UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
MIDTERM TEST

October 22, 2015 Time: 90 minutes

NAME: SOLUTIONS STUDENT NO.: ____________

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

LECTURE SECTION (please check):

- ❑ 01 Dr. M. Ghezelbash
- ❑ 02 Dr. D. Janzen
- ❑ 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.

B

A1. Which one of the following options correctly expresses the result for b when $b = (4.905\ \mathrm{m/s^2})(2.10\ \mathrm{s})^2$?

(A) 21.6 m/s (B) 21.6 m (C) 21.63 m (D) 21.63 m/s (E) 22 m/s

SIG. FIGS: 3 ; UNITS: $\mathrm{m/s^2} \cdot (\mathrm{s})^2 = \mathrm{m}$; $b = (4.905\,\mathrm{m/s^2})(2.10\,\mathrm{s})^2 = 21.6\,\mathrm{m}$

A

A2. Newton's law of universal gravitation is represented by $F = G\dfrac{Mm}{r^2}$, where F is the gravitational force, M and m are masses, and r is a distance. What are the SI units of the proportionality constant G?

(A) $\mathrm{m^3\,kg^{-1}\,s^{-2}}$ (B) $\mathrm{m^2\,kg^{-1}\,s^{-2}}$ (C) $\mathrm{m^3\,kg^{-1}\,s^{-3}}$ (D) $\mathrm{m^2\,kg^{-1}\,s^{-3}}$ (E) $\mathrm{m^2\,kg^{-2}\,s^{-2}}$

$G = \dfrac{Fr^2}{Mm} \Rightarrow [G] = \dfrac{\mathrm{N\cdot m^2}}{(\mathrm{kg})(\mathrm{kg})} = \dfrac{(\mathrm{kg\cdot m/s^2})\mathrm{m^2}}{\mathrm{kg^2}} = \dfrac{\mathrm{m^3/s^2}}{\mathrm{kg}} = \mathrm{m^3\,kg^{-1}\cdot s^{-2}}$

C

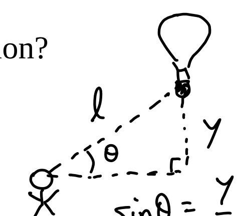
A3. Based on its apparent size, you estimate that a hot air balloon is a distance ℓ from your eyes. You also estimate that when looking directly at the distant balloon, your line of sight is at an angle of θ above the horizontal. Which one of the following expressions is correct for the altitude of the balloon above your eyes?

(A) $\ell\tan\theta$ (B) $\dfrac{\ell}{\tan\theta}$ (C) $\ell\sin\theta$ (D) $\ell\cos\theta$ (E) $\dfrac{\ell}{\cos\theta}$

D

A4. In which one of the following scenarios does ~~the~~ an object in straight-line motion have a positive acceleration?

(A) Object moving in positive direction at constant speed. $\Rightarrow a = 0$
(B) Object moving in negative direction at constant speed.
(C) Object moving in positive direction with decreasing speed. $\vec{a}$ opposite to $\vec{v}$
(D) Object moving in negative direction with decreasing speed.
(E) Object moving in negative direction with increasing speed.
$\vec{a}$ same direction as $\vec{v}$



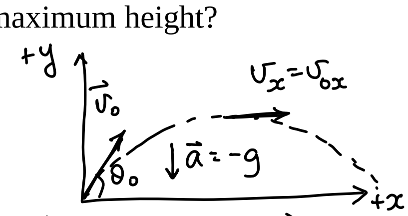
$\sin\theta = \dfrac{y}{\ell}$

$y = \ell\sin\theta$

C

A5. A ball is thrown over level ground at an angle of 60° above the horizontal with an initial speed of v_0. Which one of the following statements is **TRUE** when the ball is at maximum height?

(A) Both the velocity and acceleration of the ball are zero.
(B) The speed of the ball is v_0 and its acceleration is g downward.
(C) The speed of the ball is $\frac{1}{2}v_0$ and its acceleration is g downward.
(D) The speed of the ball is zero and its acceleration is g downward.
(E) The speed of the ball is $\frac{1}{2}v_0$ and its acceleration is zero.

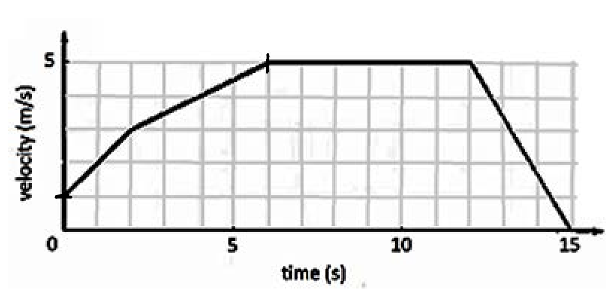


At max. height $\vec{v} = v_x$

$v_x = v_0\cos\theta_0 = v_0\cos 60° = \frac{1}{2}v_0$

D

A6. The graph below shows the velocity versus time for an object moving in one dimension. What is the object's average acceleration between $t = 0$ s and $t = 6$ s?



