UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3

MIDTERM EXAM – Alternative Sitting

October 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 $Q = (4.53\text{ cm})^2 \times (6.232\text{ m/s})$?

(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

$$Q = (4.53\text{cm} \times \frac{1\text{m}}{100\text{cm}})^2 \times 6.232\text{m/s} = 2.052 \times 10^{-3}\text{m}^2 \times 6.232\text{m/s} = 1.28 \times 10^{-2}\text{m}^3/\text{s}$$

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?

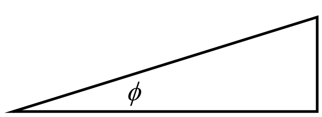
(A) $a = b^2c^{1/4}$ (B) $a = b^2c^{1/2}$ (C) $a = bc^{1/4}$ (D) $a = ¼\, b^2c$ (E) $a = ½\, bc$

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 $\tan\phi = 5.0\text{ m} / 12\text{ m}$. Therefore, $\phi = 23°$ (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.

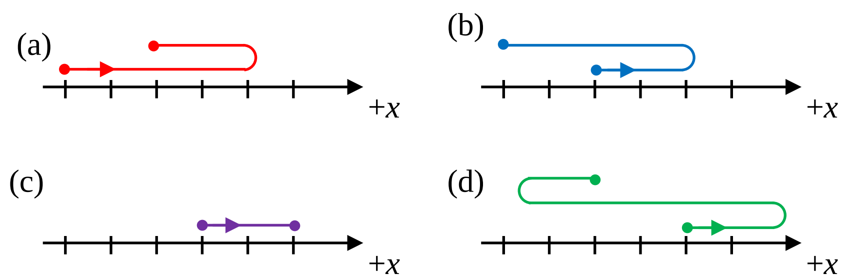
Since both the velocity and acceleration are in the same direction, the speed is increasing. Since the velocity is in the negative direction, (A) is correct.

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.

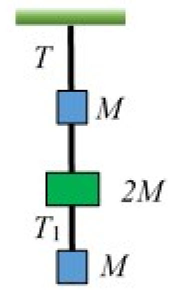
A7. A planet has twice the mass and half the radius of the Earth. Find the acceleration due to gravity near its surface, in terms of g, the acceleration near the Earth's surface.

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

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

Near the planet's surface, $a = \dfrac{G(2M_E)}{\left(\frac{1}{2}R_E\right)^2} = \dfrac{2(GM_E)}{\frac{1}{4}\left(R_E^2\right)} = 8\dfrac{GM_E}{R_E^2} = 8g$ 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) $\dfrac{3}{2}T$ (C) $\dfrac{3}{4}T$

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

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).

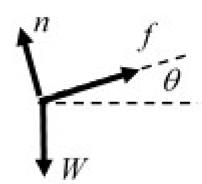
A9. One way of stating Newton's third law is to say that all forces are action/reaction pairs that are equal in magnitude and opposite in direction. An apple accelerates toward the ground after having fallen from the branch of the apple tree. If the apple's weight is the action force, which statement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



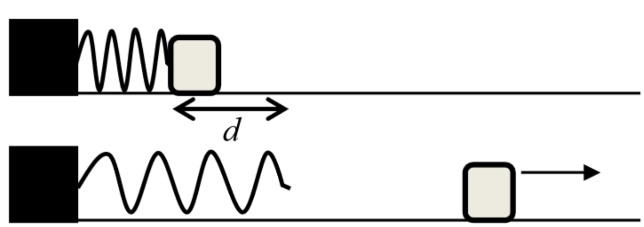
The diagram shows the forces acting on the brick. Since the brick slides with a constant speed, the net work done on the brick is zero. The normal force does no work (it is perpendicular to the displacement), so the sum of the work done by friction and the work done by gravity is zero. The work done 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.

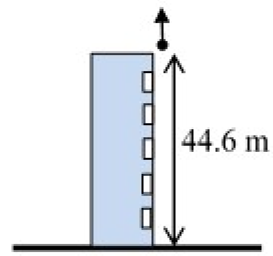
REVEALING THE STAR WITH YOUR THIRD, FOURTH, OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

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.

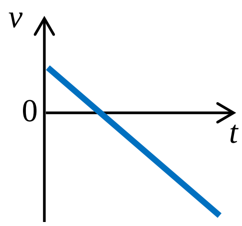
USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

Grouping B1-B4

A ball is thrown vertically upward from the roof of a building 44.6 m above the ground with an initial speed of 5.45 m/s.



B1. Choosing vertically-up to be the positive direction, which one of the following velocity vs time graphs best represents the motion of the ball?



The $+y$ direction was chosen to be up. The ball 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.

