UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3

MIDTERM TEST – Alternative Sitting

October 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.

A

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) $R = \frac{\upsilon_0^2}{g}\sin(2\theta)$ (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.

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

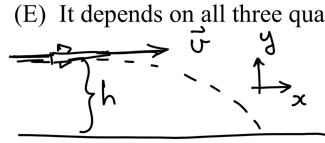
D

(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

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

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

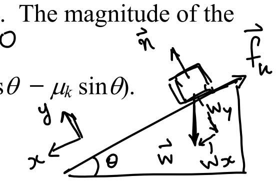
$t = \sqrt{2h/g}$

continued on page 3...

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…

D

$\Sigma F_y = 0 \Rightarrow n - mg\cos\theta = 0$

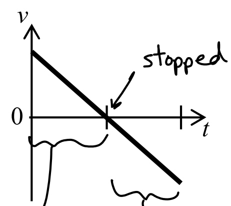


(A) $g \sin\theta$. (B) $g \cos\theta$. (C) $g(\cos\theta - \mu_k \sin\theta)$.
(D) $g(\sin\theta - \mu_k \cos\theta)$. (E) $g \tan\theta$.

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

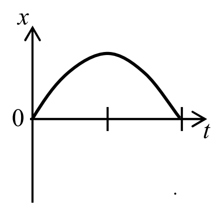
A9. An object moves along the x-axis. The graph at right shows the velocity of the object as a function of time. Which one of the following graphs is a possible graph showing the position of the object as a function of time?

A

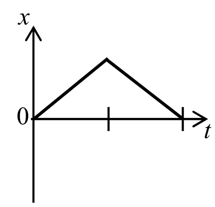


moving in positive x direction with decreasing speed

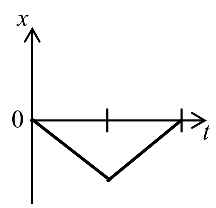
moving in -ve x direction with increasing speed



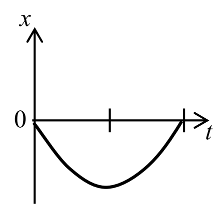
A.



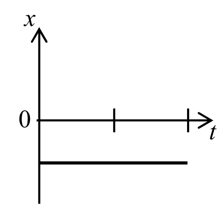
B.



C.



D.



E.

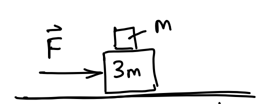
A10. A block of mass $3m$ is placed on a frictionless horizontal surface and a second block of mass m is placed on top of the first block. There is friction between the surfaces of the blocks. A constant force of magnitude F is applied to the bottom block. Assume that the upper block does not slip on 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?

C

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,

$\Sigma \vec{F}_{ext} = m\vec{a} \Rightarrow F = (m + 3m)a \Rightarrow a = \dfrac{F}{4m}$

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?

C

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

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

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?

C

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) $F_2 = 2F_1$, $PE_2 = PE_1$

$|F_{spring_1}| = kx$

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

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

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

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

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 THREE OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND INDICATE YOUR CHOICE OF QUESTIONS ON THE COVER PAGE.

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.

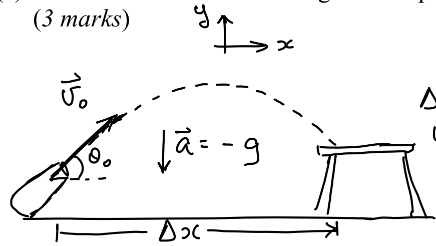
EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

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

continued on page 5...

B1. A stuntperson is shot out of a cannon at an angle of 55.0° to the horizontal with an initial speed of 25.0 m/s. A net is positioned a horizontal distance of 50.0 m from the cannon. The end of the cannon may not be at the same height as the net. You may ignore any effects due to air resistance.

(a) Calculate the time after firing that the person reaches the horizontal position of the net. (*3 marks*)



x	y
$\Delta x = 50.0\,\text{m}$	$\Delta y = ?$
$v_{0x} = v_0 \cos\theta_0$	$v_{0y} = v_0 \sin\theta_0$
$a_x = 0$	$a_y = -g$
$v_{0x} = v_x$	$v_y = ?$

$t = ?$

$\boxed{3.49\,\text{s}}$

$$\Delta x = v_{0x} t \Rightarrow t = \frac{\Delta x}{v_{0x}} = \frac{\Delta x}{v_0 \cos\theta_0} = \frac{50.0\,\text{m}}{(25.0\,\text{m/s})\cos 55.0°}$$

$$t = 3.49\,\text{s}$$

(b) Calculate the speed of the person when she reaches the horizontal position of the net. If you did not obtain an answer for (a), use a value of 3.75 s. (*4 marks*)

