UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
MIDTERM TEST

October 23, 2014 Time: 90 minutes

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

LECTURE SECTION (please check):

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

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 NSID 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.

$= (2149613.\cancel{568} \pm 3) \times 10^{-4}$

C

A1. A computer data analysis program reports a result as 2 149 613 568 × 10^2, with an uncertainty of ±3 × 10^{-4}. How many significant figures should be used when the answer is reported?

(A) two (B) five (C) seven (D) eight (E) nine

C

A2. In lab M36 you measured the mass of a steel ball and also determined its initial speed when it was fired from a spring-loaded gun. Suppose that the percentage error in the mass was 2% and the percentage error in the initial speed was calculated to be 4%. Which one of the following options is the correct value for the percentage error in the initial momentum of the ball?

(A) 2% (B) 4% (C) 6% (D) 8% (E) 0.5%

$p = mv$; % err in product = Σ % errors $\Rightarrow$ 2% + 4% = 6%

A3. Which one of the following options is **not** a valid unit for energy?

E

(A) Joule (B) Newton·metre (C) Watt·second (D) kilowatt·hour (E) kg·m²/s³

$J = N \cdot m = kg \cdot m^2/s^2$ $W = J/s$, so [Power]×[time] = [Energy]

A4. An object is held outside an open window and released from rest. Air resistance can be neglected (the object is in free fall). Which one of the following statements correctly describes the motion of the object as it falls?

E

(A) The distance of the object from the release point increases linearly with time.
(B) The magnitude of the acceleration of the object increases linearly with time.
(C) The rate of change of the speed of the object increases linearly with time.
(D) The magnitude of the acceleration of the object decreases as it approaches the ground.
(E) The speed of the object increases linearly with time.

Constant downward acceleration $\Rightarrow$ $v \uparrow$ linearly with time ($v = v_0 + at$)

A5. A ball is thrown over level ground at an angle of θ above the horizontal. 0° < θ < 90°. Which one of the following statements is true when the ball is at maximum height?

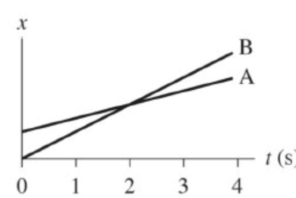
E

(A) Both the speed and acceleration of the ball are zero.
(B) The speed of the ball is zero, but the magnitude of the acceleration is not zero.
(C) The acceleration of the ball is zero, but the speed is not zero.
(D) The speed of the ball is not zero and the magnitude of the acceleration may or may not be zero, depending on the value of θ.
(E) Both the speed and the magnitude of the acceleration of the ball are not zero.

$\vec{a}$ is constant throughout free fall motion, $\vec{v}$ is horizontal at max. height.

E

A6. Two objects, A and B, are moving along the x-axis. The graph shows their positions as a function of time. At what time(s) do the two objects have the same velocity?

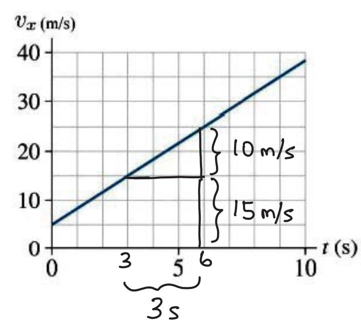


(A) at t = 0 s (B) at t = 2 s (C) at t = 4 s
(D) Always (E) Never

velocity = slope of x vs. t.

A

A7. Which one of the following options is true for the magnitude of the displacement Δx between t = 3.0 s and t = 6.0 s for an object that is moving as described by the plot of v_x vs. t?



(A) 60 m (B) 90 m (C) 150 m
(D) 160 m (E) 270 m

Δx = area under v_x vs. t

$= 15\,m/s \cdot 3\,s + \frac{1}{2}(3\,s)(10\,m/s) = 60\,m$

continued on page 3...

A8. A small car collides with a large truck. Which one of the following statements is true?

C

(A) The magnitude of the force that the truck exerts on the car is greater than the magnitude of the force that the car exerts on the truck.
(B) The magnitude of the force that the truck exerts on the car is smaller than the magnitude of the force that the car exerts on the truck.
(C) The forces that the two vehicles exert on each other are equal in magnitude.
(D) The relationship between the forces that the two vehicles exert on each other depends on the vehicles' masses.
(E) The relationship between the forces that the two vehicles exert on each other depends on the vehicles' initial speeds.