B2. Calculate the speed of the ball as it passes a window 13.7 m below the roof of the building.

$$\upsilon^2 = \upsilon_o^{\ 2} + 2a\Delta y \Rightarrow \upsilon = \sqrt{\upsilon_o^{\ 2} + 2a\Delta y} = \pm\sqrt{(5.45\text{ m/s})^2 + 2(-9.80\text{ m/s}^2)(-13.7\text{ m})} = -17.27\text{ m/s}$$

B3. Calculate the time from when the ball is initially thrown until it passes the window.

Remember that UP was chosen as the positive direction, so the velocity when the ball passes the window is negative and the acceleration is negative.

$$\upsilon = \upsilon_o + at \Rightarrow t = \frac{\upsilon - \upsilon_o}{a} = \frac{-17.27\text{ m/s} - (+5.45\text{ m/s})}{-9.80\text{ m/s}^2} = 2.32\text{ s}$$

B4. Calculate the total time of flight of the ball, from being thrown vertically upward to reaching the ground.

Note that the kinematic equations for constant acceleration only apply to the ball while it is in the air, i.e. from just after being thrown until just before it hits the ground. Therefore, the final velocity (just before it hits the ground) is not zero. We know the initial velocity, the displacement, and the acceleration for the total flight of the ball.

$$\Delta y = \upsilon_o t + \tfrac{1}{2}at^2 \Rightarrow (\tfrac{1}{2}a)t^2 + (\upsilon_o)t - \Delta y = 0 \Rightarrow (\tfrac{1}{2}(-9.80\text{ m/s}^2))t^2 + (+5.45\text{ m/s})t - (-44.6\text{ m}) = 0$$

$$(-4.90\text{ m/s}^2)t^2 + (5.45\text{ m/s})t + 44.6\text{ m} = 0$$

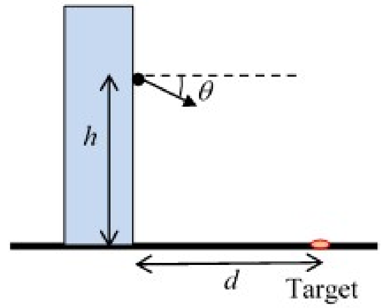
This equation is quadratic in the time, *t*.

$$t = \frac{-(5.45\text{ m/s}) \pm \sqrt{(5.45\text{ m/s})^2 - 4(-4.90\text{ m/s}^2)(+44.6\text{ m})}}{2(-4.90\text{ m/s}^2)}$$ which has the roots $t = 3.62\text{ s and } -2.51\text{ s}$

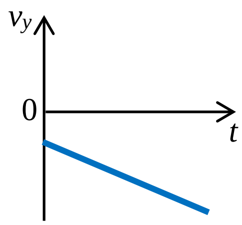
Since time cannot be negative, the answer for the total time of flight is 3.62 s.

Grouping B5-B8

Students are having a competition throwing bean bags out of a window of a tall building to hit a target drawn with chalk on the horizontal pavement below. The height of the release point above the pavement is h and the horizontal distance from the building to the target is d = 5.25 m. The winning student throws the bean bag at an angle of θ = 20.0° down from the horizontal and it hits the target 1.72 s after the bean bag was released. We can ignore the effect of air resistance in the motion of the bean bag.



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



The +y direction was chosen to be up. The ball moves downward throughout its motion, so υ_y is 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, and the value of υ_y will become increasingly negative.

B6. Which one of the following statements is correct for the bean bag during its flight, from after it is released until just before it hits the pavement?

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 bean bag's velocity is also constant.

B7. Calculate the speed with which the bean bag is thrown by the winning student.

We know the horizontal distance and the time that the bean bag is in the air, so we can calculate the constant horizontal component of the bag's velocity. Since we know the angle at which the bag was thrown, we can then calculate the initial speed.

$$\Delta x = \upsilon_{ox} t = \upsilon_o \cos(\theta) t \Rightarrow \upsilon_o = \frac{\Delta x}{\cos(\theta) t} = \frac{5.25 \text{ m}}{\cos(20.0^\circ)(1.72 \text{ s})} = 3.25 \text{ m/s}$$

B8. Calculate the height h of the bean bag's release point.

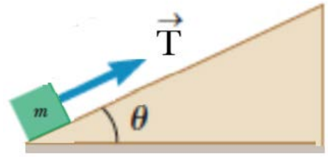
We can calculate the vertical component of the initial velocity, and we know the time of flight and the vertical acceleration…

$$\Delta y = \upsilon_{oy}t + \tfrac{1}{2}a_y t^2 = \upsilon_o \sin(\theta)t + \tfrac{1}{2}a_y t^2 = (-3.248\text{ m/s})\sin(20.0^\circ)(1.72\text{ s}) + \tfrac{1}{2}(-9.80\text{ m/s}^2)(1.72\text{ s})^2 = -16.4\text{ m}$$

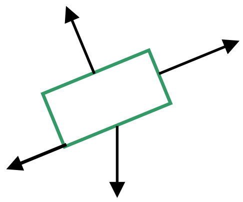
The vertical displacement is negative, the height (magnitude of displacement) is 16.4 m.

