UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
MIDTERM TEST

October 24, 2013 Time: 90 minutes

NAME: SOLUTIONS MASTER STUDENT NO.: ____________
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 Dr. M. Ghezelbash
- ❑ 02 Dr. R. Pywell
- ❑ 03 B. Zulkoskey
- ❑ C15 F. Dean
- ❑ 97 Dr. R. Kleiv

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), a formula sheet, 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 (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, 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 student number in the top right-hand corner of each page of the test paper.
5. Enter your name and STUDENT NUMBER on the OMR sheet.
6. The test paper, the formula sheet and the OMR sheet must all be submitted.
7. The marked test paper will be returned. The formula sheet and the OMR sheet will NOT be returned.

ONLY THE THREE PART B QUESTIONS THAT YOU INDICATE WILL BE MARKED

PLEASE INDICATE WHICH THREE PART B QUESTIONS ARE TO BE MARKED

QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-15	☑	15	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
TOTAL		45	

continued on page 2...

PART A

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

A1. Given $[R] = L$, $[\upsilon_0] = L/T$, $[g] = L/T^2$, which one of the following equations is dimensionally correct?

$\frac{L^2}{T^2}\cdot\frac{T^2}{L} = L$ ✓ $\frac{L}{T}\cdot\frac{T^2}{L} = T$ ✗

A

(A) $R = \frac{\upsilon_0^2}{g}\sin(2\theta)$ (B) $R = \frac{\upsilon_0}{g}\sin(2\theta)$ (C) $R = \upsilon_0 g\sin(2\theta)$

$\frac{L}{T}\cdot\frac{L}{T^2} = \frac{L^2}{T^3}$ ×

(D) $R = \sqrt{\frac{\upsilon_0}{g}\sin(2\theta)}$ (E) $R = \frac{g}{\upsilon_0}\sin(2\theta)$

$\sqrt{\frac{L}{T}\cdot\frac{T^2}{L}} = \sqrt{T}$ × $\frac{L}{T^2}\cdot\frac{T}{L} = \frac{1}{T}$ ×

A2. A spherical balloon has a radius of *r* when it is fully inflated. The balloon is then deflated until its radius is *r*/2. Assuming that the balloon remains spherical as it is deflated, what is the ratio of the deflated and fully inflated surface areas?

D

(A) 1/8 (B) 1/2 (C) 2 (D) 1/4 (E) 4

$\frac{A_d}{A_f} = \frac{4\pi r_d^2}{4\pi r_f^2} = \left(\frac{r_d}{r_f}\right)^2 = \left(\frac{r/2}{r}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

A3. Use the rules for significant figures to correctly express the answer to this addition problem: 21.4 + 15 + 17.17 + 4.003.

D

(A) 57.573 (B) 57.57 (C) 57.6 (D) 58 (E) 60

round off answer to the units place.

A4. The price of gasoline at a particular station is 1.5 euros per litre. An American student has 33 euros to buy gasoline. Knowing that there are 3.786 litres in a gallon, she quickly reasons that she can buy…

B

$\frac{33€}{1.5€/\ell} = 22\ell$

(A) less than 1 gallon of gasoline. (B) about 6 gallons of gasoline.
(C) about 8 gallons of gasoline. (D) about 10 gallons of gasoline.
(E) more than 10 gallons of gasoline.

$\frac{22\ell}{3.786\ell/\text{gal}} \simeq 6$ gal

A5. When the pilot reverses the propeller in a boat moving north, the boat has an acceleration directed south. Assume the acceleration of the boat remains constant in magnitude and direction. What is the resulting motion of the boat?

Compare with the situation of a ball thrown vertically upward.

C

(A) It eventually stops and remains stopped.
(B) It eventually stops and then moves faster and faster in the northward direction.
(C) It eventually stops and then moves faster and faster in the southward direction.
(D) It never stops but loses speed more and more slowly forever.
(E) It never stops but continues to move faster and faster in the northward direction.