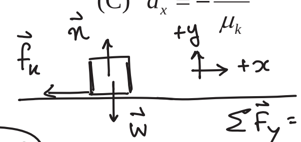
Newton III : $|\vec{F}_{\text{truck on car}}| = |\vec{F}_{\text{car on truck}}|$

A9. A book, with mass m, is sliding on a horizontal table surface following a push that gave it an initial velocity v_0 in the positive x direction. If the coefficient of kinetic friction between the book and the surface is μ_k, the acceleration of the book while it is sliding is

B

(A) $a_x = -\mu_k mg$ (B) $a_x = -\mu_k g$ (C) $a_x = -\dfrac{mg}{\mu_k}$

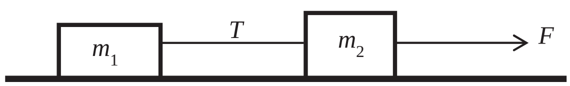
(D) $a_x = -\dfrac{g}{\mu_k}$ (E) $a_x = -\dfrac{\mu_k g}{m}$



$\Sigma F_x = ma_x \Rightarrow -f_k = ma_x$ $\Sigma \vec{F}_y = 0 \Rightarrow n = w = mg$
$-\mu_k mg = ma_x \Rightarrow \boxed{a_x = -\mu_k g}$

A10. Two blocks, with masses m_1 and m_2, on a horizontal frictionless surface, are tied together with string and pulled by a constant horizontal force of magnitude F as shown. If we can ignore the mass of the string, how is the magnitude of the tension T in the string between the blocks related to F?

C



Both blocks have the same accel'n
$F = (m_1 + m_2)a$
$a = \dfrac{F}{m_1 + m_2}$

(A) $T = F$ (B) $T = \dfrac{m_2}{m_1 + m_2}F$ (C) $T = \dfrac{m_1}{m_1 + m_2}F$

(D) $T = \dfrac{m_2}{m_1}F$ (E) $T = \dfrac{m_1}{m_2}F$

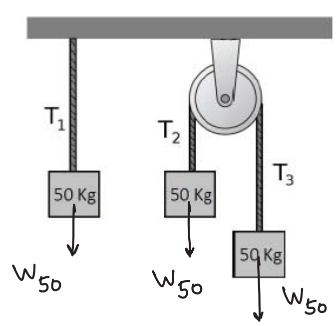
$\boxed{T = m_1 a = \dfrac{m_1}{m_1 + m_2} \cdot F}$

A11. All three of the 50 kg blocks shown in the figure are at rest. Which one of the following options is the correct relationship between the magnitudes of the tension forces T_1, T_2, and T_3?

E

(A) $T_2 > T_3 > T_1$
(B) $T_3 > T_2 > T_1$
(C) $T_2 = T_3 > T_1$
(D) $T_2 = T_3 < T_1$
(E) $T_1 = T_2 = T_3$

$T_1 = T_2 = T_3$ = weight of 50 kg



A12. If particle 2 has a momentum whose magnitude is twice as large as that of particle 1, under what condition would the two particles have the same kinetic energy?

D

(A) $m_2 = 0$ (B) $m_2 = m_1$ (C) $m_2 = 2m_1$ (D) $m_2 = 4m_1$ (E) $m_1 = 0$

$p_2 = 2p_1$; recall that $KE = \dfrac{p^2}{2m}$; want $KE_2 = KE_1$

$\dfrac{p_2^2}{\cancel{2}m_2} = \dfrac{p_1^2}{\cancel{2}m_1} \Rightarrow \dfrac{(2p_1)^2}{m_2} = \dfrac{p_1^2}{m_1} \Rightarrow \dfrac{4}{m_2} = \dfrac{1}{m_1}$

continued on page 4...

$\boxed{m_2 = 4m_1}$

A13. Eugenie Bouchard receives a shot with the tennis ball (m = 60.0 g) travelling horizontally at 40.0 m/s and returns it in the opposite direction with a speed of 50.0 m/s. What is the magnitude of the impulse delivered to the ball by the racket?

