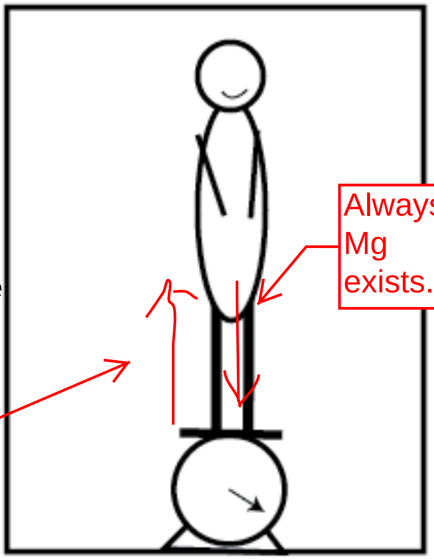
The following 3 questions concern the same physical situation:

A person with body mass 55 kg is standing on the scale on an elevator.

4. The elevator starts to go up. What is the reading of the scale at this moment?

a. The reading of the scale is larger than 55 kg.
b. The reading of the scale is smaller than 55 kg.
c. The reading is 55 kg.

`The effective gravity is g + a, where a is the acceleration upward. Hence, you feel heavier.`



Always Mg exists.

This normal force is measured by the scale; its reading x g is the force in newtons.

5. The reading of the scale is 57 kg. What can you say about the movement of the elevator?

a. The elevator is going up.
b. The elevator is going down.
c. There is not enough information.

`You can tell only the change in velocity; nothing about the velocity itself.`

6. The reading of the scale is 50 kg. What is the (magnitude of) acceleration of the elevator?

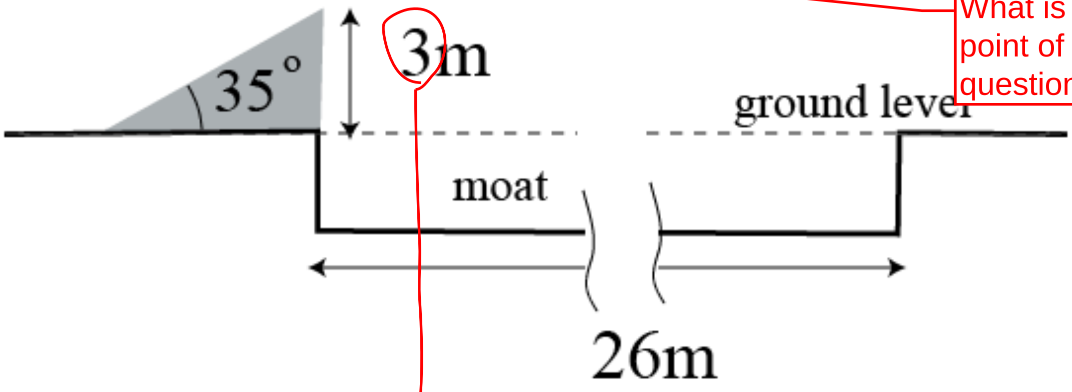
a. 0.23 m/s^2
b. 0.45 m/s^2
c. 0.89 m/s^2
d. 0.98 m/s^2
e. 1.21 m/s^2

```
Look at the `free-body diagram above.' The second law
tells us that the acceleration a of the body obeys
     Ma = N - Mg = 50g - 55g = -5g,
where N is the normal force from the scale.
Therefore,
      a = -5g/55 = -0.89 m/s^2.
```

The following 3 questions concern the same physical situation:

There is a ramp that makes an angle of 35 degrees with the horizontal ground. The top of the ramp is 3m from the ground. There is a moat of width 26m beyond the ramp as illustrated in the figure.

What is the key point of the questions?



7. The speed of the ball reaching the top of the ramp is 5.0 m/s. What is the height of the highest point of the trajectory of the ball from the ground?

a. 3.2 m
b. 3.4 m
c. 3.6 m
d. 3.8 m
e. 4.0 m

v_{0y} = 5 \sin 35, so it takes v_{0y}/g s = 0.2926 s to reach the top. Therefore, (1/2)9.8(0.2926)^2 = 0.42m. Therefore, 3 + 0.42 is the height from the ground. [If you know the conservation law of energy, you can apply it to the y direction: (1/2) Mv_{0y}^2 = Mgh, so h = v_{0y}^2/2g = 0.4196 m.]