A6. A car moving at constant speed around a circular track…

Uniform circular motion, centripetal acceleration

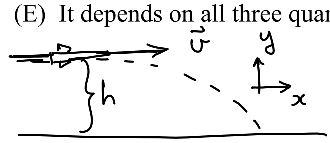
D

(A) has zero acceleration.
(B) has an acceleration component in the direction of its velocity.
(C) has an acceleration directed away from the centre of its circular path.
(D) has an acceleration directed toward the centre of its circular path.
(E) has an acceleration with a direction that cannot be determined from the information given.

A7. A model rocket is launched from the ground. It follows a curved path until it is eventually travelling horizontally at a height *h* above the horizontal ground at a speed υ. At that moment the rocket engine stops and the rocket falls to the ground. At the time the rocket engine stops the rocket has a mass *m*. If we ignore the effects of the air, on which quantities does the time interval between when the rocket engine stops and the rocket hits the ground depend?

B

(A) It depends on *m* and *h* but not υ. (B) It depends on *h* only.
(C) It depends on υ and *h* but not *m*. (D) It depends on υ and *m* but not *h*.
(E) It depends on all three quantities *m*, υ and *h*.



when engine stops, $\vec{a} = g$ downward

$\Delta y = \upsilon_{0y}t + \frac{1}{2}a_y t^2$

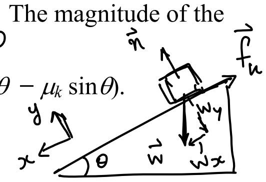
$-h = 0 + \frac{1}{2}(-g)t^2$

$t = \sqrt{2h/g}$

continued on page 3...

D

A8. A crate of mass m is sliding down a ramp that is inclined at an angle of θ with the horizontal. The coefficient of kinetic friction between the crate and the ramp is μ_k. The magnitude of the acceleration of the crate is… $\sum F_y = 0 \Rightarrow n - mg\cos\theta = 0$

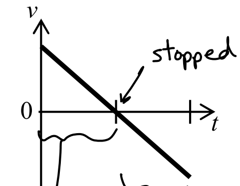


(A) $g\sin\theta$. (B) $g\cos\theta$. (C) $g(\cos\theta - \mu_k\sin\theta)$.
(D) $g(\sin\theta - \mu_k\cos\theta)$. (E) $g\tan\theta$.

$\sum F_x = ma \Rightarrow w_x - f_k = ma$
$mg\sin\theta - \mu_k mg\cos\theta = ma$

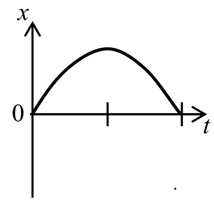
A

A9. An object moves along the x-axis. The graph at right shows the velocity of the object as a function of time. Which one of the following graphs is a possible graph showing the position of the object as a function of time?

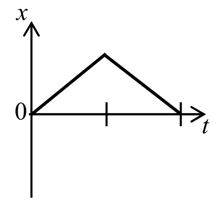


moving in positive x direction with decreasing speed

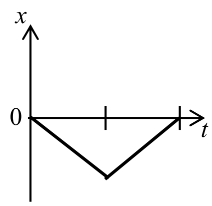
moving in -ve x direction with increasing speed



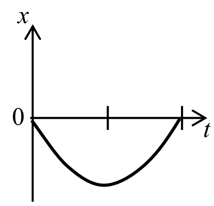
A.



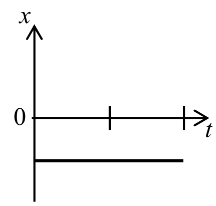
B.



C.



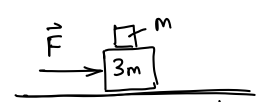
D.



E.

C

A10. A block of mass $3m$ is placed on a frictionless horizontal surface and a second block of mass m is placed on top of the first block. There is friction between the surfaces of the blocks. A constant force of magnitude F is applied to the bottom block. Assume that the upper block does not slip on the lower block. What are the acceleration of the upper block, a_1, and the lower block, a_3, in terms of F and m? no slipping ⇒ both blocks have the same acceleration



(A) $a_1 = \dfrac{F}{m}$, $a_3 = \dfrac{F}{3m}$ (B) $a_1 = \dfrac{F}{3m}$, $a_3 = \dfrac{F}{m}$

(C) $a_1 = \dfrac{F}{4m}$, $a_3 = \dfrac{F}{4m}$ (D) $a_1 = \dfrac{F}{2m}$, $a_3 = \dfrac{F}{2m}$

(E) The coefficient of kinetic friction between the blocks must be known.