D

O→ $\vec{v}_i$ (+ve) ←O $\vec{v}_f$ (-ve)

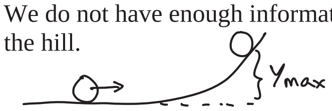
(A) 0.6 kg·m/s (B) 2.4 kg·m/s (C) 3.0 kg·m/s (D) 5.4 kg·m/s (E) 7.5 kg·m/s

$$|I| = |F\Delta t| = |\Delta p| = |p_f - p_i| = |mv_f - mv_i| = |m(v_f - v_i)| = |(0.060\,kg)(-50.0\,m/s - 40.0\,m/s)| \boxed{= 5.4\ kg\cdot m/s}$$

A14. A golf ball and a Ping-Pong ball are sliding with equal velocities over a horizontal frictionless surface. The golf ball has the greater kinetic energy because it has the greater mass. They encounter a frictionless hill and slow down as they slide up it. Which one of the following statements is correct?

D

(A) The golf ball slides to a greater height than the Ping-Pong ball since it has the greater kinetic energy.
(B) The Ping-Pong ball slides to a greater height than the golf ball since it has the smaller weight.
(C) The Ping-Pong ball slides to a greater height than the golf ball since the work done by gravity on it is less.
(D) Both the golf ball and the Ping-Pong ball slide to the same height since the result is independent of the mass.
(E) We do not have enough information to decide since the result will depend on the slope of the hill.



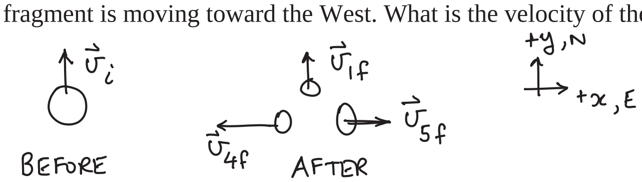
Cons. of Mech. Energy: $\frac{1}{2}mv^2 + 0 = 0 + mgy_{max}$

$$\boxed{y_{max} = v^2/2g}$$

A15. A small bomb with a total mass of 10 kg is moving toward the North with a speed of 4 m/s. It explodes into three fragments. After the explosion it is observed that a 5 kg fragment is moving toward the East, while a 4 kg fragment is moving toward the West. What is the velocity of the third 1 kg fragment?

C

(A) Zero.
(B) 4 m/s North.
(C) 40 m/s North.
(D) 40 m/s South.
(E) It is impossible to determine since we are not given the speeds of the other two fragments.



momentum must be conserved in both the x (E-W) and y (N-S) directions.

In the y-dir'n: $p_{tot_{i_y}} = +(10\,kg)(4\,m/s) = 40\ kg\cdot m/s$

$p_{tot_{f_y}} = +(1\,kg)(v_{1f})$

$p_{tot_{i_y}} = p_{tot_{f_y}} \Rightarrow \boxed{v_{1f} = +40\,m/s}$ North

PART B

ANSWER <u>THREE</u> OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND <u>INDICATE ON THE COVER PAGE WHICH THREE PART B QUESTIONS ARE TO BE MARKED</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.

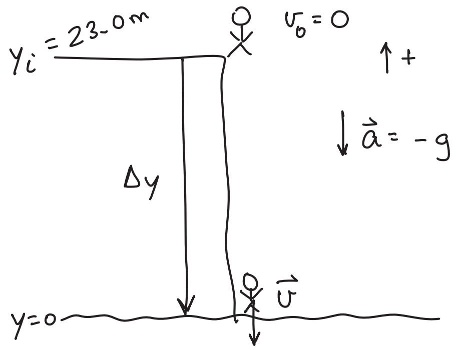
EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

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

continued on page 5...

B1. A stuntperson steps off a bridge and falls vertically to the water 23.0 m below.

(a) Calculate the time between the stuntperson stepping off the bridge and contacting the water. (*4 marks*)



Choose UP to be the +ve direction.