$\bar{\vec{a}} = \dfrac{\Delta v}{\Delta t}$

$\bar{\vec{a}} = \dfrac{+5.0\,\mathrm{m/s} - (+1.0\,\mathrm{m/s})}{6.0\,\mathrm{s}}$

$\bar{\vec{a}} = +0.67\,\mathrm{m/s^2}$

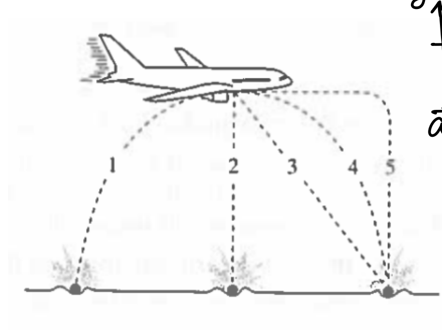
(A) $3.0\ \mathrm{m/s^2}$ (B) $1.5\ \mathrm{m/s^2}$ (C) $0.83\ \mathrm{m/s^2}$ (D) $0.67\ \mathrm{m/s^2}$ (E) $0.50\ \mathrm{m/s^2}$

continued on page 3...

 Stu. No.: ______________________

A7. A bowling ball accidently falls out of the cargo bay of an airliner as it flies in a horizontal direction. As observed by a person standing on the ground and viewing the plane as in the figure below, which of the paths 1-5 would the bowling ball most closely follow after leaving the airplane?

D



+y +x

$\vec{a}$

v_x = constant

$v_y = 0 + a_y t$

Parabolic, projectile motion.

(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

A8. A person pulls a block across a rough horizontal surface at a constant speed by applying a force *F*. The arrows in the diagram below correctly indicate the directions, but not necessarily the magnitudes, of the various forces on the block. Which one of the following relations among the force magnitudes *w*, f_k, *n*, and *F* must be true?

D

Constant speed in straight line

$\Rightarrow \vec{a} = 0 \Rightarrow \Sigma\vec{F} = 0$

$\Sigma F_x = 0 \Rightarrow F\cos\theta = f_k$

$\therefore F = \frac{f_k}{\cos\theta}$

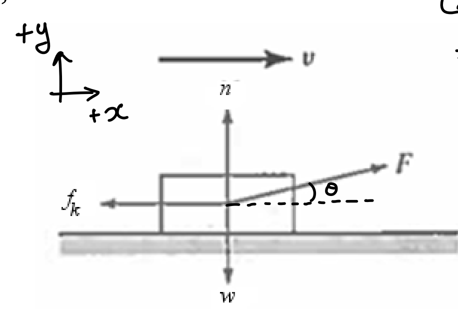
$\therefore F > f_k$

$\Sigma F_y = 0$

$n + F\sin\theta - w = 0$

$n = w - F\sin\theta$

$n < w$



(A) $F = f_k$ and $n = w$ (B) $F = f_k$ and $n > w$ (C) $F = f_k$ and $n < w$
(D) $F > f_k$ and $n < w$ (E) $F > f_k$ and $n = w$

A9. The velocity of an object as a function of time is shown in the graph directly below. Which one of the force versus time graphs best represents the net force vs. time relationship for this object?

E

When $\vec{v}$ is constant, $\vec{F}_{net} = 0$

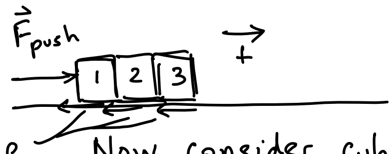
When $\vec{v}$ is positive and increasing linearly with time, $\vec{a}$, and $\therefore \vec{F}_{net}$, are constant and positive

(A) (B) (C) (D) (E)

A10. Three identical 6.0-kg cubes are placed on a horizontal surface in contact with one another. The cubes are lined up from left to right and a 36-N force is applied to the left side of the left cube, causing all three cubes to accelerate to the right. If the cubes are each subject to a frictional force of 6.0 N, what is the magnitude of the force exerted on the middle cube by the left cube?

B

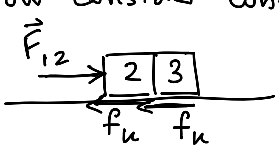
(A) 12 N (B) 24 N (C) 36 N (D) 30 N (E) 6.0 N



Consider all 3 cubes as a system:

$\Sigma\vec{F} = m\vec{a} \Rightarrow +36\text{N} - 3(6.0\text{N}) = (18.0\text{kg})a \Rightarrow a = 1.0\text{m/s}^2$

Now consider cubes 2 and 3 together:

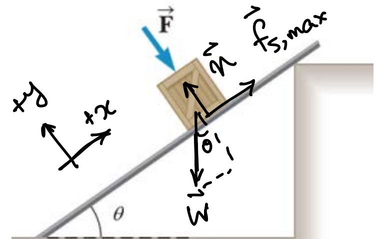


$\Sigma\vec{F} = m\vec{a} \Rightarrow F_{12} - 2f_k = 2m\cdot a$

$F_{12} = (12.0\text{kg})(1.0\text{m/s}^2) + 2(6.0\text{N}) = 24\text{N}$

continued on page 4...

