UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3
MIDTERM EXAM

October 18, 2018 Time: 90 minutes

NAME: ________Solutions______________________________ STUDENT NO.: ____________

(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 A. Zulkoskey
- ❑ 02 Dr. R. Pywell
- ❑ 03 B. Zulkoskey
- ❑ 97 Dr. A. Farahani
- ❑ C15 Dr. A. Farahani

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card and an OMR sheet. The test paper consists of 8 pages, including this cover page. **It is the responsibility of the student to check that the test paper is complete**.
3. Only a basic scientific calculator may be used. Graphing or programmable calculators, or calculators with communication capability, or calculators in smart phones are **not** allowed.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

QUESTION NUMBER	MAXIMUM MARKS	MARKS OBTAINED
A1-12	12	
B1-4	8	
B5-8	8	
B9-12	8	
B13-16	8	
MARK	out of 36:	

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. Which one of the following choices correctly represents the quantity Q, where Q = (4.53 cm)^2 × (6.232 m/s)?

(A) 128 m^3/s (B) 1.2789 × 10^4 m^3/s (C) 1.28 × 10^{-2} m^2/s
(D) 1.28 × 10^{-2} m^3/s (E) 1.279 × 10^{-2} m^3/s

$$Q = (4.53\text{cm}\times\frac{1\text{m}}{100\text{cm}})^2\times 6.232\text{m/s} = 2.052\times10^{-3}\text{m}^2\times 6.232\text{m/s} = 1.28\times10^{-2}\text{m}^3/\text{s}$$

3 significant figures in answer because 4.53 cm only has 3 significant figures. (D)

A2. Given that the dimensions of a, b and c are: $[a] = \frac{[L]}{[T]^2}$; $[b] = \frac{[M]^2}{[T]}$; $[c] = \frac{[L]^2}{[M]^8}$, which one of the following expressions is dimensionally correct?

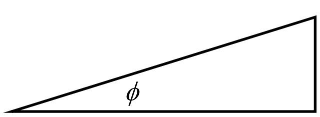
(A) $a = b^2c^{1/4}$ (B) $a = b^2c^{1/2}$ (C) $a = bc^{1/4}$ (D) $a = \frac{1}{4} b^2c$ (E) $a = \frac{1}{2} bc$

Note that a does not have mass in its dimensions. Also note that a depends on the product of different powers of b and c. Therefore, the appropriate powers of b and c are those that result in mass cancelling-out. This cancellation of mass only occurs for option (B):

$$\left[b^2c^{1/2}\right] = \left(\frac{[M]^2}{[T]}\right)^2\left(\frac{[L]^2}{[M]^8}\right)^{1/2} = \frac{[M]^4}{[T]^2}\times\frac{[L]^1}{[M]^4} = \frac{[L]}{[T]^2} = [a]$$

A3. A right triangle has sides of length 5.0 m, 12 m, and 13 m. The smallest angle of this triangle is

(A) 21° (B) 23° (C) 43° (D) 47° (E) 67°



ϕ is the smallest angle, and $\tan\phi$ = 5.0 m / 12 m. Therefore, ϕ = 23° (to 2 significant figures), which is option (B)

A4. As a result of the coordinate system chosen to describe its motion, a car in straight line motion has a negative velocity and a negative acceleration. Which one of the following statements could possibly be correct for the motion of the car?

(A) The car is moving in the negative direction with increasing speed.
(B) The car is moving in the positive direction with increasing speed.
(C) The car is moving in the positive direction with decreasing speed.
(D) The car is moving in the negative direction with decreasing speed.
(E) The car is moving in the negative direction with constant speed.