$\boxed{2.17\,\text{s}}$

$\Delta y = -23.0\,\text{m}$

$a = -9.80\,\text{m/s}^2$

$v_0 = 0$

$$\Delta y = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2\Delta y}{a}} = \sqrt{\frac{2(-23.0\,\text{m})}{-9.80\,\text{m/s}^2}} = 2.17\,\text{s}$$

(b) Calculate the speed of the stuntperson just before hitting the water. (*3 marks*)

$\boxed{21.2\,\text{m/s}}$

$$v^2 = v_0^2 + 2a\Delta y$$

$$v^2 = 0 + 2a\Delta y$$

$$v = \sqrt{2a\Delta y}$$

$$v = \sqrt{2(-9.80\,\text{m/s}^2)(-23.0\,\text{m})}$$

$$v = 21.2\,\text{m/s}$$

ALT. METHOD:

Ignoring air resistance, $W_{nc} = 0$

$\therefore E_{mechanical}$ is conserved.

$$E_f = E_i$$

$$KE_f + PE_{grav_f} = KE_i + PE_{grav_i}$$

$$\frac{1}{2}\cancel{m}v_f^2 + 0 = 0 + \cancel{m}gy_i$$

$$v_f^2 = 2gy_i$$

$$v_f = \sqrt{2gy_i} = 21.2\,\text{m/s}$$

(c) If the speed of sound in air is 343 m/s, calculate the time after the stuntperson stepped off the bridge until an observer on the bridge heard the splash. If you did not obtain an answer for (a), use a value of 2.20 s. (*3 marks*)

$\boxed{2.24\,\text{s}}$

$$t_{total} = t_{fall} + t_{sound}$$

$t_{fall} = 2.17\,\text{s}$ from (a)

Speed of sound is constant. $v_{sound} = \dfrac{|\Delta y|}{t_{sound}} \Rightarrow t_{sound} = \dfrac{|\Delta y|}{v_{sound}}$

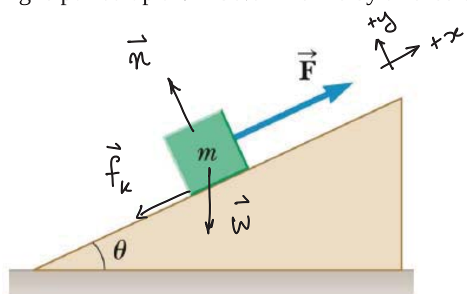
$$t_{sound} = \frac{23.0\,\text{m}}{343\,\text{m/s}} = 0.0671\,\text{s}$$

(ALT. ANS.: 2.27 s)

$$t_{total} = 2.17\,\text{s} + 0.0671\,\text{s} = 2.24\,\text{s}$$

continued on page 6...

B2. A block of mass m = 5.00 kg is pulled up a θ = 30.0° incline by a force of magnitude F = 30.0 N, as shown in the diagram.



(a) On the diagram above, show all the forces acting on the block, including friction. Be sure to label the diagram appropriately. (*3 marks*)

(b) Assuming that the incline is frictionless, calculate the acceleration of the block. (*3 marks*)

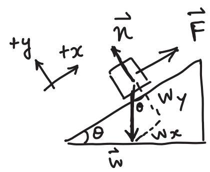
With no friction, the forces along the incline are $\vec{F}$ and the x-component of the weight.

$\boxed{1.10 \text{ m/s}^2}$

$\Sigma F_x = ma_x$

$+F - w\sin\theta = ma_x$

$F - mg\sin\theta = ma_x$



$W_x = -W\sin\theta$

$W = mg$

$$a_x = \frac{F - mg\sin\theta}{m} = \frac{30.0\text{N} - (5.00\text{kg})(9.80\text{m/s}^2)\sin 30.0°}{5.00\text{ kg}} = 1.10 \text{ m/s}^2$$

(c) Now consider the situation when there **is** friction between the block and the incline. If the block is being pulled up the incline at a constant speed, calculate the coefficient of kinetic friction between the block and the incline. (*4 marks*)

Constant speed in a straight line ⇒ $a = 0$

With friction, Newton II in the x-direction becomes:

$\boxed{0.130}$

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$+F - mg\sin\theta - f_k = 0$