A11. A crate of mass m is on a ramp that is inclined at an angle θ as shown in the diagram. The coefficient of static friction between the crate and the ramp is μ_s. A force of magnitude F is applied to the crate perpendicular to the ramp. Which one of the following expressions is correct for the minimum value of F that is required to prevent the crate from sliding down the ramp?



Required F is minimum when $f_s = f_{s,max} = \mu_s n$

$\Sigma \vec{F} = 0 \Rightarrow \Sigma F_y = 0 \Rightarrow n - F - mg\cos\theta = 0 \Rightarrow n = F + mg\cos\theta$; $\Sigma F_x = 0 \Rightarrow f_{s,max} - mg\sin\theta = 0$

$\mu_s n = mg\sin\theta$

A

(A) $\dfrac{mg(\sin\theta - \mu_s\cos\theta)}{\mu_s}$ (B) $\dfrac{mg(\sin\theta + \mu_s\cos\theta)}{\mu_s}$ (C) $\dfrac{mg(\cos\theta - \mu_s\sin\theta)}{\mu_s}$

(D) $\dfrac{mg(\cos\theta + \mu_s\sin\theta)}{\mu_s}$ (E) $\dfrac{mg(\tan\theta - \mu_s\cot\theta)}{\mu_s}$

$\mu_s(F + mg\cos\theta) = mg\sin\theta$

$\mu_s F + \mu_s mg\cos\theta = mg\sin\theta$

$\mu_s F = mg(\sin\theta - \mu_s\cos\theta) \Rightarrow F = \dfrac{mg(\sin\theta - \mu_s\cos\theta)}{\mu_s}$

A12. The work required to accelerate an object on a frictionless surface from a speed v to a speed $2v$ is

B

Work = ΔKE

(A) twice the work required to accelerate the object from $v = 0$ to v.
(B) three times the work required to accelerate the object from $v = 0$ to v.
(C) four times the work required to accelerate the object from $2v$ to $3v$.
(D) not known without knowledge of the acceleration.
(E) equal to the work required to accelerate the object from $v = 0$ to v.

$W_{v\to 2v} = \frac{1}{2}m(2v)^2 - \frac{1}{2}mv^2$

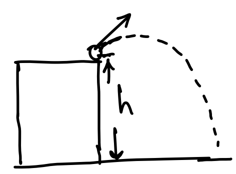
$W_{v\to 2v} = \frac{1}{2}m(4v^2 - v^2) = \frac{1}{2}m(3v^2) = 3\left(\frac{1}{2}mv^2\right)$

$W_{0\to v} = \frac{1}{2}mv^2 - 0 = \frac{1}{2}mv^2$; $W_{2v\to 3v} = \frac{1}{2}m(9v^2) - \frac{1}{2}m(4v^2) = 5\left(\frac{1}{2}mv^2\right)$

A13. Three projectiles with different masses are launched from the top of a building each at different angles of elevation. Each particle has the same initial kinetic energy. Which particle has the greatest speed just as it impacts with the ground?

D

(A) The projectile launched at the highest angle of elevation has the greatest speed.
(B) The projectile launched at the lowest angle of elevation has the greatest speed.
(C) The projectile with the highest mass has the greatest speed.
(D) The projectile with the lowest mass has the greatest speed.
(E) They all have the same speed on impact with the ground.



$h = 0$

$KE_f = KE_i + PE_i$

$\frac{1}{2}mv_f^2 = KE_i + mgh$

$mv_f^2 = 2(KE_i + mgh)$

$v_f = \sqrt{2\left(\frac{KE_i}{m} + gh\right)}$

$\therefore v_f \uparrow$ as $m \downarrow$

A14. If two particles have equal kinetic energies, are their momenta equal?

C

(A) Yes, always.
(B) Yes, as long as their masses are equal.
(C) Yes, if both their masses and directions of motion are the same.
(D) No, never.
(E) No, unless they are moving perpendicular to each other.

$KE = \frac{1}{2}mv^2$; $\vec{p} = m\vec{v}$; $KE = p^2/2m \Rightarrow p = \sqrt{2mKE}$

A15. Water flows over a section of Niagara Falls at a rate of 1.20×10^6 kg/s and falls 50.0 m. How much power is available at the bottom of the waterfall? (Ignore any frictional effects.)