Treating the two blocks as a system,
$\sum \vec{F}_{ext} = m\vec{a} \Rightarrow F = (m + 3m)a \Rightarrow a = \dfrac{F}{4m}$

C

A11. An extra-solar planet is observed to have a mass that is 4 times that of the Earth's mass, and a radius that is 2 times that of the Earth's radius. What is the acceleration due to gravity on the surface of this planet, in terms of the acceleration due to gravity on the Earth's surface, g?

(A) ¼ g (B) ½ g (C) 1 g (D) 2 g (E) 4 g

$F_{grav} = mg_{eff} \Rightarrow \dfrac{GM_p m}{R_p^2} = mg_{eff} \Rightarrow g_{eff} = \dfrac{GM_p}{R_p^2} = \dfrac{G(4M_E)}{(2R_E)^2} = G\dfrac{M_E}{R_E^2} = g$

C

A12. Two objects of different masses start from rest. The mass of object 2 is twice the mass of object 1. The same net force acts on each object as they move over equal distances. How do their final kinetic energies compare? Work-Energy Theorem: $W_{net} = \Delta KE$

(A) The kinetic energy of object 2 is half the kinetic energy of object 1.
(B) The kinetic energy of object 2 is twice the kinetic energy of object 1.
(C) The kinetic energies are the same.
(D) The kinetic energy of object 2 is one-quarter the kinetic energy of object 1.
(E) The kinetic energy of object 2 is four times the kinetic energy of object 1.

same net force, same distance means W_{net} same for both objects

continued on page 4...

A13. A mass m is pushed against an ideal spring until the spring is compressed a distance x from its equilibrium position. The force exerted by the spring is F_1 and the potential energy stored in the mass-spring system is PE_1. If the mass is now pushed until the compression of the spring is $2x$, how are the new force, F_2, and the new potential energy, PE_2, related to F_1 and PE_1?

B

(A) $F_2 = 2F_1$, $PE_2 = 2PE_1$
(B) $F_2 = 2F_1$, $PE_2 = 4PE_1$
(C) $F_2 = 4F_1$, $PE_2 = 2PE_1$
(D) $F_2 = 4F_1$, $PE_2 = 4PE_1$
(E) $F_2 = 2F_1$, $PE_2 = PE_1$

$|F_{spring_1}| = kx$

$|F_2| = kx_2 = k(2x) = 2kx = 2|F_1|$

$PE_{spring_1} = \frac{1}{2}kx^2$

$PE_2 = \frac{1}{2}kx_2^2 = \frac{1}{2}k(2x)^2 = \frac{1}{2}k \cdot 4x^2 = 4\left(\frac{1}{2}kx^2\right) = 4PE_1$

A14. Which one of the following statements concerning the physical quantity "work" is **<u>FALSE</u>**?

C

(A) Work is a scalar quantity. T
(B) The work done on an object by a force depends on the angle between the force and the displacement. T
(C) If the total work done on an object is zero, the object must be at rest. F
(D) Positive work is done by a force when the force and the displacement are in the same direction. T
(E) The component of force perpendicular to the displacement does not contribute to the work done by the force. T

$W_{total} = 0$ means no change in KE

A15. An object of mass m moving with speed v in the $+x$ direction strikes an object of mass $2m$ which had been at rest. Following the collision, the object of mass $2m$ moves with speed $\frac{1}{2}v$ in the $+x$ direction. The velocity of the object of mass m after the collision is

A

(A) zero.
(B) also $\frac{1}{2}v$ in the $+x$ direction.
(C) still v in the $+x$ direction.
(D) v in the $-x$ direction.
(E) impossible to determine without knowing whether or not the collision was elastic.

Cons. of Linear Momentum

$\vec{p}_{tot_i} = \vec{p}_{tot_f} \Rightarrow +mv = 2m\left(+\frac{1}{2}v\right) + mv_f$

$mv = mv + mv_f$

$\therefore v_f = 0.$

PART B

ANSWER <u>THREE</u> OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND <u>INDICATE YOUR CHOICE OF QUESTIONS ON THE COVER PAGE</u>.

FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

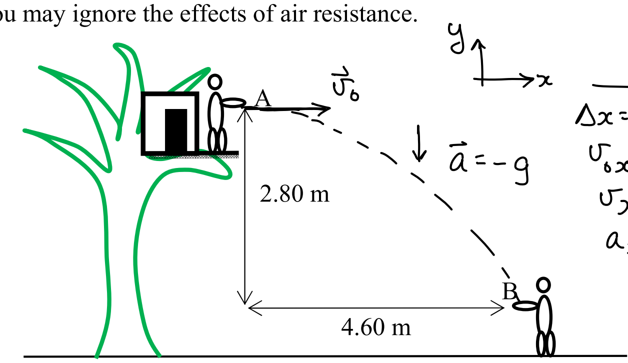
<u>SHOW AND EXPLAIN YOUR WORK</u> – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 5...

B1. A boy in a tree house throws an apple to his girlfriend on the ground. When he throws the apple he releases it with an initial horizontal velocity at point A. The girl catches it at point B. Point B is a horizontal distance of 4.60 m from point A and a vertical distance of 2.80 m below point A as shown. You may ignore the effects of air resistance.



x	y
$\Delta x = +4.60\,m$	$\Delta y = -2.80\,m$
$v_{0x} = v_0$	$v_{0y} = 0$
$v_x = v_0$	$v_y = ?$
$a_x = 0$	$a_y = -g$

(a) Calculate the time of flight of the apple from A to B. (*3 marks*)

$$\Delta y = v_{0y} t + \frac{1}{2} a_y t^2$$

$$\Delta y = 0 + \frac{1}{2}(-g) t^2$$

$$t = \sqrt{\frac{2\Delta y}{g}} = \sqrt{\frac{2(-2.80\,m)}{-9.80\,m/s^2}} = 0.756\,s$$

$$\boxed{0.756\,s}$$

(b) Calculate the initial speed with which the boy throws the apple. If you did not obtain an answer for (a), use a value of 0.800 s. (*3 marks*)

$$\Delta x = v_{0x} t$$

$$v_0 = v_{0x} = \frac{\Delta x}{t} = \frac{4.60\,m}{0.756\,s} = 6.09\,m/s$$

$$\boxed{6.09\,m/s}$$

ALT. VALUE: $\frac{4.60\,m}{0.800\,s} = 5.75\,m/s$

(b) Calculate the speed of the apple when the girl catches it at B. (*4 marks*)

$$\boxed{9.59\,m/s}$$

Method 1 (kinematics)

$$v_y = v_{0y} + a_y t$$

$$v_y = -gt$$

$$v_y = (-9.80\,m/s^2)(0.756\,s)$$

$$v_y = -7.41\,m/s$$

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(6.09\,m/s)^2 + (-7.41\,m/s)^2}$$

$$v = 9.59\,m/s$$

Method 2 (Cons. of Mechanical Energy)

$W_{nc} = 0$ so $E_f = E_i$

Choose B as reference height

$$KE_A + PE_{gA} = KE_B + PE_{gB}$$

$$\frac{1}{2} m v_0^2 + mg|\Delta y| = \frac{1}{2} m v^2 + 0$$

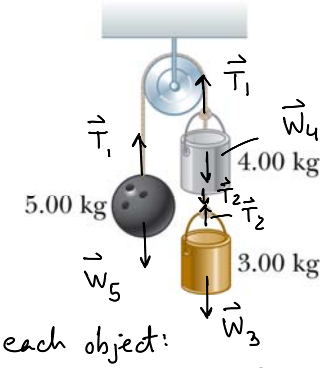
$$v = \sqrt{v_0^2 + 2g|\Delta y|}$$

$$v = \sqrt{(6.09\,m/s)^2 + 2(9.80\,m/s^2)(2.80\,m)}$$

$$v = 9.59\,m/s$$

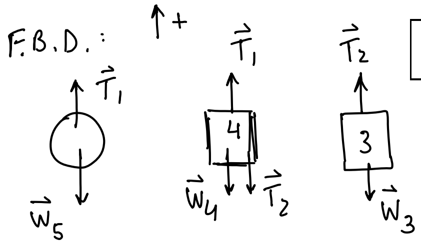
continued on page 6...