$+n - mg\cos\theta = 0$

$n = mg\cos\theta$

$F - mg\sin\theta - \mu_k n = 0$

$F - mg\sin\theta - \mu_k mg\cos\theta = 0$

$F - mg\sin\theta = \mu_k mg\cos\theta$

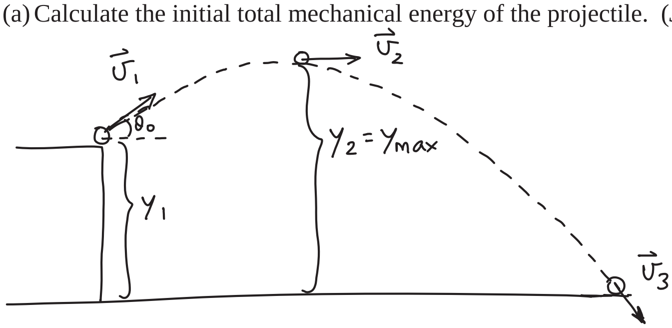
$$\mu_k = \frac{F - mg\sin\theta}{mg\cos\theta} = \frac{30.0\text{N} - (5.00\text{kg})(9.80\text{m/s}^2)\sin 30.0°}{(5.00\text{kg})(9.80\text{ m/s}^2)\cos 30.0°}$$

$\mu_k = 0.130$

continued on page 7...

B3. A 50.0-kg projectile is fired at an angle of 30.0° above the horizontal, with an initial speed of 121 m/s, from the top of a cliff 142 m above level ground. The ground is taken to be $y = 0$.

(a) Calculate the initial total mechanical energy of the projectile. (*3 marks*)



$\boxed{4.36 \times 10^5 \text{ J}}$

$$E_1 = KE_1 + PE_1 = \frac{1}{2}mv_1^2 + mgy_1$$

$$E_1 = \frac{1}{2}(50.0\,\text{kg})(121\,\text{m/s})^2 + (50.0\,\text{kg})(9.80\,\text{m/s}^2)(142\,\text{m})$$

$$E_1 = 4.36 \times 10^5 \text{ J}$$

(b) Suppose the projectile is traveling at a speed of 85.0 m/s at its maximum height of $y = 427$ m. Calculate the work that has been done on the projectile by air friction between launch and maximum height. If you did not obtain an answer for (a), use a value of 4.40×10^5 J. (*3 marks*)

Air friction is a non-conservative force.

$\boxed{-4.61 \times 10^4 \text{ J}}$

$$E_1 + W_{nc} = E_2$$

$$W_{nc} = E_2 - E_1 = \frac{1}{2}mv_2^2 + mgy_2 - E_1$$

$$W_{nc} = \frac{1}{2}(50.0\,\text{kg})(85.0\,\text{m/s})^2 + (50.0\,\text{kg})(9.80\,\text{m/s}^2)(427\,\text{m}) - 4.36 \times 10^5 \text{ J}$$

$$W_{nc} = -4.61 \times 10^4 \text{ J}$$

ALT. ANS.: -5.01×10^4 J

(c) Calculate the speed of the projectile just before it hits the ground if air friction does one and a half times as much work on the projectile when it is going down as it did when it was going up. If you did not obtain an answer for (b), use a value of -4.60×10^4 J. (*4 marks*)

$\boxed{113 \text{ m/s}}$

$$E_2 + W_{nc_{2-3}} = E_3$$

Told that $W_{nc_{2-3}} = 1.5\, W_{nc_{1-2}}$

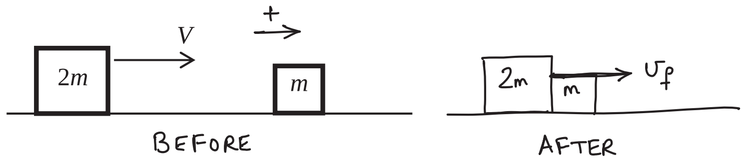
$$\frac{1}{2}mv_2^2 + mgy_2 + 1.5\, W_{nc_{1-2}} = \frac{1}{2}mv_3^2 + 0$$

$$v_3^2 = v_2^2 + 2gy_2 + \frac{2(1.5)\, W_{nc_{1-2}}}{m}$$

$$v_3 = \sqrt{(85.0\,\text{m/s})^2 + 2(9.80\,\text{m/s}^2)(427\,\text{m}) + \frac{3(-4.61 \times 10^4 \text{ J})}{50.0\,\text{kg}}} = 113 \text{ m/s}$$

continued on page 8...