A

(A) 588 MW (B) 294 MW (C) 147 MW (D) 60.0 MW (E) 74.0 MW

$P = \dfrac{W}{t} = \dfrac{mgh}{t} = \left(\dfrac{m}{t}\right)\cdot gh = (1.20\times10^6\ \text{kg/s})(9.80\ \text{m/s}^2)(50.0\ \text{m}) = 588\times10^6\ \text{W}$

PART B

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

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.

SHOW AND EXPLAIN YOUR WORK – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

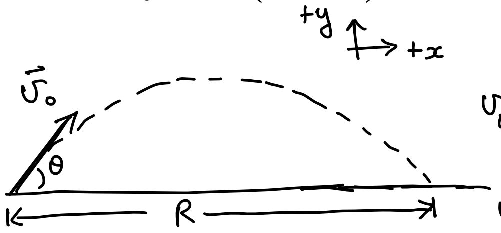
EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

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

continued on page 5...

B1. A rock is thrown upward from level ground with initial velocity υ_o directed at an angle θ, and eventually lands a horizontal distance R from where it was thrown.

(a) By analysing the rock's horizontal motion, find an expression for the time of flight in terms of R, υ_o and θ. (*2 marks*)



x	y
$\Delta x = R$	$\Delta y = 0$
$v_{0x} = v_0 \cos\theta$	$v_{0y} = v_0 \sin\theta$
$a_x = 0$	$a_y = -g$
$v_x = v_0 \cos\theta$	$v_y = ?$

$$\boxed{t = \frac{R}{v_0 \cos\theta}}$$

horizontally, $\Delta x = v_{0x} t + \frac{1}{2} a_x t^2$

$R = (v_0 \cos\theta) t + 0$ → $t = \dfrac{R}{v_0 \cos\theta}$

(b) By analysing the rock's vertical motion, find an expression for the time of flight in terms of υ_o, θ and g. (*2 marks*)

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

$$0 = (v_0 \sin\theta) t + \frac{1}{2}(-g) t^2$$

$$\frac{1}{2} g t = v_0 \sin\theta$$

$$t = \frac{2 v_0 \sin\theta}{g}$$

$$\boxed{t = \frac{2 v_0 \sin\theta}{g}}$$

(c) Use your answers to (a) and (b) to write an expression for R in terms of υ_o, θ and g. *(2 marks)*

$$\frac{R}{v_0 \cos\theta} = \frac{2 v_0 \sin\theta}{g}$$

$$R = \frac{2 v_0^2 \sin\theta \cos\theta}{g}$$

$$\boxed{R = \frac{2 v_0^2 \sin\theta \cos\theta}{g}}$$

(d) What is the maximum horizontal distance R_{max} that the rock can reach? Express your answer in terms of υ_o and g. Hint: You may find the trig. identity $\sin 2\theta = 2\sin\theta\cos\theta$ useful. (*2 marks*)

$$R = \frac{v_0^2 (2 \sin\theta \cos\theta)}{g} = \frac{v_0^2 (\sin 2\theta)}{g}$$

$$\boxed{v_0^2/g}$$

max. value of sine function is 1.

$$\therefore \quad R_{max} = \frac{v_0^2 (1)}{g} = v_0^2/g$$

(e) For what angle θ does $R = R_{max}$? Hint: You may find the trig. identity $\sin 2\theta = 2\sin\theta\cos\theta$ useful. (*2 marks*)

R_{max} occurs when $\sin(2\theta) = 1$

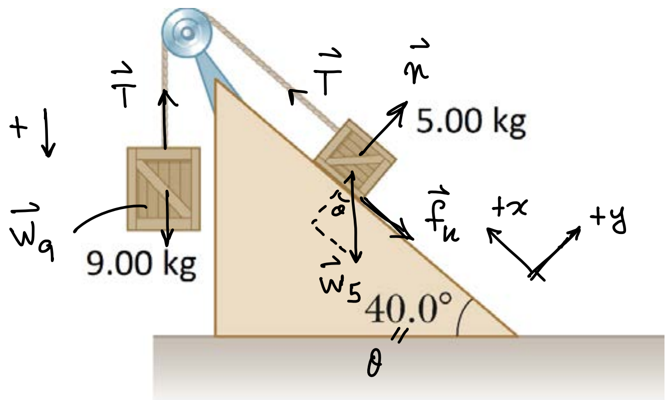
$$\boxed{45^\circ}$$

i.e. $2\theta = 90^\circ \Rightarrow \theta = 45^\circ$

continued on page 6...