Grouping B9-B12

A block of mass m = 5.20 kg is pulled up a θ = 34.0° incline as in the figure below with a string with a tension force of magnitude T = 54.0 N. The block starts from rest from the bottom of the incline and is pulled up 2.25 m along the incline in 1.95 s. There is friction between the block and the inclined surface.



B9. Which one of the following diagrams best represents the free-body diagram for the block?



The tension force is up the incline, friction force opposes the motion and so is directed down the incline. The gravitational force is vertically down and the normal force is perpendicular to, and away from, the incline.

B10. Which one of the following expressions is correct for the magnitude of the normal force acting on the block?

Choose a coordinate system with the $+x$ axis directed up the incline and the $+y$ axis directed perpendicularly away from the incline. Since there is no motion perpendicular to the incline, 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 acceleration of the block.

The block starts from rest and we are given the time required for it to move a certain distance along the incline.

$$\Delta x = \upsilon_{ox} t + \tfrac{1}{2} a_x t^2 = \tfrac{1}{2} a_x t^2 \Rightarrow a_x = \frac{2\Delta x}{t^2} = \frac{2(2.25\text{ m})}{(1.95\text{ s})^2} = 1.183\text{ m/s}^2$$

B12. Calculate the coefficient of kinetic friction between the block and the incline.

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

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

$$f_k = T - ma - mg\sin\theta \text{ and } f_k = \mu_k n = \mu_k mg\cos\theta$$

$$\therefore \quad \mu_k mg\cos\theta = T - ma - mg\sin\theta \Rightarrow \mu_k = \frac{T - ma - mg\sin\theta}{mg\cos\theta}$$

$${}_k = \frac{54.0\text{ N} - (5.20\text{ kg})(1.183\text{ m/s}^2) - (5.20\text{ kg})(9.80\text{ m/s}^2)\sin(34.0^\circ)}{(5.20\text{ kg})(9.80\text{ m/s}^2)\cos(34.0^\circ)} = 0.458$$

Grouping B13-B16
A ball of mass 0.145 kg is thrown vertically upward with an initial speed of 26.0 m/s. Air resistance is present. The ball returns to the same height from which it was released, and the work done by air resistance on the ball is –7.40 J during the ball's upward flight and –6.80 J during the ball's downward flight.

B13. Which one of the following statements is correct about the work done by the gravitational force on the ball?

The total work done by the gravitational force on the ball from start to finish of its flight is zero.

The work done by the gravitational force equals the negative of the change in the gravitational potential energy of the ball. Since the ball returns to the same height from which it was released, there is no net change in its gravitational potential energy, and therefore the work done by the gravitational force on the ball is zero.

B14. Calculate the change in the ball's kinetic energy between its point of release and its return to the height from which it was released.

Since air resistance is present, W_{nc} is not equal to zero. Therefore, use $E_i + W_{nc} = E_f$.

$$E_i + W_{nc} = E_f \Rightarrow KE_i + PE_i + W_{nc} = KE_f + PE_f \Rightarrow KE_f - KE_i = PE_i - PE_f + W_{nc}$$

$$\Delta KE = W_{nc} - \Delta PE = W_{nc} - 0 = W_{nc} = -7.40\text{ J} + (-6.80\text{ J}) = -14.2\text{ J}$$

B15. Calculate the speed of the ball just as it returns to the height from which it was released.

$$\Delta KE = KE_f - KE_i = \tfrac{1}{2}m(\upsilon_f^2 - \upsilon_i^2) \Rightarrow \frac{2\Delta KE}{m} = \upsilon_f^2 - \upsilon_i^2 \Rightarrow \upsilon_f^2 = \frac{2\Delta KE}{m} + \upsilon_i^2$$

$$\upsilon_f = \sqrt{\frac{2\Delta KE}{m} + \upsilon_i^2} = \sqrt{\frac{2(-14.2\text{ J})}{0.145\text{ kg}} + (26.0\text{ m/s})^2} = 21.9\text{ m/s}$$

B16. Calculate the maximum height, above the release point, reached by the ball.

At maximum height the speed is zero, the change in the gravitational potential energy of the ball is *mgh*, and the work done by air resistance is −7.40 J.

$$E_i + W_{nc,up} = E_f \Rightarrow KE_i + PE_i + W_{nc,up} = KE_f + PE_f$$

$$KE_i - KE_f + W_{nc,up} = +PE_f - PE_i$$

$$\tfrac{1}{2} m\upsilon_i^2 - 0 + W_{nc,up} = mgh$$

$$h = \frac{\tfrac{1}{2} m\upsilon_i^2 + W_{nc,up}}{mg} = \frac{\tfrac{1}{2}(0.145\text{ kg})(26.0\text{ m/s})^2 + (-7.40\text{ J})}{(0.145\text{ kg})(9.80\text{ m/s}^2)} = 29.3\text{ m}$$

END OF EXAMINATION