B4. A box, of mass $2m$, slides with a speed V on a horizontal frictionless surface and collides head-on with another box, which has a mass m and is initially stationary. When they collide, the two boxes stick together and slide as one in the same direction as the initial velocity of the first box.



(a) Derive an expression for the speed of the two boxes after the collision. Your answer may only contain symbols given in the statement of the question. (*5 marks*)

frictionless $\Rightarrow \Sigma F_{ext} = 0$, so momentum is conserved.

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

$\boxed{v_f = \frac{2}{3}V}$

boxes stick together (perfectly inelastic collision), so $v_{f_1} = v_{f_2} = v_f$

$(m + 2m)\, v_f = 2m \cdot V + m \cdot 0$

$$v_f = \frac{2m \cdot V}{3m}$$

$$v_f = \frac{2}{3}V$$

(b) Derive an expression for the change in the kinetic energy of the two-box system during the collision. i.e. derive an expression for $\Delta KE = KE_{final} - KE_{initial}$. Your answer may only contain symbols given in the statement of the question. (*5 marks*)

$\Delta KE = KE_f - KE_i$

$\boxed{\Delta KE = -\frac{1}{3}mV^2}$

$$\Delta KE = \frac{1}{2}(m + 2m)\left(\frac{2}{3}V\right)^2 - \frac{1}{2}(2m)V^2$$

$$\Delta KE = \frac{1}{2} \cdot 3m \cdot \frac{4}{9}V^2 - mV^2$$

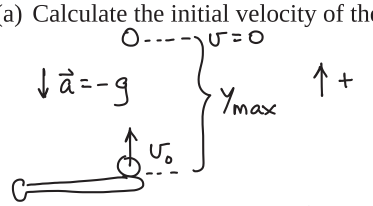
$$\Delta KE = \frac{12}{18}mV^2 - mV^2 = -\frac{6}{18}mV^2$$

$$\Delta KE = -\frac{1}{3}mV^2$$

END OF EXAMINATION

B1. A baseball is deflected straight up after striking the bat, which is held by the hitter at a height of 1.40 m above the ground. The ball travels vertically for 4.00 s before reaching its maximum height.

(a) Calculate the initial velocity of the ball when it loses contact with the bat. (*3 marks*)



$\boxed{39.2\ \text{m/s}}$

$$v = v_0 + at$$

$$0 = v_0 - gt$$

$$v_0 = gt = (9.80\ \text{m/s}^2)(4.00\text{s}) = 39.2\ \text{m/s}$$

(b) Calculate the maximum height above the ground reached by the ball. If you did not obtain an answer for (a), use a value of 40.0 m/s. (*4 marks*)

$\boxed{79.8\text{m}}$

$v^2 = v_0^2 + 2a y_{max}$; y_{max} = height above bat

$$0 = v_0^2 + 2(-g)(y_{max})$$

$$2g y_{max} = v_0^2$$

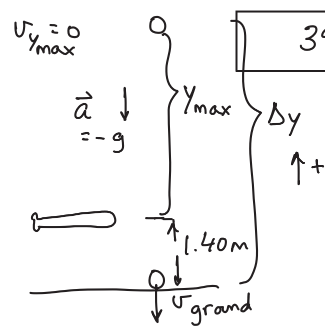
$$y_{max} = \frac{v_0^2}{2g} = \frac{(39.2\text{m/s})^2}{2(9.80\ \text{m/s}^2)} = 78.4\text{m}$$

Δy = height above ground = $1.40\text{m} + 78.4\text{m} = 79.8\text{m}$

ALT. ANS.: 83.0 m

(c) Calculate the speed of the ball just before it hits the ground. If you did not obtain an answer for (b), use a value of 80.0 m. (*3 marks*)