8. What is the speed of the ball when it reaches the ground level, if its speed is 5.0 m/s when it leaves the ramp?

a. 5.0 m/s
b. 6.1 m/s
c. 7.3 m/s
d. 8.1 m/s
e. 9.2 m/s

v_y = \sqrt{gh} = 8.16 m,
v_x = v_{0x} = 5 cos 35 = 4.095, so
v = \sqrt{v_x^2 + v_y^2} = 9.154 m/s
[If you know conservation of energy, we can directly go as (1/2) M 5^2 + Mg x 3 = (1/2)M v^2, so
v = \sqrt{25 + 2x3x9.8} = 9.154 m/s !
Isn't it much simpler? Learn more!]

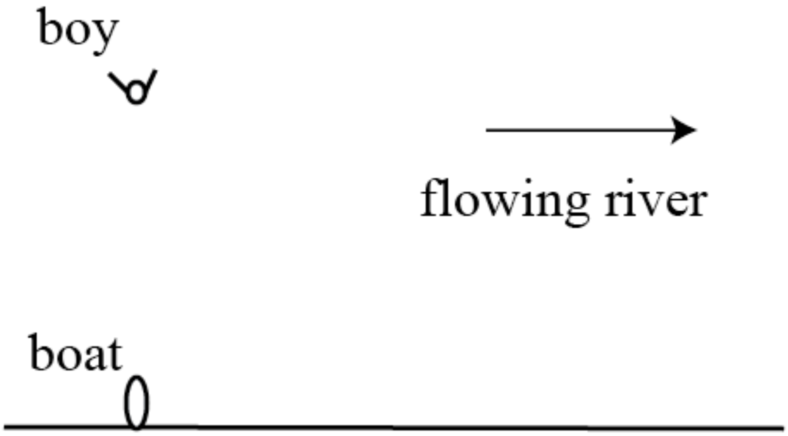
If we consider the motion beyond the highest point, it is a free fall with zero initial velocity.

9. We know the initial speed given above is insufficient for the ball to go beyond the moat. What is the minimum speed when the ball leaves the top of the ramp in order for the ball to go over the moat?

a. 11.2 m/s
b. 12.5 m/s
c. 13.3 m/s
d. 14.9 m/s
e. 15.3 m/s

Let V be the desired speed. 26/V_x = t is the required time to go beyond the moat. Let us compute the y coordinate Y at this time t. If Y is not less than 0, we are happy!
Y = 3 + V_y t -(1/2)gt^2.
We know V_x = V cos 35, V_y = V sin 35, so
Y = 3 + 26 tan 35 - 4.9(26/V cos 35)^2
= 3 + 18.2 - 4936.5/V^2
The `worst case' is Y = 0, so we obtain V^2 from this and
V = \sqrt{4936.5/21.2} = 15.33 m/s.

10. There is a river flowing with speed 7 km/h. A boy is in danger of drowning in the river 1.1 km from the shore. When you set out to rescue him, your boat is the closest to (i.e., 1.1 km from) the boy as illustrated in the figure.



The speed of your boat is 15 km/h relative to water. How long will it take for you to reach the boy?

a. 2.2 min.
b. 3.3 min.
c. 4.4 min.
d. 5.5 min.
e. 6.6 min.

```
Everybody is flowing together, so you can totally
forget about the flow:
     1.1/15 x 60 = 4.4 min.
```