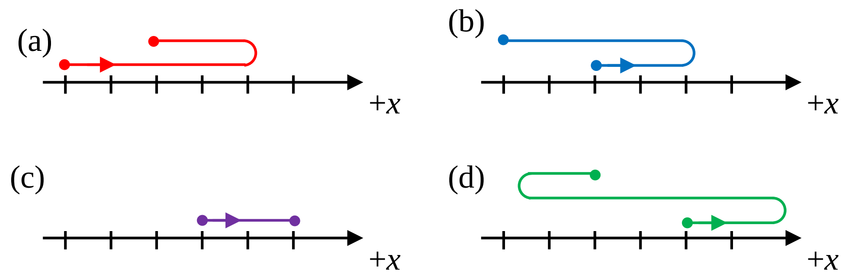
Since both the velocity and acceleration are in the same direction, the speed is increasing. Since the velocity is in the negative direction, (A) is correct.

A5. A ball is thrown from near the ground with an initial velocity that is at an angle of 45° to the horizontal. If we can neglect the effects of air resistance, what happens to the horizontal component of the ball's velocity during its motion?

(A) It decreases slowly, reaching zero just before the ball hits the ground.
(B) It decreases slowly throughout the motion, but is not zero just before the ball hits the ground.
(C) It increases slowly throughout the motion.
(D) It decreases as the ball climbs to the highest point of its motion, then increases as it falls to the ground.
(E) It remains constant throughout the motion.

Neglecting air resistance, only the gravitational force acts on the ball during its motion. Therefore the ball has an acceleration that is only in the vertical direction. So the horizontal component of the ball's velocity remains constant throughout the motion, option (E).

A6. Four paths are illustrated below for a particle moving in one dimension. In the diagrams the marks along the x-axis are equally spaced. The particle moves back and forth along the x-axis only, the vertical separation of different parts of the motion is for clarity only. The starting and ending points of the motion are indicated by the dots and the initial direction is shown by the arrow. For each motion the time interval between the initial and final positions is the same.



For which of the motions is the magnitude of the average velocity the greatest?

(A) Motion (a). (B) Motion (b). (C) Motion (c). (D) Motion (d).
(E) The average velocity has the same magnitude for all of the motions.

Average velocity = displacement divided by elapsed time. We are given that the time intervals are the same for each motion. In each of the 4 motions, the magnitude of the displacement is 2 units. Therefore, (E) is correct.

A7. A planet has twice the mass and half the radius of the Earth. Find the acceleration due to gravity near its surface, in terms of g, the acceleration near the Earth's surface.

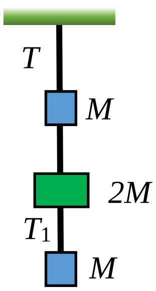
(A) g (B) $2\,g$ (C) $4\,g$ (D) $8\,g$ (E) $\frac{1}{2}\,g$

$$F_{grav} = \frac{GMm}{r^2} = ma \Rightarrow a = \frac{GM}{r^2}\text{, so near the Earth's surface, } a = \frac{GM_E}{R_E^2} = g$$

$$\text{Near the planet's surface, } a = \frac{G(2M_E)}{\left(\frac{1}{2}R_E\right)^2} = \frac{2(GM_E)}{\frac{1}{4}\left(R_E^2\right)} = 8\frac{GM_E}{R_E^2} = 8g$$

so (D) is correct

A8. Three blocks are suspended from the roof by strings as shown. The top block and the bottom block each have mass M, and the middle block has mass $2M$. The tension in the string between the top block and the roof is T. What is the tension, T_1, in the string connecting the bottom block and middle block?



(A) $4\,T$ (B) $\frac{3}{2}T$ (C) $\frac{3}{4}T$

(D) $\frac{1}{4}T$ (E) $\frac{1}{3}T$

The tension, T_1, in the bottom string must be of the same magnitude as the weight of the bottom block, Mg. The top string is supporting all three blocks, so the tension, T, in the top string must be equal in magnitude to the total weight of the blocks, $4\,Mg$. Therefore, $T_1 = \frac{1}{4}\,T$, option (D).

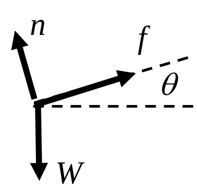
A9. One way of stating Newton's third law is to say that all forces are action/reaction pairs that are equal in magnitude and opposite in direction. An apple accelerates toward the ground after having fallen from the branch of the apple tree. If the apple's weight is the action force, which statement is correct concerning the reaction force?

