UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
MIDTERM TEST

October 22, 2010 Time: 90 minutes

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

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. R. Pywell
- ❑ 03 Dr. K. McWilliams
- ❑ C15 F. Dean

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. **It is the responsibility of the student to check that the test paper is complete.**
3. Only Hewlett-Packard HP 10s or HP 30s or Texas Instruments TI-30X series calculators may be used.
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. The equation for the speed of sound υ in a gas is $\upsilon = \sqrt{\frac{\gamma k_B T}{m}}$. Speed υ is measured in m/s, γ is a dimensionless constant, T is temperature in kelvins (K), and m is mass in kg. What are the units for the Boltzmann constant k_B?

B

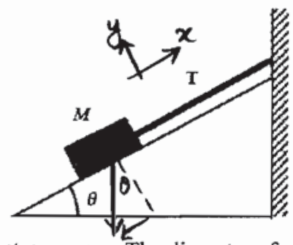
(A) kg m^2 s^2 K (B) kg m^2 s^{-2} K^{-1} (C) kg^{-1} m^{-2} s^2 K (D) kg m s^{-1} (E) kg m s^{-2}

$k_B = \frac{m\upsilon^2}{\gamma T}$ $[k_B] = kg \cdot m^2 s^{-2} K^{-1}$

A2. A block of mass M is held motionless on a frictionless inclined plane by means of a string attached to a vertical wall as shown in the drawing. What is the magnitude of the tension T in the string?

D

(A) zero (B) Mg (C) $Mg\cos\theta$
(D) $Mg\sin\theta$ (E) $Mg\tan\theta$



$\Sigma F_x = 0$

$T - W\sin\theta = 0$

$T = W\sin\theta$

A3. The average size of a transistor in a microchip is about 200 nanometres across. The diameter of a human hair is about 70 micrometres. What is the order of magnitude of the number of microchip transistors that can fit across the width of a human hair?

B

(A) 10^1 (B) 10^2 (C) 10^3 (D) 10^4 (E) 10^5

$70\,\mu m = 70{,}000$ nm

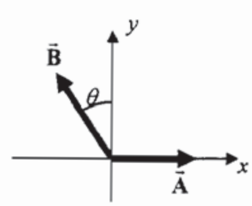
$\# = \frac{70{,}000\ nm}{200\ nm} = 350 \simeq 100$

A4. We add the three lengths: 3.22×10^{-3} m + 12.0061 m + 6.80752 m. What is the correct number of significant figures in the result?

D

(A) 3 (B) 4 (C) 5 (D) 6 (E) 7

A5. The figure shows two vectors $\vec{A}$ and $\vec{B}$. The angle θ is the magnitude of the angle between the +y-axis direction and the direction of the vector $\vec{B}$ as shown. The components of the vector $\vec{R} = \vec{A} + \vec{B}$ are



D

(A) $R_x = A + B\cos\theta, \quad R_y = B\sin\theta$
(B) $R_x = A - B\cos\theta, \quad R_y = B\sin\theta$
(C) $R_x = A + B\sin\theta, \quad R_y = B\cos\theta$
(D) $R_x = A - B\sin\theta, \quad R_y = B\cos\theta$
(E) $R_x = A - B, \quad R_y = B\tan\theta$

A6. A ball is thrown straight up into the air. Ignoring air resistance, while in the air the acceleration of the ball

D

(A) is zero.
(B) increases.
(C) decreases on the way up and increases on the way back down.
(D) remains constant.
(E) changes direction.

continued on page 3...

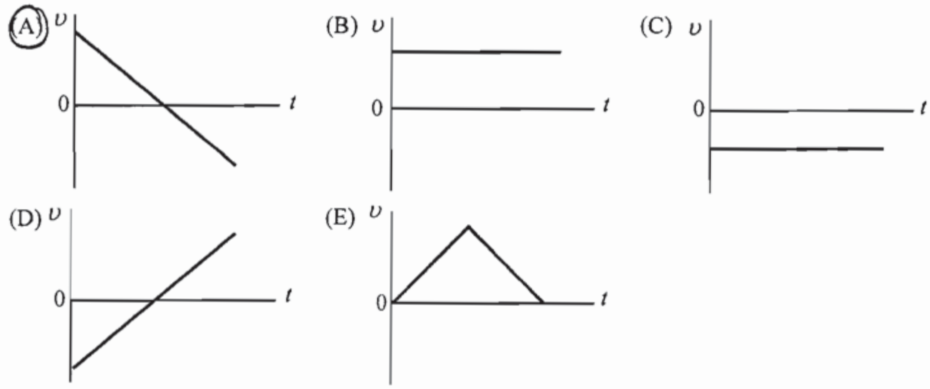
A7. The term *force* most accurately describes

E

(A) the mass of an object.
(B) the inertia of an object.
(C) the quantity that causes displacement.
(D) the quantity that keeps an object moving.
(E) the quantity that changes the velocity of an object.