Stu. No.: ______________________

B2. Two packing crates of masses 9.00 kg and 5.00 kg are connected by a light string that passes over a frictionless pulley as shown. The 5.00-kg crate is on an incline surface of angle 40.0°. The coefficient of friction between the 5.00-kg crate and the incline surface is 0.200.



both crates will have the same magnitude of acceleration, a

(a) On the above diagram, show all the forces on the 5.00-kg crate. Show your choice of coordinate system. (Air resistance can be ignored.) (*3 marks*)

(b) Calculate the acceleration of the 5.00-kg crate. (*4 marks*)

$n = 37.54\,\text{N}$

$f_k = \mu_k n = 7.51\,\text{N}$

$\boxed{3.51\ \text{m/s}^2}$

$$\sum F_{x_5} = m_5 a \Rightarrow T - m_5 g \sin\theta - f_k = m_5 a \quad ①$$

$$\sum F_{y_5} = 0 \Rightarrow n - m_5 g\cos\theta = 0 \Rightarrow n = m_5 g \cos\theta \quad ②$$

$$\sum F_9 = m_9 a \Rightarrow m_9 g - T = m_9 a \Rightarrow m_9 g - m_9 a = T \quad ③$$

Substitution into ①: $m_9 g - m_9 a - m_5 g \sin\theta - \mu_k (m_5 g \cos\theta) = m_5 a$

$$m_9 g - m_5 g \sin\theta - \mu_k m_5 g \cos\theta = (m_5 + m_9) a$$

$$a = \frac{g(m_9 - m_5 \sin\theta - \mu_k m_5 \cos\theta)}{m_5 + m_9}$$

$$a = \frac{9.80\,\text{m/s}^2\left(9.00\,\text{kg} - (5.00\,\text{kg})(\sin 40.0°) - (0.200)(5.00\,\text{kg})(\cos 40.0°)\right)}{(5.00\,\text{kg} + 9.00\,\text{kg})}$$

$a = 3.51\ \text{m/s}^2$

Early substitution of values:

③ into ①: $m_9 g - m_9 a - m_5 g \sin\theta - f_k = m_5 a$

$$88.2\,\text{N} - m_9 a - 31.5\,\text{N} - 7.51\,\text{N} = m_5 a \Rightarrow a = \frac{49.19\,\text{N}}{14.0\,\text{kg}} = 3.51\,\text{m/s}^2$$

(c) Calculate the tension in the string. If you did not obtain an answer for (b), use a value of 0.350 m/s^2. (*3 marks*)

$\boxed{56.6\ \text{N}}$

From ③: $m_9 g - m_9 a = T$

$$m_9 (g - a) = T$$

$$(9.00\,\text{kg})(9.80\,\text{m/s}^2 - 3.51\,\text{m/s}^2) = T$$

$T = 56.6\ \text{N}$

Using Alt. value:

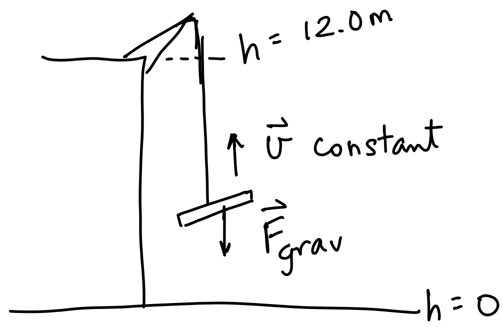
$T = 85.1\,\text{N}$

continued on page 7...

B3. A crane is used to lift a 193-kg steel beam straight up at a constant speed to a work site that is 12.0 m above the ground. The crane produces a constant power of 378 W.

(a) Calculate the work done by gravity. (*3 marks*)

$\boxed{-2.27 \times 10^4 \text{ J}}$



$W_{grav} = F_{grav} d \cos\theta$

$W_{grav} = mg(h)\cos 180°$

$W_{grav} = -(193 \text{ kg})(9.80 \text{ m/s}^2)(12.0 \text{ m})$

$W_{grav} = -2.27 \times 10^4 \text{ J}$

(b) Calculate the net work done by all the forces acting on the beam. (*3 marks*)

$\boxed{0}$

Since the beam is moving at constant speed, there is no change in its kinetic energy.

∴ From the Work-Energy Theorem,

$W_{net} = \Delta KE = 0$

(c) Calculate the time required to lift the beam from the ground to the work site. (Ignore any frictional effects.) If you did not obtain an answer for (a), use a value of -2.20×10^4 J. (*4 marks*)

$\boxed{60.0 \text{ s}}$

Since $W_{net} = 0$ and $W_{net} = W_{grav} + W_{crane}$,

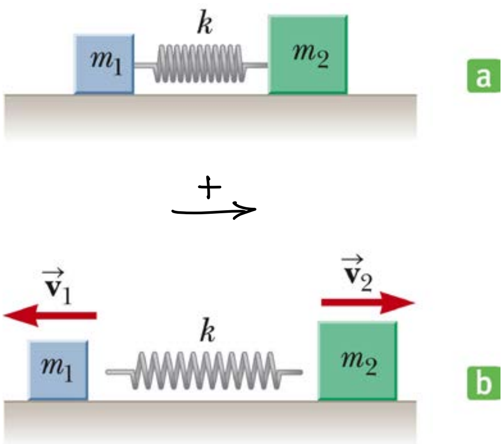
$W_{crane} = -W_{grav} = -(-2.27 \times 10^4 \text{ J})$

$W_{crane} = 2.27 \times 10^4 \text{ J}$

$\bar{P} = \dfrac{W}{\Delta t} \Rightarrow \Delta t = \dfrac{W}{\bar{P}} = \dfrac{2.27 \times 10^4 \text{ J}}{378 \text{ W}} = 60.0 \text{ s}$

continued on page 8...