(A) The reaction force is the air resistance force on the apple as it falls.
(B) The reaction force is the force of the ground on the apple when it hits the ground.
(C) The reaction force is the force of the apple pulling up on the Earth.
(D) There is no reaction force while it is falling since it is in free-fall.
(E) There is no reaction force while it is falling since the apple is not touching the ground.

The apple's weight is the gravitational force of the Earth on the apple, so the reaction force is the gravitational force of the apple on the Earth, option (C).

A10. A brick of mass M slides down a ramp that has length L and is inclined at an angle θ to the horizontal. If the brick slides down the entire ramp with a constant speed, what is the work done by friction?

(A) 0 (B) $-MgL\cos^2\theta$ (C) $-MgL\cos\theta$
(D) $-MgL\sin\theta$ (E) $-MgL\sin\theta\cos\theta$



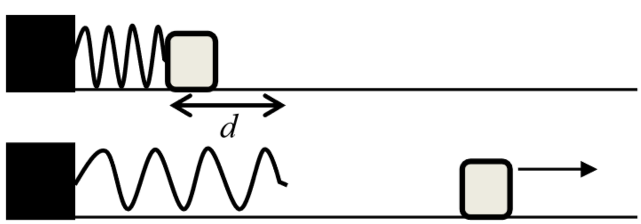
The diagram shows the forces acting on the brick. Since the brick slides with a constant speed, the net work done on the brick is zero. The normal force does no work (it is perpendicular to the displacement), so the sum of the work done by friction and the work done by gravity is zero. The work done by gravity is the negative of the change in the gravitational potential energy $= -(0 - Mgh) = Mgh$ where h is the height of the ramp, and the reference height for gravitational potential energy has been chosen as the bottom of the ramp. Since $h = L\sin\theta$, the work done by friction as the brick slides down the entire ramp $= -MgL\sin\theta$, option (D).

A11. If both the mass and speed of a ball are doubled, the kinetic energy is increased by a factor of

(A) 2. (B) 4. (C) 6. (D) 8. (E) 16.

$KE_1 = \frac{1}{2}m\upsilon^2$; $KE_2 = \frac{1}{2}(2m)(2\upsilon)^2 = \frac{1}{2}(2\times 4)m\upsilon^2 = 8\times\frac{1}{2}m\upsilon^2 = 8KE_1$ so (D) is correct.

A12. A Hooke's law spring is mounted horizontally over a frictionless surface. The spring is then compressed a distance d from its uncompressed length and is used to launch a mass m from rest along the frictionless surface. What compression distance of the spring is needed for the mass to attain double the speed attained in the previous situation?



(A) $\sqrt{2}d$ (B) $2d$ (C) $2\sqrt{2}d$ (D) $4d$ (E) $8d$

Since the surface is frictionless, mechanical energy is conserved.
$KE_i + PE_i = KE_f + PE_f \Rightarrow 0 + \frac{1}{2}kd^2 = \frac{1}{2}m\upsilon_1^2 + 0 \Rightarrow \upsilon_1 = d\sqrt{k}$ That is, the speed is directly proportional to the compression of the spring (k is a constant). So to obtain double the speed, the compression must be doubled. Option (B) is correct.

PART B

WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.

BEFORE SCRATCHING ANY OPTIONS, BE SURE TO DOUBLE-CHECK YOUR LOGIC AND CALCULATIONS.

YOU MAY FIND IT ADVANTAGEOUS TO DO AS MANY OF THE PARTS OF A QUESTION AS YOU CAN BEFORE SCRATCHING ANY OPTIONS.

WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).

IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE 1.2 MARKS OUT OF 2.