$\boxed{19.8\,\text{m/s}}$

$$v_x = v_{0x} = (25.0\,\text{m/s})\cos 55.0°$$

$$v_x = 14.3\,\text{m/s}$$

$$v_y = v_{0y} + a_y t = v_0 \sin\theta_0 - gt = (25.0\,\text{m/s})\sin 55.0° - (9.80\,\text{m/s}^2)(3.49\,\text{s})$$

$$v_y = -13.7\,\text{m/s}$$

$$v = \sqrt{v_x^2 + v_y^2} = 19.8\,\text{m/s}$$

ALT. ANS: $v_y = -16.3\,\text{m/s}$; $v = 21.7\,\text{m/s}$

(c) Calculate the height above the cannon that the net should be placed in order to catch the person. (*3 marks*)

$\boxed{11.8\,\text{m}}$

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

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

$$\Delta y = (25.0\,\text{m/s})(\sin 55.0°)(3.49\,\text{s}) - \frac{1}{2}(9.80\,\text{m/s}^2)(3.49\,\text{s})^2 = 11.8\,\text{m}$$

Alt. Method

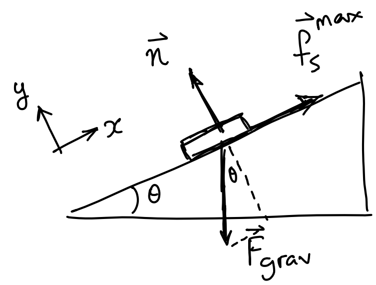
$$v_y^2 = v_{0y}^2 + 2a_y \Delta y$$

$$\Delta y = \frac{v_y^2 - v_{0y}^2}{2a_y} = \frac{(-13.7\,\text{m/s})^2 - (25.0\,\text{m/s})^2 \sin^2(55.0°)}{2(-9.80\,\text{m/s}^2)} = 11.8\,\text{m}$$

continued on page 6...

B2. A coin of mass m sits on top of a physics textbook. The textbook is gradually tilted, until it reaches an angle θ with the horizontal, at which point the coin begins to slide.

(a) Draw a free body diagram for the coin just before it starts to slide. (*4 marks*)



(b) Determine the expression for the coefficient of static friction μ_s between the textbook and the coin. Your answer may contain, at most, the symbols m, θ, and g and must be in its simplest form. (*6 marks*)

When the coin is on the verge of sliding, it is still in equilibrium:

$$\sum \vec{F} = 0 \Rightarrow \sum F_x = 0 \text{ and } \sum F_y = 0$$

$$\sum F_x = 0 \Rightarrow f_s^{max} - F_{grav} \sin\theta = 0$$

$$\mu_s n - mg\sin\theta = 0 \quad (1)$$

$$\sum F_y = 0 \Rightarrow n - F_{grav}\cos\theta = 0 \Rightarrow n = mg\cos\theta \quad (2)$$

(2) into (1):

$$\mu_s(mg\cos\theta) - mg\sin\theta = 0$$

$$\mu_s(\cancel{mg}\cos\theta) = \cancel{mg}\sin\theta$$

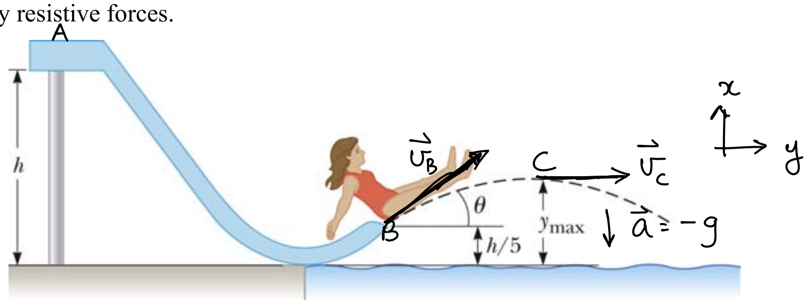
$$\mu_s = \frac{\sin\theta}{\cos\theta}$$

$$\mu_s = \tan\theta$$

$$\boxed{\mu_s = \tan\theta}$$

continued on page 7...

B3. A child starts from rest and slides without friction from a height h = 5.00 m along a curved waterslide. She is launched, at an angle θ = 30.0°, from a height h/5, into the pool. You may ignore any resistive forces.



(a) Calculate her speed at the point where she leaves the waterslide. (*4 marks*)

$\boxed{8.85 \text{ m/s}}$

Choose the base of the slide (the water level) as the reference height for gravitational potential energy.