B4. Two objects of masses $m_1 = 1.00$ kg and $m_2 = 2.00$ kg are placed on a horizontal frictionless surface and a compressed spring of force constant 6.00×10^2 N/m is placed between them. Neglect the mass of the spring. The spring is not attached to either object and is compressed a distance of 20.5 cm. If the objects are released from rest, find the final velocity of each object as shown in the figure. (*10 marks*)



Momentum is conserved.

Total Energy is conserved

horizontal ⇒ no change in gravitational potential energy.

$\vec{v}_1$ = 4.10 m/s to left
$\vec{v}_2$ = 2.05 m/s to right

Conservation of Momentum:

$$\vec{p}_f = \vec{p}_i$$

$$m_2\vec{v}_2 + m_1\vec{v}_1 = 0$$

$$m_2 v_2 - m_1 v_1 = 0$$

$$m_2 v_2 = m_1 v_1 \Rightarrow v_2 = \frac{m_1 v_1}{m_2} \quad (1)$$

Conservation of Energy:

$$E_f = E_i \Rightarrow \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 = \frac{1}{2}kx^2$$

$$m_1 v_1^2 + m_2 v_2^2 = kx^2 \text{ ; substitute } (1)$$

$$m_1 v_1^2 + m_2\left(\frac{m_1 v_1}{m_2}\right)^2 = kx^2 \Rightarrow \left(m_1 + \frac{m_1^2}{m_2}\right)v_1^2 = kx^2$$

$$v_1 = \sqrt{\frac{k}{m_1 + m_1^2/m_2}} \cdot x = \sqrt{\frac{600\text{ N/m}}{1.00\text{ kg} + (1.00\text{ kg})^2/2.00\text{ kg}}} \cdot (0.205\text{ m})$$

$v_1 = 4.10$ m/s to left

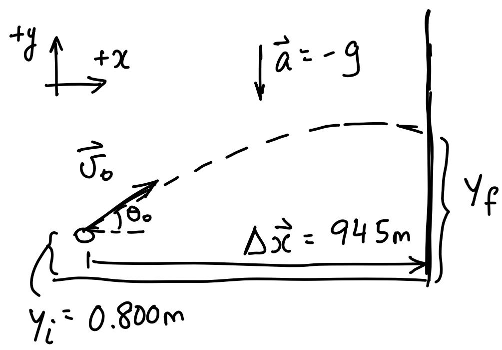
$$v_2 = \frac{m_1 v_1}{m_2} = \frac{(1.00\text{ kg})(4.10\text{ m/s})}{2.00\text{ kg}} = 2.05\text{ m/s}$$ to right

END OF EXAMINATION

B1. At Fenway Park in Boston there is a wall (the Green Monster) that is 11.3 m high. The wall is 94.5 m from home plate. Suppose that a batter hits a baseball at home plate such that it is at an initial height of 80.0 cm above the ground and has an initial velocity of 48.9 m/s at an angle of 55.0° above the horizontal.

(a) Calculate the time for the ball to travel from home plate to the wall. (*3 marks*)

$\boxed{3.37\,s}$



$$\Delta x = v_x t \Rightarrow t = \frac{\Delta x}{v_x} = \frac{\Delta x}{v_0 \cos\theta_0}$$

$$t = \frac{+94.5\,m}{(48.9\,m/s)(\cos 55.0^\circ)} = 3.37\,s$$

(b) Calculate the height of the ball above the ground when it reaches the wall. If you did not obtain an answer for (a), use a value of 3.30 s. (*4 marks*)

$\boxed{80.1\,m}$

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

$$\Delta y = (v_0 \sin\theta_0)(t) - \tfrac{1}{2} g t^2$$

$$\Delta y = (48.9\,m/s)(\sin 55.0^\circ)(3.37\,s) - \tfrac{1}{2}(9.80\,m/s^2)(3.37\,s)^2$$

$$\Delta y = 79.3\,m$$

$$\Delta y = y_f - y_i \Rightarrow y_f = y_i + \Delta y = 0.800\,m + 79.3\,m = 80.1\,m$$

(c) Calculate the speed of the ball when it reaches the wall. If you did not obtain an answer for (a), use a value of 3.30 s. (*3 marks*)