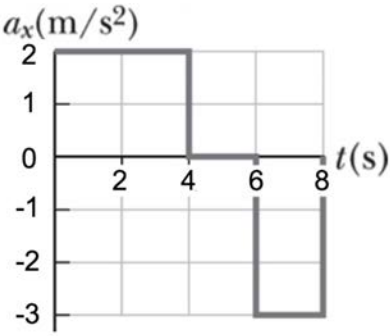
REVEALING THE STAR WITH YOUR THIRD, FOURTH, OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

YOU MAY ANSWER ALL FOUR PART B QUESTION GROUPINGS (1-4, 5-8, 9-12, AND 13-16) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 3 GROUPINGS.

USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

Grouping B1-B4

A ball has a constant acceleration for 4.00 seconds as it rolls down an incline. It then continues along level ground for 2.00 seconds, and then encounters an upward slope that slows it down for 2.00 seconds. See the acceleration versus time graph at the right. You may assume that values determined from the diagram are accurate to 3 significant figures.



B1. What is the displacement of the ball between t = 0 and t = 4.00 s?

From t = 0 to 4.00 s, the acceleration is constant at 2.00 m/s^2, and the ball starts from rest.

$$\Delta x = \upsilon_o t + \tfrac{1}{2}at^2 = 0 + \tfrac{1}{2}(+2.00\text{ m/s}^2)(4.00\text{ s})^2 = +16.0\text{ m}$$

B2. If the ball comes to a flat surface at t = 8.00 s, what will be its subsequent velocity along the surface?

Note that there are 3 regions of constant acceleration between t = 0 and 8.00 s. a_1 = +2.00 m/s^2 from 0 to 4.00 s, a_2 = 0 from 4.00 to 6.00 s, and a_3 = –3.00 m/s^2 from 6.00 to 8.00 s.

$$\upsilon_8 = \upsilon_o + a_1t_1 + a_2t_2 + a_3t_3$$

$$\upsilon_8 = 0 + (+2.00\text{ m/s}^2)(4.00\text{ s} - 0) + (0\text{ m/s}^2)(6.00\text{ s} - 4.00\text{ s}) + (-3.00\text{ m/s}^2)(8.00\text{ s} - 6.00\text{ s}) = +2.00\text{ m/s}$$

B3. What is the average acceleration of the ball between t = 0 and t = 8.00 s?

Average acceleration equals the change in velocity divided by the time interval.

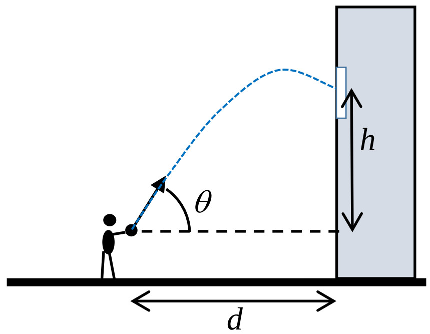
$$\bar{a}_{0\to 8\text{s}} = \frac{\Delta\upsilon_{0\to 8\text{s}}}{8.00\text{ s}} = \frac{\upsilon_{8\text{s}} - \upsilon_o}{8.00\text{ s}} = \frac{+2.00\text{ m/s} - 0}{8.00\text{ s}} = +0.250\text{ m/s}^2$$

B4. From time t = 8.00 s to 10.0 s, the ball is on level ground (zero acceleration) and then the ball encounters another incline at time t = 10.0 s, causing it to accelerate with $a_x = -2.00$ m/s^2. At what time, t, will the ball come to a halt (and subsequently roll back down the incline)?

When it reaches the new incline, at 10.0 s, the ball is moving at +2.00 m/s. The time, Δt, measured from t_i = 10.0 s, when the ball comes to a halt is obtained as follows:

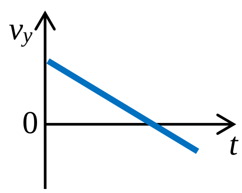
$$\upsilon = \upsilon_{10} + a_{10}\Delta t \Rightarrow \Delta t = \frac{\upsilon - \upsilon_{10}}{a_{10}} = \frac{0-(+2.00\text{ m/s})}{(-2.00\text{m/s}^2)} = 1.00\text{ s} \Rightarrow t = 10.0\text{ s} + 1.00\text{ s} = 11.0\text{ s}$$

Grouping B5-B8



Romeo attracts Juliet's attention by throwing a stone to hit her window. Romeo throws the stone at an angle $\theta = 65.0°$ up from the horizontal. The stone follows the path shown in the diagram and it hits the window 0.766 s after it was released. The release point is a horizontal distance d = 2.50 m from the window. We can ignore the effect of air resistance on the flight of the stone.