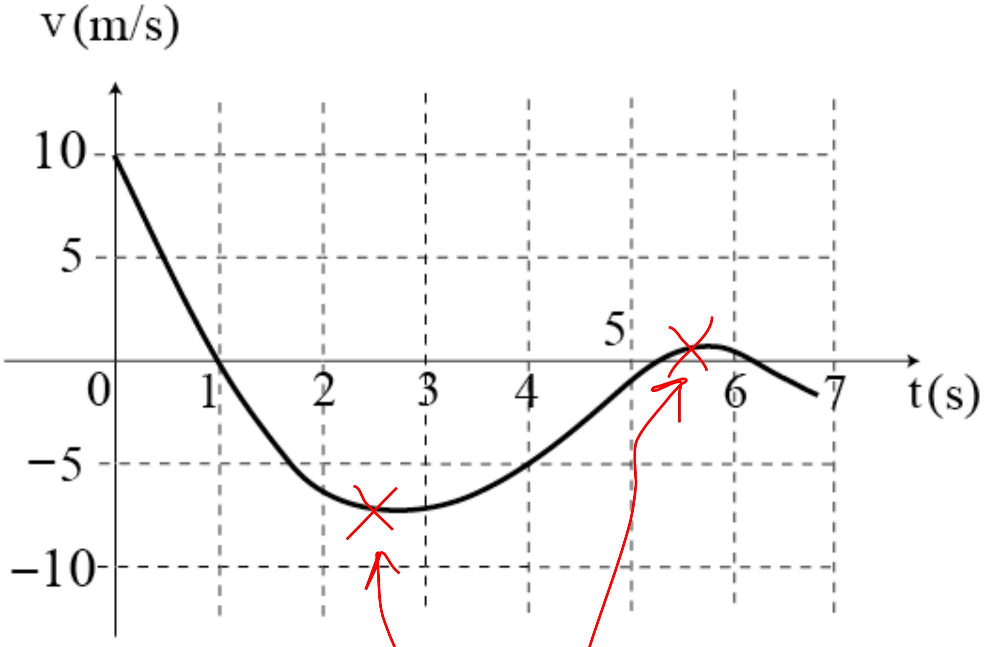
11. Which of the following is closest to the gravitational force between you (mass about 50 kg) and your neighbor (same mass) at a distance of about 1 meter?

a. 10^{-11} N
b. 10^{-9} N
c. 10^{-7} N
d. 10^{-5} N
e. 10^{-3} N

```
F = GmM/r^2 = 6.7 x10^{-11} x 50 x 50/1^2
  = 1.67 x 10^{-7} N.
```

The following 3 questions concern the same physical situation:

Consider a one-dimensional motion of a 1.3 kg mass along the x-coordinate. The velocity v as a function of time t is graphed in the following figure.



12. There are moments when there is no total force acting on the mass. How many such moments are there before t = 7 sec?

a. 1
b. 2
c. 3

No total force implies no acceleration, that is, no velocity change.

13. What is the magnitude of the total force acting on the mass around t = 1/2 sec approximately?

a. 6.5 N
b. 8.5 N
c. 13 N
d. 21 N
e. 26 N

The changing rate of the velocity is -10 m/s, so F = ma = 1.3 x 10.

14. Does the mass return to its starting point before t = 5 sec?

a. The mass does not return to the starting point
b. The mass returns to the starting point once.
c. The mass returns to the starting point twice.

The position coordinate x is obtained by computing the (signed) area `below' the curve.

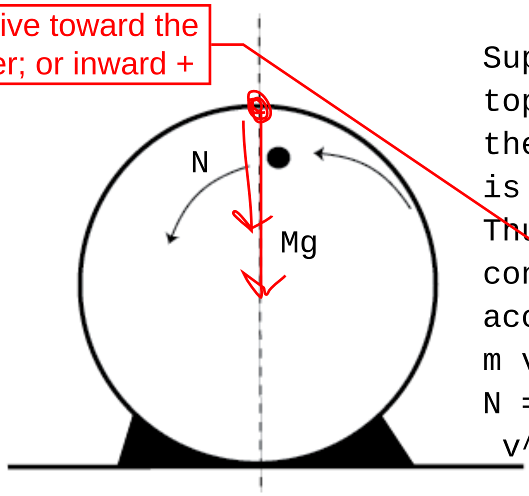
As a function of time x(t) is initially positive, and later it is negative, so there is one time when x(t) = 0.