$\boxed{39.5\ \text{m/s}}$



$$v_{ground}^2 = v_{y_{max}}^2 + 2a\Delta y$$

$$v_{ground}^2 = 0 + 2(-g)(\Delta y)$$

$$v_{ground} = \sqrt{2(-g)(\Delta y)}$$

$$v_{ground} = \sqrt{2(-9.80\text{m/s}^2)(-79.8\text{m})}$$

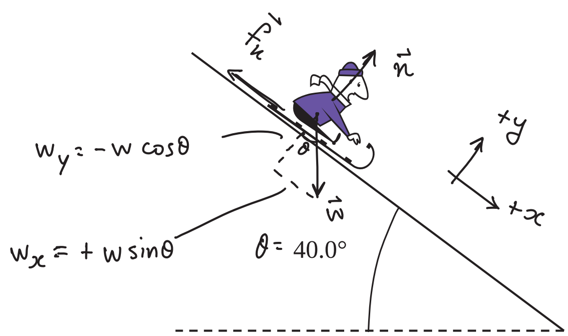
$$v_{ground} = 39.5\ \text{m/s}$$

ALT. ANS.: 39.6 m/s

continued on page 6...

B2. A man on a sled slides down a snow-covered slope which makes a constant angle of 40.0° with the horizontal. As he slides, his speed increases. It is found that the magnitude of his acceleration down the slope is 5.30 m/s^2.

(a) On the diagram provided below, draw a labelled free body diagram showing all the forces on the sled as it slides (Consider the man and sled as one object.) (*3 marks*)



(b) Calculate the coefficient of kinetic friction between the sled and the snow. (*7 marks*)

$\boxed{\mu_k = 0.133}$

$\Sigma\vec{F} = m\vec{a}$

$\vec{a}$ occurs along the slope, choose this as the $+x$- direction.

$\therefore \quad \Sigma F_x = ma$ and $\Sigma F_y = 0$

$+w\sin\theta - f_k = ma$ $\qquad n - w\cos\theta = 0$

$mg\sin\theta - \mu_k n = ma$ $\qquad n = w\cos\theta$

$\cancel{m}g\sin\theta - \mu_k \cancel{m}g\cos\theta = \cancel{m}a$ $\qquad n = mg\cos\theta$

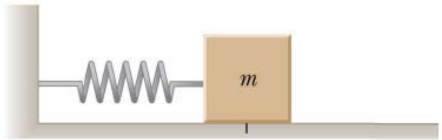
$g\sin\theta - a = \mu_k g\cos\theta$

$$\mu_k = \frac{g\sin\theta - a}{g\cos\theta} = \frac{(9.80\,\text{m/s}^2)(\sin 40.0°) - 5.30\,\text{m/s}^2}{(9.80\,\text{m/s}^2)(\cos 40.0°)}$$

$\mu_k = 0.133$

continued on page 7...

B3. A 0.500-kg wood block on a horizontal table is firmly attached to a very light horizontal spring (k = 181 N/m) as shown. It is noted that the block-spring system, when initially compressed 5.00 cm and released, stretches to a distance of 2.50 cm beyond the equilibrium point before stopping and moving back.



(a) Calculate the magnitude of the force of kinetic friction between the block and the table. (*5 marks*)

friction is a non-conservative force

$\therefore W_{nc} \neq 0$

$E_1 + W_{nc} = E_2$

Let 1 be when the spring is compressed $x_1 = 5.00$ cm and the mass is not moving

$\frac{1}{2}kx_1^2 + W_{nc} = \frac{1}{2}kx_2^2$

Let 2 be when the spring is stretched $x_2 = 2.50$ cm and the mass is not moving

$W_{nc} = \frac{1}{2}k(x_2^2 - x_1^2)$

Note that $W_{nc} = W_{fr} = f_k(\cos 180°)(x_1 + x_2) = -f_k(x_1 + x_2)$

$\therefore -f_k(x_1+x_2) = \frac{1}{2}k(x_2^2 - x_1^2)$

$$f_k = -\frac{\frac{1}{2}k(x_2^2 - x_1^2)}{x_1 + x_2} = -\frac{1}{2}k(x_2 - x_1) = \frac{1}{2}k(x_1 - x_2)$$

$$f_k = \frac{1}{2}(181\text{ N/m})(0.0500\text{ m} - 0.0250\text{ m}) = 2.26\text{ N}$$

(b) Calculate the speed of the block when it first passes the equilibrium position. If you did not obtain an answer for (a), use a value of 2.00 N. (*5 marks*)

$\boxed{0.673 \text{ m/s}}$

Now let 1 be when the spring is compressed 5.00 cm and the mass is at rest

Let 2 be when the spring is relaxed and the mass passes through the equilibrium position