B5. If we choose the $+y$ direction to be up, which one of the following graphs best represents the y-component of the stone's velocity during its flight?



The $+y$ direction was chosen to be up. The stone moves upward, reaches maximum height, and then starts to move downward, so υ_y starts positive, decreases to zero, and then becomes negative. Since air resistance can be ignored, the acceleration is constant and downward, so υ_y vs. time will be linear with a negative slope. The y-component of the stone's velocity is given by graph shown above.

B6. Which statement is correct for the stone during its flight, from after it is released until just before it hits the window?

Both its acceleration and the horizontal component of the stone's velocity are constant during its flight.

The acceleration is constant (magnitude g, directed vertically downward) and therefore the horizontal component of the stone's velocity is also constant.

B7. Calculate the speed with which the stone was thrown.

$\Delta x = 2.50\text{ m}$, $t = 0.766\text{ s}$ and $\Delta x = \upsilon_{ox}t$ and $\upsilon_{ox} = \upsilon_o \cos\theta$

$$\Delta x = (\upsilon_o \cos\theta)t \;\Rightarrow \upsilon_o = \frac{\Delta x}{t(\cos\theta)} = \frac{2.50\text{ m}}{0.766\text{ s }(\cos 65.0^\circ)} = 7.72\text{ m/s}$$

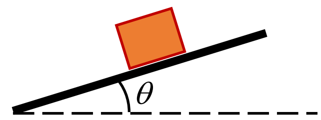
B8. Calculate the vertical distance *h* between where the stone was released and where it hits the window.

$$h = \Delta y = \upsilon_{oy}t + \tfrac{1}{2}a_y t^2 = (\upsilon_o \sin\theta)t + \tfrac{1}{2}a_y t^2$$

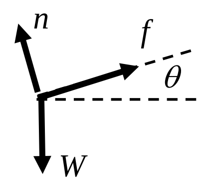
$$h = (7.723\text{ m/s})(\sin 65.0^\circ)(0.766\text{ s}) + \tfrac{1}{2}(-9.80\text{ m/s}^2)(0.766\text{ s})^2 = 2.49\text{ m}$$

Grouping B9-B12

A block, with mass m = 2.20 kg, is sliding down an inclined plane with an acceleration of magnitude 2.80 m/s^2. The plane is at an angle θ = 35.0° to the horizontal. The coefficient of kinetic friction between the block and the plane is μ_k.



B9. Let the magnitude of the weight of the block be W, the magnitude of the normal force on the block be n, and the magnitude of the kinetic friction force on the block be f. Which one of the following is a correct free-body diagram of the forces on the block?



The weight force is vertically downward, the normal force is perpendicular to the inclined plane, and the friction force is directed along the plane and opposite to the motion.

B10. Which one of the following is a correct expression for the magnitude of the normal force on the block? (Let a be the magnitude of the block's acceleration.)

Choose a coordinate system with the $+x$ axis directed up the plane and the $+y$ axis directed perpendicularly away from the plane. Since there is no motion perpendicular to the plane, the sum of the forces in the y direction must be zero:

$$\sum F_y = 0 \Rightarrow +n - W_y = 0 \Rightarrow +n - W\cos\theta = 0 \Rightarrow +n - mg\cos\theta = 0 \Rightarrow n = mg\cos\theta$$

B11. Calculate the magnitude of the kinetic friction force on the block.