A8. A ball is thrown vertically upward. Eventually it returns to the point from which it was thrown. Which one of the following velocity versus time graphs is correct for the motion of the ball while it is in free fall? (Up has been chosen as the positive direction and air resistance is negligible.)

A



A9. Which car has a westward acceleration?

D

(A) a car travelling westward at a constant speed — $\vec{a} = 0$
(B) a car travelling eastward and speeding up — $\vec{a}$ East
(C) a car travelling westward and slowing down — $\vec{a}$ East
(D) a car travelling eastward and slowing down — $\vec{a}$ West
(E) a car starting from rest and moving toward the east — $\vec{a}$ East

A10. A space probe leaves the solar system to explore interstellar space. Once it is far from any other objects, when **must** it fire its rocket engines?

E

(A) all the time, in order to keep moving
(B) **only** when it wants to speed up
(C) **only** when it wants to speed up or slow down
(D) **only** when it wants to change direction
(E) when it wants to speed up, slow down, or change direction

A11. Two children stand on a rotating platform. George is at a greater distance from the axis of rotation than Jacques. Comparing their linear speeds and their angular speeds with respect to the axis of rotation of the platform, which statement is correct?

C

(A) George has the same linear speed as Jacques, but a greater angular speed than Jacques.
(B) George has a greater linear speed than Jacques, and a greater angular speed than Jacques.
(C) George has a greater linear speed than Jacques, but the same angular speed as Jacques.
(D) George has the same linear speed as Jacques, and the same angular speed as Jacques.
(E) George has a smaller linear speed than Jacques, but the same angular speed as Jacques.

ω the same

$v = \omega r$.

continued on page 4...

A12. Two satellites are in orbit about the Earth with the same orbital radius. Satellite B has twice the mass of satellite A. The radial acceleration of satellite B has a magnitude that is

A

(A) the same as the magnitude of the radial acceleration of satellite A.
(B) one half the magnitude of the radial acceleration of satellite A.
(C) two times the magnitude of the radial acceleration of satellite A.
(D) four times the magnitude of the radial acceleration of satellite A.
(E) eight times the magnitude of the radial acceleration of satellite A.

$$\frac{GM_E \cancel{m}}{r^2} = \frac{\cancel{m} v^2}{\cancel{r}}$$

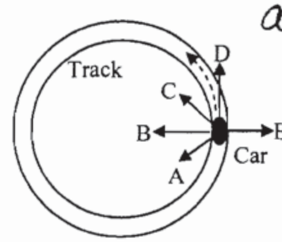
$$v = \sqrt{\frac{GM_E}{r}} ; \; v_A = v_B$$

$$a_{r_A} = \frac{v_A^2}{r} = \frac{v_B^2}{r} = a_{r_B}$$

A13. A car is driving at a constant speed around a circular track. In the diagram the car is moving counter clockwise. Which of the arrows best represents the direction of the net force on the car when it is at the position shown?

B

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



Let P = Period

A14. A ball on a string moves around a complete circle, once a second, on a frictionless, horizontal table. The tension in the string is T. What would the tension be if the ball went around a complete circle in only half a second?

E

(A) ¼ T (B) ½ T (C) T (D) 2 T (E) 4 T

$v \propto \frac{1}{P}$,

so $v_2 = 2v_1$

$\Sigma F_r = ma_r$

$$T = \frac{mv^2}{r}$$

$$T_1 = \frac{mv_1^2}{r}$$

$$T_2 = \frac{mv_2^2}{r} = \frac{m(2v_1)^2}{r} = 4\frac{mv_1^2}{r} = 4T_1$$

A15. A motorcycle stunt rider drives his motorcycle at a constant speed in a vertical loop-the-loop. The magnitude of the normal force of the loop on the motorcycle is

B

(A) greatest at the top of the loop.
(B) greatest at the bottom of the loop.
(C) greatest when the motorcycle is moving vertically upward.
(D) greatest when the motorcycle is moving vertically downward.
(E) the same everywhere on the loop.