$\boxed{28.9\,m/s}$

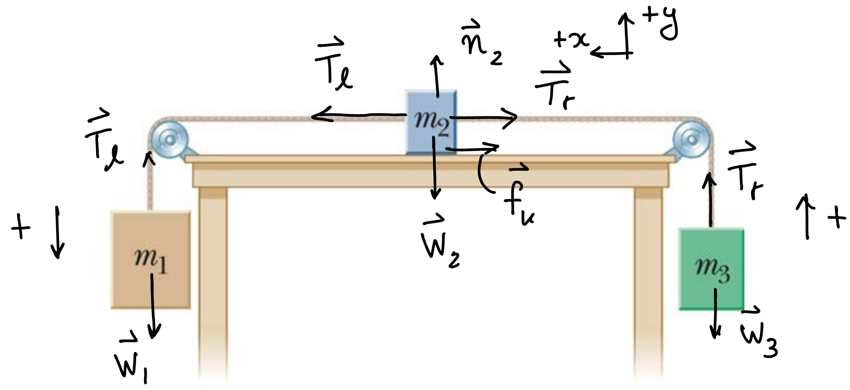
$$v_{y_{wall}} = v_{0y} + a_y t = v_0 \sin\theta_0 - gt = (48.9\,m/s)(\sin 55.0^\circ) - (9.80\,m/s^2)(3.37\,s)$$

$$v_{y_{wall}} = +7.03\,m/s \qquad v_{x_{wall}} = v_{0x} = v_0 \cos\theta_0 = 28.0\,m/s$$

$$v_{wall} = \sqrt{v_{x_{wall}}^2 + v_{y_{wall}}^2} = 28.9\,m/s$$

continued on page 6...

B2. Three objects are connected by two cords as shown in the figure below. The coefficient of kinetic friction between the block of mass m_2 and the table is 0.350. The objects have masses of $m_1 = 4.00$ kg, $m_2 = 1.00$ kg, and $m_3 = 2.00$ kg. The pulleys are frictionless.



(a) On the diagram above, draw the forces acting on each object. (*3 marks*)

(b) Determine the acceleration of each object, including its direction. (*3 marks*)

The magnitudes of the accelerations are equal.

$\sum \vec{F}_1 = m_1 \vec{a} \Rightarrow W_1 - T_\ell = m_1 a \Rightarrow m_1 g - T_\ell = m_1 a$ ①

$\sum \vec{F}_3 = m_3 \vec{a} \Rightarrow T_r - W_3 = m_3 a \Rightarrow T_r - m_3 g = m_3 a$ ②

$\sum F_{2x} = m_2 a \Rightarrow T_\ell - T_r - f_k = m_2 a$ ③

$\sum F_{2y} = 0 \Rightarrow +n_2 - W_2 = 0 \Rightarrow n_2 = m_2 g$ ④

Use ①, ②, and ④ to substitute into ③:

$(m_1 g - m_1 a) - (m_3 a + m_3 g) - \mu_k m_2 g = m_2 a$

$(m_1 - m_3 - \mu_k m_2) g = (m_1 + m_2 + m_3) a$

$$a = \frac{(m_1 - m_3 - \mu_k m_2) g}{m_1 + m_2 + m_3} = \frac{[4.00\text{ kg} - 2.00\text{ kg} - (0.350)(1.00\text{ kg})]\, 9.80\text{ m/s}^2}{4.00\text{ kg} + 1.00\text{ kg} + 2.00\text{ kg}}$$

$a = 2.31\text{ m/s}^2$

$a_1 = 2.31\text{ m/s}^2$ DOWN

$a_2 = 2.31\text{ m/s}^2$ LEFT

$a_3 = 2.31\text{ m/s}^2$ UP

(c) Determine the tensions in the two cords. If you did not obtain answers for (b), use a value of 2.30 m/s^2 for the magnitude of the acceleration of each object. (*2 marks*)

From ①: $T_\ell = m_1(g - a)$

$T_\ell = (4.00\text{ kg})(9.80\text{ m/s}^2 - 2.31\text{ m/s}^2)$

$T_\ell = 30.0\text{ N}$

From ②: $T_r = m_3(a + g) = (2.00\text{ kg})(9.80\text{ m/s}^2 + 2.31\text{ m/s}^2) = 24.2\text{ N}$

$T_{left} =$ 30.0 N

$T_{right} =$ 24.2 N

(d) If the tabletop were smooth (frictionless), would the tensions increase, decrease, or remain the same? (*2 marks*)

If the tabletop were smooth, $\mu_k = 0$

$\therefore a = \left(\frac{m_1 - m_3}{m_1 + m_2 + m_3}\right) g = 2.80\text{ m/s}^2$

a increases, $\therefore T_\ell \downarrow$ and $T_r \uparrow$

T_{left} will decrease

T_{right} will increase

continued on page 7...

B3. A 7.80-g bullet moving at 575 m/s penetrates a solid wood wall and eventually comes to rest in the wall. Assume that the bullet moves horizontally in the wall.