The block is accelerating down the plane, so apply Newton's Second Law in the chosen x direction:

$$\sum F_x = ma \Rightarrow +f_k - W_x = ma \Rightarrow +f_k - W\sin\theta = ma \Rightarrow +f_k - mg\sin\theta = ma \Rightarrow f_k = ma + mg\sin\theta$$

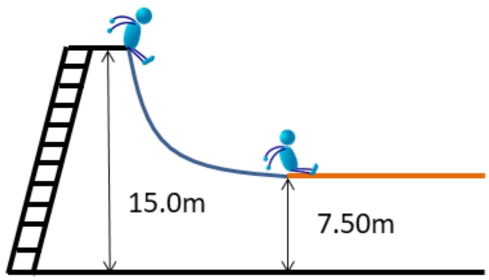
$$f_k = (2.20\text{ kg})(-2.80\text{ m/s}^2) + (2.20\text{ kg})(9.80\text{ m/s}^2)\sin(35.0^\circ) = 6.206\text{ N}$$

B12. Calculate the coefficient of kinetic friction, μ_k.

$$f_k = \mu_k n \Rightarrow \mu_k = \frac{f_k}{n} = \frac{f_k}{mg\cos\theta} = \frac{6.206\text{ N}}{(2.20\text{ kg})(9.80\text{ m/s}^2)\cos(35.0^\circ)} = 0.351$$

Grouping B13-B16

A child of mass m = 45.0 kg climbs a vertical ladder to a height h_i = 15.0 m above the ground. Once at the top, starting from rest, the child travels vertically downward to a height h_f = 7.50 m above the ground along a frictionless slide before encountering a horizontal section with a coefficient of kinetic friction $\mu_k = 0.150$.



B13. Which one of the following expressions describes the work done by gravity as the child slides down the ramp just before the horizontal section with friction?

$$W_{grav} = -\Delta PE_{grav} = -(PE_{grav,f} - PE_{grav,i}) = PE_{grav,i} - PE_{grav,f} = mgh_i - mgh_f = mg(h_i - h_f)$$

B14. Calculate the speed of the child just before she interacts with the frictional portion of the slide.

Just before the child reaches the frictional portion, $Wnc = 0$ and the normal force does no work, so, from the work-energy theorem, $W_{net} = W_{grav} = \Delta KE = KE_f - KE_i = KE_f = \frac{1}{2}(m\upsilon^2)$

$$W_{grav} = \tfrac{1}{2}m\upsilon^2 \Rightarrow mg(h_i - h_f) = \tfrac{1}{2}m\upsilon^2 \Rightarrow \upsilon = \sqrt{2g(h_i - h_f)} = \sqrt{2(9.80\text{ m/s}^2)(15.0\text{ m} - 7.50\text{ m})} = 12.12\text{ m/s}$$

B15. Calculate the work done by gravity as the child slides along the horizontal frictional portion of the slide for a distance of 4.25 m.

Since the child is moving horizontally and the gravitational force is vertical, the gravitational force does no work. The angle between the force and the displacement is 90° and cos(90°) = 0.

B16. Calculate the distance that the child travels along the frictional portion of the slide before coming to rest.

Now both the normal force and the gravitational force are perpendicular to the motion of the child. The only force doing work on the child is kinetic friction. Again applying the work-energy theorem, $W_{net} = \Delta KE = KE_f - KE_i$ and since the child stops, $KE_f = 0$.

$$W_{net} = -KE_i \Rightarrow W_f = -\tfrac{1}{2}m\upsilon_i^2 \Rightarrow f_k\cos(180^\circ)d = -\tfrac{1}{2}m\upsilon_i^2 \Rightarrow -\mu_k nd = -\tfrac{1}{2}m\upsilon_i^2$$

where d is the distance the child slides before stopping.

Since this portion of the slide is horizontal, and the only vertical forces are gravity and the normal force, and there is no vertical motion, $\Sigma F_{vert} = 0$, which means that the magnitude of the normal force equals the magnitude of the child's weight. That is, $n = mg$.

So $\mu_k mgd = \tfrac{1}{2}m\upsilon_i^2 \Rightarrow d = \dfrac{\upsilon_i^2}{2\mu_k g} = \dfrac{(12.12\text{ m/s})^2}{2(0.150)(9.80\text{ m/s}^2)} = 50.0\text{ m}$

END OF EXAMINATION