$E_1 + W_{nc} = E_2$

$\frac{1}{2}kx_1^2 + f_k(\cos 180°)(x_1) = \frac{1}{2}mv_2^2$

$\frac{1}{2}kx_1^2 - f_kx_1 = \frac{1}{2}mv_2^2$

$kx_1^2 - 2f_kx_1 = mv_2^2$

$$v_2 = \sqrt{\frac{kx_1^2 - 2f_kx_1}{m}} = \sqrt{\frac{(181\text{ N/m})(0.0500\text{ m})^2 - 2(2.26\text{ N})(0.0500\text{ m})}{0.500\text{ kg}}}$$

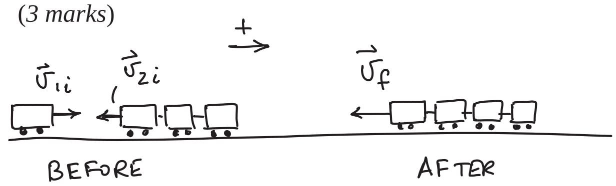
$v_2 = 0.673$ m/s

ALT. ANS.: 0.667 m/s

continued on page 8...

B4. A railroad car (mass $m = 1.80 \times 10^4$ kg), initially moving at 4.21 m/s, collides with a group of three joined railroad cars (each of the same mass as the single car). The group of three cars is initially travelling at 2.15 m/s in the direction opposite to that of the single car. After the collision all four cars are joined together.

(a) Calculate the magnitude of the momentum of the four coupled cars after the collision. (*3 marks*)



$\boxed{4.03 \times 10^4 \text{ kg}\cdot\text{m/s}}$

Assume that $\sum \vec{F}_{ext} = 0$ during the collision. Then momentum is conserved

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

$$P_{tot_f} = m \cdot v_{1i} + 3m \cdot v_{2i}$$

$$P_{tot_f} = m(v_{1i} + 3v_{2i}) = (1.80 \times 10^4 \text{ kg})(+4.21 \text{ m/s} + 3(-2.15 \text{ m/s}))$$

$$P_{tot_f} = -4.03 \times 10^4 \text{ kg}\cdot\text{m/s} \; ; \; |P_{tot_f}| = 4.03 \times 10^4 \text{ kg}\cdot\text{m/s}$$

(b) Calculate the speed of the four coupled cars after the collision. If you did not obtain an answer for (a), use a value of 4.00×10^4 kg·m/s. (*3 marks*)

$\boxed{0.560 \text{ m/s}}$

$$P_{tot_f} = m_{tot} v_f$$

$$P_{tot_f} = 4m v_f$$

$$v_f = \frac{P_{tot_f}}{4m} = \frac{-4.03 \times 10^4 \text{ kg}\cdot\text{m/s}}{4(1.80 \times 10^4 \text{ kg})} = -0.560 \text{ m/s}$$

$$\text{speed} = |v_f| = 0.560 \text{ m/s}$$

(c) Calculate the kinetic energy that is lost in the collision. If you did not obtain an answer for (b), use a value of 0.500 m/s. (*4 marks*)

$\boxed{2.73 \times 10^5 \text{ J}}$

$$\Delta KE = KE_f - KE_i$$

$$\Delta KE = \frac{1}{2} m_{tot} v_f^2 - \left(\frac{1}{2} m v_{1i}^2 + \frac{1}{2} 3m v_{2i}^2\right)$$

$$\Delta KE = \frac{1}{2} \cdot 4m \cdot v_f^2 - \frac{1}{2} m v_{1i}^2 - \frac{1}{2} \cdot 3m v_{2i}^2$$

$$\Delta KE = \frac{1}{2} \cdot m \left(4v_f^2 - v_{1i}^2 - 3v_{2i}^2\right)$$

$$\Delta KE = \frac{1}{2}(1.80 \times 10^4 \text{ kg})\left(4(0.560 \text{ m/s})^2 - (4.21 \text{ m/s})^2 - 3(2.15 \text{ m/s})^2\right)$$

$$\Delta KE = -2.73 \times 10^5 \text{ J} \qquad \therefore \text{lost KE} = 2.73 \times 10^5 \text{ J}$$

ALT. ANS.: 2.75×10^5 J

END OF EXAMINATION