No resistive forces means mechanical energy is conserved

$$E_A = E_B \Rightarrow KE_A + PE_{grav_A} = KE_B + PE_{grav_B}$$

$$0 + \cancel{m}gh = \frac{1}{2}\cancel{m}v_B^2 + \cancel{m}g\left(\frac{h}{5}\right)$$

$$g\left(h - \frac{h}{5}\right) = \frac{v_B^2}{2}$$

$$v_B = \sqrt{2gh\left(\frac{4}{5}\right)} = \sqrt{2(9.80 \text{ m/s}^2)(5.00 \text{ m})\left(\frac{4}{5}\right)}$$

$$v_B = 8.85 \text{ m/s}$$

(b) Calculate her maximum airborne height y_{max}. If you did not obtain an answer for (a), use a value of 9.00 m/s. (*6 marks*)

$\boxed{2.00 \text{ m}}$

She is moving only horizontally at maximum height.

$$\therefore v_C = v_{Bx} = v_B \cos\theta = (8.85 \text{ m/s}) \cos 30.0° = 7.664 \text{ m/s}$$

$$E_A = E_C \Rightarrow \cancel{m}gh = \frac{1}{2}\cancel{m}v_C^2 + \cancel{m}g y_{max}$$

$$y_{max} = h - \frac{v_C^2}{2g} = 5.00 \text{ m} - \frac{(7.664 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = 2.00 \text{ m}$$

ALT. METHOD:

$v_{Cy} = 0$, 2-d kinematics from B to C yields:

$$v_{Cy}^2 = v_{By}^2 + 2a_y \Delta y \Rightarrow \Delta y = \frac{v_{Cy}^2 - v_{By}^2}{2a_y}$$

$$\Delta y = \frac{0 - v_B^2 \sin^2\theta}{2(-g)} = \frac{-(8.85 \text{ m/s})^2 \sin^2(30.0°)}{2(-9.80 \text{ m/s}^2)} = 1.00 \text{ m}$$

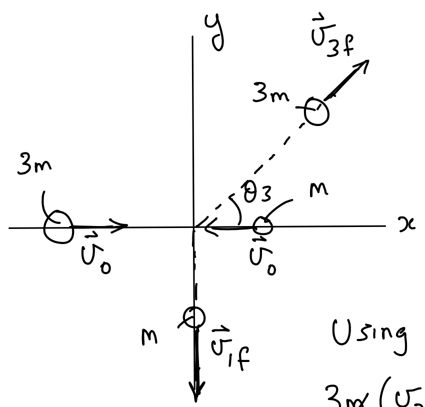
$$y_{max} = \frac{h}{5} + \Delta y = \frac{5.00 \text{ m}}{5} + 1.00 \text{ m} = 2.00 \text{ m}$$

continued on page 8...

B4. Two objects of masses *m* and 3*m* are moving toward each other along the *x*-axis with the same initial speed v_0. The object of mass *m* is travelling to the left (–*x* direction) and the object of mass 3*m* is travelling to the right (+*x* direction). They undergo a glancing collision such that the object of mass *m* is moving in the –*y* direction after the collision, at a right angle from its initial direction. After the collision, the object of mass 3*m* is moving at 2.00 m/s at an angle of 30.0° counter-clockwise from the +*x* axis.

(a) Calculate the after-collision speed of the object of mass *m*. (*5 marks*)

$\boxed{3.00\ \text{m/s}}$



Momentum is conserved.

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

$$p_{tot_{fx}} = p_{tot_{ix}} \text{ and } p_{tot_{fy}} = p_{tot_{iy}}$$

Using y-equation:

$$3\cancel{m}(v_{3f}\sin\theta_3) - \cancel{m}v_{1f} = 0$$

$$v_{1f} = 3v_{3f}\sin\theta_3$$

$$v_{1f} = 3(2.00\text{ m/s})\sin 30.0°$$

$$v_{1f} = 3.00\text{ m/s}$$

(b) Calculate the before-collision speed of the masses. (*5 marks*)

$\boxed{2.60\ \text{m/s}}$

Apply cons. of momentum in the x direction:

$$p_{tot_{fx}} = p_{tot_{ix}}$$

$$3\cancel{m}v_{3f}\cos\theta_3 = 3\cancel{m}v_0 - \cancel{m}v_0$$

$$3v_{3f}\cos\theta_3 = 2v_0$$

$$v_0 = \frac{3v_{3f}\cos\theta_3}{2} = \frac{3(2.00\text{ m/s})\cos(30.0°)}{2}$$

$$v_0 = 2.60\text{ m/s}$$

END OF EXAMINATION