What is the key point?

The following 2 questions concern the same physical situation:

There is a vertical hoop of radius 1.2 m fixed on the ground. A small block of mass 0.7 kg is sliding along the frictionless inside surface of the hoop. Its speed is not sufficiently large, so the mass cannot run along the hoop to the highest point as illustrate blow.

Positive toward the center; or inward +



Suppose the mass could reach the top. If the normal force N due to the hoop is not positive, the mass is actually not touching the hoop. Thus, N < 0 is the `falling condition.' The centripetal acceleration is given by
m v^2/R = N + Mg, so
N = M(v^2/R -g). That is
v^2 < Rg or v < \sqrt{Rg}.

15. Since the block falls off before reaching the top, its speed when it falls off the hoop cannot be larger than a certain value. Choose the correct answer from the following.

a. The speed cannot exceed 1.2 m/s.
b. The speed can be larger than 1.2 m/s but cannot exceed 2.5 m/s.
c. The speed can be larger than 2.5 m/s but cannot exceed 3.2 m/s.
d. The speed can be larger than 3.2 m/s but cannot exceed 3.5 m/s.
e. The speed can be larger than 3.5 m/s.

\sqrt{Rg} = 3.429 m/s,
so faster than 3.2 m/s
is OK, but not 3.5 m/s.

16. If the mass of the block is doubled but if its speed is the same as above, what happens? Choose an appropriate answer.

a. The block still falls off the hoop.
b. The block can complete the rotation along the hoop.
c. Insufficient information is supplied to answer this question.

Notice that the condition is indifferent to the mass.

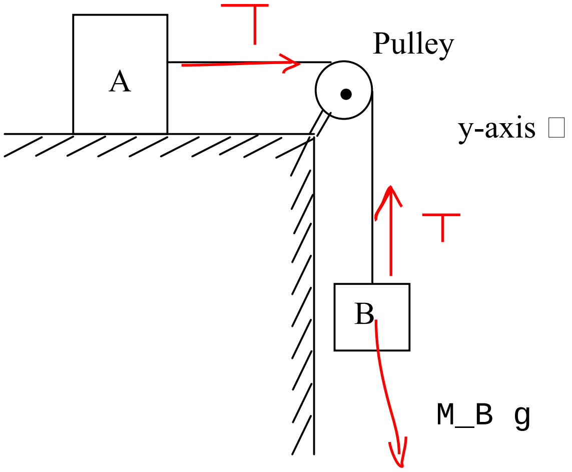
The following 3 questions concern the same physical situation.

A block A of mass M_A = 3kg rests on a table and is attached by a string that runs over a frictionless, massless pulley, to a second block B of mass M_B = 0.75 kg (see figure). The blocks are at rest. The coefficient of static friction between block A and the table is μ_s = 0.3, and the coefficient of kinetic friction is μ_k = 0.2.

17. What is the tension T in the string?

a. 0.75 N
b. 2.5 N
c. 3 N
d. 5.75 N
e. 7.35 N

Stationary, so T = M_B g
 = 0.75 x 9.8 = 7.35 N



18. What is the friction force on block A?

a. $\mu_s M_A g$
b. $\mu_k M_A g$
c. $M_B g$

Static friction is determined by the force balance.
\mu_s N only gives the maximum possible magnitude.
In this case, T must be opposed by the friction force, so it must be equal to M_B g.

We declared our positive direction to be downward, so M_Bg term does NOT have a negative sign.

19. The mass of block B is doubled, so that $\overset{M}{\cancel{m}}_B$ is now 1.5 kg. The blocks now accelerate from rest. What is the acceleration of block B?

a. $a_y = 1.44\ m/s^2$
b. $a_y = 0.24\ m/s^2$
c. $a_y = -0.17\ m/s^2$
d. $a_y = -2.0\ m/s^2$
e. $a_y = -9.8\ m/s^2$

Let a be the acceleration of mass B DOWNWARD. Then
M_A a = T -\mu_k M_A g,
M_B a = M_Bg -T.
Therefore,
(M_A + M_B)a = M_B g - \mu_k M_A g or
 a = g(M_B - \mu_k M_A)/(M_A + M_B)
= 9.8 x (1.5- 0.6)/4.5 = 2 m/s^2.