Constant speed, $\Rightarrow a_r$ = constant
Constant radius

PART B

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

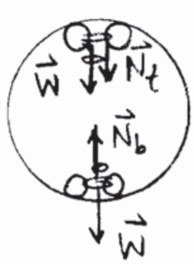
FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

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.



At top $\Sigma F_r = ma_r$

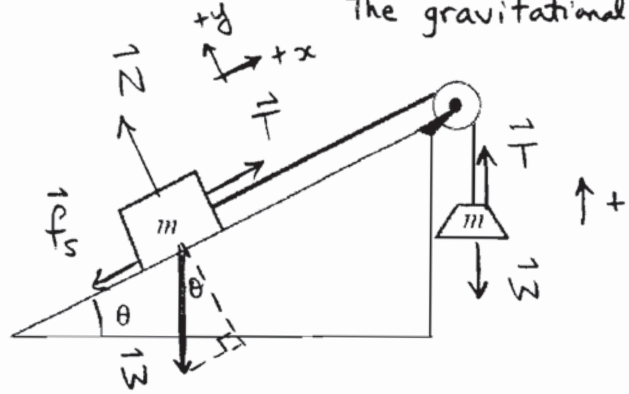
$$W + N_t = ma_r \Rightarrow N_t = ma_r - W$$

At bottom $\Sigma F_r = ma_r$

$$N_b - W = ma_r \Rightarrow N_b = ma_r + W$$

continued on page 5...

B1. A block of mass m is at rest on a rough ~~inclined~~ plane inclined at an angle θ, and is connected to an object with the same mass as shown. The rope may be considered massless; and the pulley may be considered frictionless. and massless. The coefficient of static friction between the block and the plane is μ_s; and the coefficient of kinetic friction is μ_k. The gravitational field strength is g.



(a) On the diagram above, show the forces acting on the block resting on the inclined plane and show the coordinate system that you will use for analysing these forces. (*3 marks*)

(b) Derive an expression for the magnitude of the static frictional force acting on the block, in terms of the given symbols. (*4 marks*)

$\boxed{mg(1-\sin\theta)}$

Note that for the hanging mass:

$\Sigma\vec{F}=0 \Rightarrow T-W=0 \Rightarrow T=W \Rightarrow T=mg$

For the mass on the plane: remaining at rest $\Rightarrow \Sigma\vec{F}=0$

$\Sigma F_x = 0 \Rightarrow T_x + f_{s,x} + W_x = 0$

$+T + f_{s,x} + (-mg\sin\theta) = 0$

$f_{s,x} = mg\sin\theta - T = mg\sin\theta - mg$

$f_{s,x} = -mg(1-\sin\theta)$

$f_s = mg(1-\sin\theta)$ in the $-$ve x direction

(c) Derive an expression for the normal force of the plane on the block (*3 marks*) in terms of the given symbols

$\boxed{mg\cos\theta}$

$\Sigma F_y = 0$ since at rest

$N_y + W_y = 0$

$+N + (-W\cos\theta) = 0$

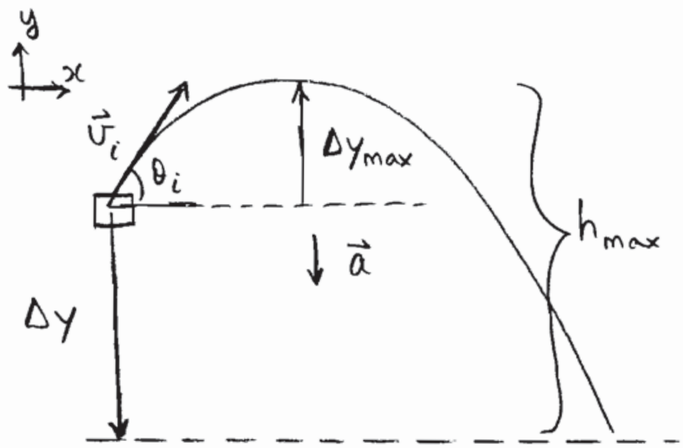
$N = W\cos\theta$

$N = mg\cos\theta$

continued on page 6...

B2. An airplane is climbing with a speed of 86.5 m/s at an angle of 60.0° above the horizontal. When the plane's altitude is 835 m the pilot releases a package.