B2. Three objects are connected by massless strings as shown. The string connecting the 5.00-kg object and the 4.00-kg object passes over a massless frictionless pulley.



(a) Calculate the acceleration of the objects. (*4 marks*)

F.B.D.: $\uparrow +$



$\boxed{1.63\ m/s^2}$

$a = |a_3| = |a_4| = |a_5|$

Apply Newton II to each object:

$T_1 - w_5 = m_5 a \Rightarrow T_1 = m_5 a + w_5$ ①

$T_1 - w_4 - T_2 = m_4(-a)$ ②

$T_2 - w_3 = m_3(-a) \Rightarrow T_2 = -m_3 a + w_3$ ③

Substituting ① and ③ into ② yields:

$m_5 a + w_5 - w_4 - (-m_3 a + w_3) = -m_4 a$

$m_5 a + m_3 a + m_4 a = w_3 + w_4 - w_5$

$a = \left(\dfrac{m_3 + m_4 - m_5}{m_3 + m_4 + m_5}\right) g = \left(\dfrac{2.00\ kg}{12.00\ kg}\right)(9.80\ m/s^2) = 1.63\ m/s^2$

ALT. METHOD: Treating the 3 masses as a system: $\Sigma \vec{F} = m\vec{a}$

$w_3 + w_4 - w_5 = m_{tot} a$

$a = \dfrac{m_3 + m_4 - m_5}{m_3 + m_4 + m_5} \cdot g$

(b) Calculate the tension in the string connecting the 4.00 kg and 3.00 kg objects. If you did not obtain an answer for (a), use a value of 1.50 m/s². (*3 marks*)

Using equation ③ from (a):

$\boxed{24.5\ N}$

$T_2 = -m_3 a + w_3$

$T_2 = -(3.00\ kg)(1.63\ m/s^2) + (3.00\ kg)(9.80\ m/s^2)$

$T_2 = 24.5\ N$

ALT. ANS: 24.9 N

(c) Calculate the tension in the string connecting the 5.00 kg and 4.00 kg objects. (*3 marks*)

Substituting into equation ① from (a):

$\boxed{57.2\ N}$

$T_1 = m_5 a + w_5$

$T_1 = (5.00\ kg)(1.63\ m/s^2) + (5.00\ kg)(9.80\ m/s^2)$

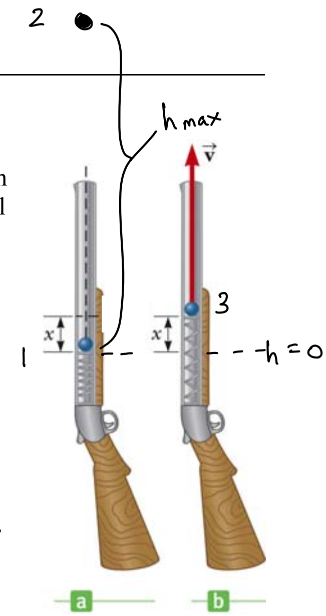
$T_1 = 57.2\ N$

ALT ANS.:

$T_1 = 56.5\ N$

continued on page 7...

B3. The launching mechanism of a toy gun consists of a spring of spring constant 544 N/m. The spring is compressed a distance $x = 0.120$ m from its equilibrium length and the gun is fired vertically. You may neglect all resistive forces.



(a) Calculate the maximum height (above its initial position on the compressed spring) to which the gun can launch a 20.0 g projectile. (*5 marks*)

$\boxed{20.0 \text{ m}}$

Initially, the projectile is at rest on the compressed spring. Finally, the projectile is momentarily at rest at maximum height. Mechanical energy is conserved.

$$E_1 = E_2 \Rightarrow KE_1 + PE_{grav_1} + PE_{spring_1} = KE_2 + PE_{grav_2} + PE_{spring_2}$$

$$0 + 0 + \tfrac{1}{2}kx^2 = 0 + mgh_{max} + 0$$

$$h_{max} = \frac{kx^2}{2mg}$$

$$h_{max} = \frac{(544 \text{ N/m})(0.120 \text{ m})^2}{2(20.0 \times 10^{-3} \text{ kg})(9.80 \text{ m/s}^2)} = 20.0 \text{ m}$$