20. An astronaut carries a box of equipment with her from the Earth to the Moon, where the gravitational acceleration is 1/6 that on Earth. On Earth she has to push on the box with a force F_{start} to get the box moving. Once the box starts moving she must apply a force F_{stop} to stop it over a distance of one meter. How do the forces necessary to start the box moving and to stop it compare on Earth and Moon? Assume $\mu_k = 0$ and $\mu_s = 0.3$ on both Earth and Moon.

a. F_{start} (Moon) = F_{start}(Earth), F_{stop}(Moon) = F_{stop}(Earth)
b. F_{start} (Moon) = F_{start}(Earth), F_{stop}(Moon) < F_{stop}(Earth)
c. F_{start} (Moon) < F_{start}(Earth), F_{stop}(Moon) = F_{stop}(Earth)
d. F_{start} (Moon) < F_{start}(Earth), F_{stop}(Moon) < F_{stop}(Earth)
e. F_{start} (Moon) > F_{start}(Earth), F_{stop}(Moon) < F_{stop}(Earth)

The key points are:
1)static friction is proportional to gravity;
2)to accelerate/decelerate in the horizontal direction has nothing to do with gravity.

Due to 1) a,b,e are out. Due to 2) b is out.

The following 3 questions concern the same physical situation.

21. Your solar powered car can manage a constant acceleration of 1 m/s^2. How long will it take you to cross a two-lane road (width 10m), starting from rest (treat the car like a point, not an extended object)?

a. 10 s
b. 7 s
c. 5 s
d. 4.5 s
e. 3.1 s

(1/2) a t^2 = 10, so t = \sqrt{20} = 4.47 s.

22. Suppose the answer to the last question is T. How long would it take you to cross an eight lane road?

a. T
b. 2 T
c. 4 T

The width is quadrupled. t is proportional to the \sqrt of the width, so the time would be doubled.

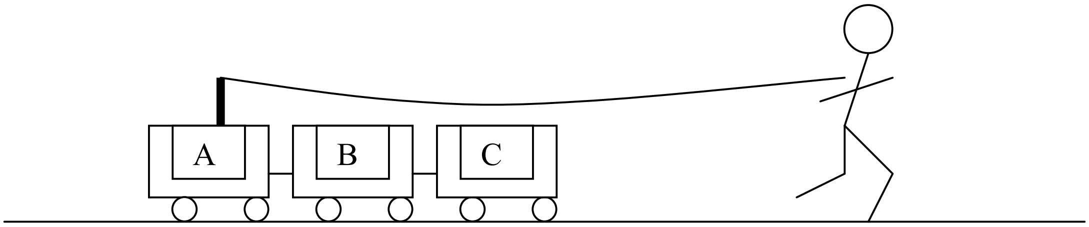
23. What is your speed when you reach the other side of the two lane road?

a. 9.8 m/s
b. 5 m/s
c. 4.7 m/s
d. 4.5 m/s
e. 3.1 m/s

v = at; for the two lane case: v = 1 x 4.47 = 4.47 m/s

The following 2 questions concern the same physical situation.

A man pulls a group of three, rigidly connected, identical carts forward in a straight line using a rope attached to the last car (A) in the group:



24. Using a tension T_A in the rope produces an acceleration a of the carts. If he instead attached the rope to cart C and produced the same acceleration a, then the tension in the rope T_C obeys

a. $T_A < T_C$
b. $T_A = T_C$
c. $T_A > T_C$

Obvious.

25. Given the arrangement of the rope shown in the figure, which of the following is largest in magnitude?

a. T_A
b. Normal force of A on B
c. Normal force of B on A
d. Normal force of B on C
e. Normal force of C on B

Obvious; or look at a similar problem in Discussion.
(Note that b=c, d=e due to the third law.)

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