(a) Calculate the work done by the frictional force of the wall on the bullet in stopping the bullet. (*4 marks*)

$\boxed{-1.29 \times 10^{3}\ \mathrm{J}}$

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

$$\tfrac{1}{2}mv_i^2 + mgh_i + W_{nc} = \tfrac{1}{2}mv_f^2 + mgh_f$$

horizontal motion $\Rightarrow h_f = h_i$; stopping $\Rightarrow v_f = 0$

$$W_{nc} = -\tfrac{1}{2}mv_i^2 = -\tfrac{1}{2}(7.80 \times 10^{-3}\,\mathrm{kg})(575\,\mathrm{m/s})^2$$

$$W_{nc} = -1.29 \times 10^{3}\ \mathrm{J}$$

ALT METHOD: Determine accel'n, then f_k, then $W_{fric} = |f_k||\Delta x|(\cos 180^\circ)$

$$W_{fric} = (7.80 \times 10^{-3}\,\mathrm{kg})(3.01 \times 10^{6}\,\mathrm{m/s^2})(0.0550\,\mathrm{m})(-1) = -1.29 \times 10^{3}\ \mathrm{J}$$

(b) Assuming the frictional force of the wall on the bullet is constant, and given that the elapsed time between the moment the bullet enters the wall and the moment it stops moving is 1.91×10^{-4} s, calculate the distance that the bullet penetrates the wall. (*3 marks*)

$\boxed{5.49\ \mathrm{cm}}$

$$\Delta x = \tfrac{1}{2}(v_0 + v)t = \tfrac{1}{2}(575\,\mathrm{m/s} + 0)(1.91 \times 10^{-4}\,\mathrm{s}) = 5.49\ \mathrm{cm}$$

(c) Calculate the magnitude of the frictional force of the wall on the bullet. If you did not obtain an answer for (a), use a value of -1.25×10^{3} J and if you did not obtain an answer for (b), use a value of 0.0500 m. (*3 marks*)

$\boxed{2.35 \times 10^{4}\ \mathrm{N}}$

$$W_{nc} = |f_k||\Delta x|\cos 180^\circ \Rightarrow f_k = -\frac{W_{nc}}{\Delta x} = \frac{1.29 \times 10^{3}\,\mathrm{J}}{0.0549\,\mathrm{m}} = 2.35 \times 10^{4}\ \mathrm{N}$$

continued on page 8...

B4. A 65.0-kg adult throws a 0.100-kg snowball forward with a ground speed of 30.0 m/s. A child, with a mass of 30.0 kg, catches the snowball. Both the adult and the child are on skates. The adult is initially moving forward with a speed of 2.50 m/s, and the child is initially at rest. Calculate the velocities of the adult and child after the snowball is exchanged. You may ignore any change in the speed or trajectory of the snowball as it travels from the adult to the child. Disregard the friction between the skates and the ice. (*10 marks*).

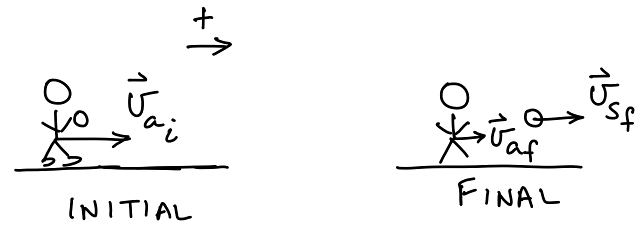
v_{adult} = 2.46 m/s, right

v_{child} = 0.0997 m/s, right

Linear momentum is conserved in the "interaction" between the adult and the snowball, and in the interaction between the snowball and the child.

Adult - Snowball:

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



m_a = mass of adult

m_s = mass of snowball

m_c = mass of child

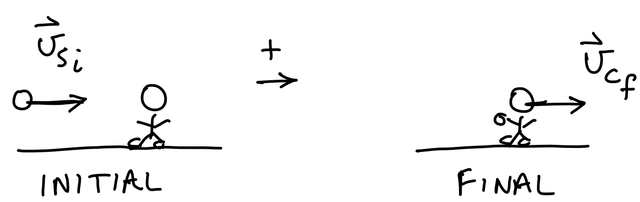
$$m_a v_{af} + m_s v_{sf} = (m_a + m_s) v_{a_i}$$

$$v_{af} = \frac{(m_a + m_s) v_{a_i} - m_s v_{sf}}{m_a}$$

$$v_{af} = \frac{(65.0\text{ kg} + 0.100\text{ kg})(2.50\text{ m/s}) - (0.100\text{ kg})(30.0\text{ m/s})}{65.0\text{ kg}} = 2.46\text{ m/s}$$

Snowball - Child:

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



$$(m_s + m_c) v_{cf} = m_s v_{s_i} + 0$$

$$v_{cf} = \frac{m_s v_{s_i}}{m_s + m_c} = \frac{(0.100\text{ kg})(30.0\text{ m/s})}{(0.100\text{ kg} + 30.0\text{ kg})} = 0.0997\text{ m/s}$$

END OF EXAMINATION