(b) Calculate the speed of the projectile as it moves through the equilibrium (unstretched) position of the spring. (*5 marks*)

$\boxed{19.7 \text{ m/s}}$

Again using conservation of mechanical energy: $E_1 = E_3$

$$KE_1 + PE_{grav_1} + PE_{spring_1} = KE_3 + PE_{grav_3} + PE_{spring_3}$$

$$0 + 0 + \tfrac{1}{2}kx^2 = \tfrac{1}{2}mv^2 + mgx + 0$$

$$\tfrac{1}{2}mv^2 = \tfrac{1}{2}kx^2 - mgx \Rightarrow mv^2 = kx^2 - 2mgx$$

$$v^2 = \frac{k}{m}x^2 - 2gx \Rightarrow v = \sqrt{\frac{k}{m}x^2 - 2gx}$$

$$v = \sqrt{\left(\frac{544 \text{ N/m}}{20.0 \times 10^{-3} \text{ kg}}\right)(0.120 \text{ m})^2 - 2(9.80 \text{ m/s}^2)(0.120 \text{ m})}$$

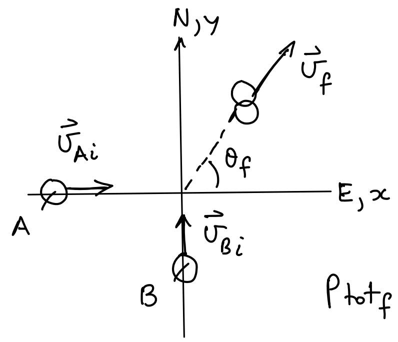
$$v = 19.7 \text{ m/s}$$

continued on page 8...

B4. Two pucks sliding on the ice collide. The pucks are coated with double-sided sticky-tape so that when they collide they stick together and slide as one. Before the collision puck A, with a mass of 0.300 kg, was moving toward the East at a speed of 3.00 m/s, while puck B, with a mass of 0.500 kg, was moving toward the North. After the collision the two pucks slide in the direction of 75.0° North of East. You may assume that the ice is frictionless.

(a) Calculate the speed of the two pucks sliding together after the collision. (*5 marks*)

$\boxed{4.35 \text{ m/s}}$



frictionless surface, $\sum \vec{F}_{ext} = 0$.

Linear momentum is conserved.

$\vec{P}_{tot_f} = \vec{P}_{tot_i}$

$P_{tot_{f\,x}} = P_{tot_{i\,x}}$ and $P_{tot_{fy}} = P_{tot_{iy}}$

$$(m_A + m_B)\,v_{fx} = m_A v_{Aix} + m_B v_{Bix}$$

$$(m_A + m_B)\,v_f \cos\theta_f = m_A v_{Ai} + 0$$

$$v_f = \frac{m_A v_{Ai}}{(m_A + m_B)\cos\theta_f} = \frac{(0.300\text{ kg})(3.00\text{ m/s})}{(0.300\text{ kg} + 0.500\text{ kg})\cos 75.0°}$$

$$v_f = 4.35\text{ m/s}$$

(b) Calculate the initial speed of puck B. If you did not obtain an answer for (a), use a value of 4.50 m/s. (*5 marks*)

$\boxed{6.72 \text{ m/s}}$

$$P_{tot_{fy}} = P_{tot_{iy}}$$

$$(m_A + m_B)\,v_{fy} = m_A v_{Aiy} + m_B v_{Biy}$$

$$(m_A + m_B)\,v_f \sin\theta_f = 0 + m_B v_B$$

$$v_B = \frac{(m_A + m_B)\,v_f \sin\theta_f}{m_B} = \frac{(0.300\text{ kg} + 0.500\text{ kg})(4.35\text{ m/s})(\sin 75.0°)}{0.500\text{ kg}}$$

$$v_B = 6.72\text{ m/s}$$

ALT. ANS: 6.95 m/s

END OF EXAMINATION