(a) Calculate the maximum height of the package above the ground. (*4 marks*)



$\boxed{1.12\text{ km}}$

x	y
$\Delta x = ?$	$\Delta y = -835\text{m}$
	$\Delta y_{max} = ?$
$v_{ix} = v_i \cos\theta_i$	$v_{iy} = v_i \sin\theta_i$
$v_{fx} = v_{ix}$	$v_{fy} = ?;\ v_{fy_{max}} = 0$
$a_x = 0$	$a_y = -g$

$\Delta t = ?$

At max. height, $v_{fy_{max}} = 0$

$$v_{fy_{max}}^2 - v_{iy}^2 = 2a_y \Delta y_{max}$$

$$0 - (v_i \sin\theta_i)^2 = 2(-g)(\Delta y_{max}) \Rightarrow \Delta y_{max} = \frac{-(v_i \sin\theta_i)^2}{-2g}$$

$$\Delta y_{max} = \frac{(86.5\text{m/s})^2 \sin^2(60.0)}{2(9.80\text{m/s}^2)} = 286\text{m}\ ;\ h_{max} = |\Delta y_{max}| + |\Delta y| = 286\text{m} + |-835\text{m}| = 1.12\times10^3\text{m}$$

(b) Calculate the time that the package is in the air, measured from when it is released until just before it hits the ground. (*6 marks*)

$\boxed{22.8\text{s}}$

Use $\Delta y = v_{iy}\Delta t + \frac{1}{2}a_y(\Delta t)^2$

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

$$\frac{1}{2}(-9.80\text{m/s}^2)(\Delta t)^2 + (86.5\text{m/s})(\sin 60.0°)\Delta t - (-835\text{m}) = 0$$

$$\underbrace{(-4.90\text{m/s}^2)}_{a}(\Delta t)^2 + \underbrace{74.9\text{m/s}}_{b}\Delta t \underbrace{+835\text{m}}_{c} = 0$$

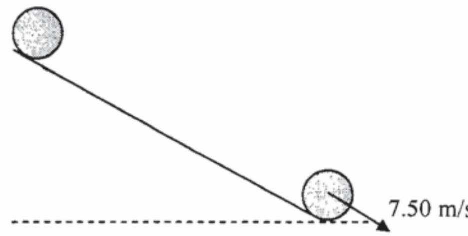
$$\Delta t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-74.9\text{m/s} \pm \sqrt{(74.9\text{m/s})^2 - 4(-4.90\text{m/s}^2)(835\text{m})}}{-9.80\text{m/s}^2}$$

$$\Delta t = -7.48\text{s}\ ;\ +22.8\text{s}$$

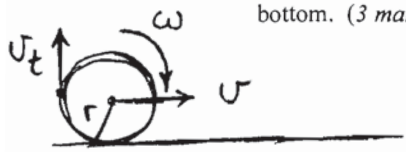
not physically meaningful

continued on page 7...

B3. A drum of radius 45.0 cm rolls down an inclined ramp as shown. It starts from rest at the top and when it reaches the bottom, 3.20 s later, it is moving with a speed of 7.50 m/s. Assume the drum rolls without slipping and has a constant acceleration as it rolls.



(a) Calculate the angular speed (in rad/s) of the drum rotating about its centre when it reaches the bottom. (*3 marks*)



For rolling w/o slipping,

$$v = v_t = r\omega$$

$\boxed{16.7 \text{ rad/s}}$

$$\omega = \frac{v}{r} = \frac{7.50\,\text{m/s}}{0.450\,\text{m}} = 16.7 \text{ rad/s}$$

(b) How far did the drum move down the ramp from the top to the bottom? (*3 marks*)

$\boxed{12.0 \text{ m}}$

$$\Delta x = \frac{1}{2}(v_{ix} + v_{fx})\Delta t$$

$$\Delta x = \frac{1}{2}(0 + 7.50\,\text{m/s})(3.20\,\text{s})$$

$$\Delta x = 12.0\,\text{m}$$

(c) How many revolutions did the drum make when rolling from top to bottom? If you did not obtain an answer for (b) use a value of 15.0 m. (*4 marks*)

$\boxed{4.24 \text{ rev}}$

$$\Delta x = \Delta s = r\,\Delta\theta$$

$$\Delta\theta = \frac{\Delta x}{r} = \frac{12.0\,\text{m}}{0.450\,\text{m}} = 26.7 \text{ rad}$$

$$\Delta\theta = 26.7 \text{ rad} \times \frac{1 \text{ rev}}{2\pi \text{ rad}} = 4.24 \text{ rev}$$

continued on page 8...

Stu. No.: ____________________

B4. A 35.0-kg child swings on a rope ~~with a length of 6.50 m~~ that is hanging from a tree branch. At the bottom of the swing, the child is moving with a speed of 4.20 m/s. You may ignore any effects due to air resistance.

The rope is 6.50 m long.

(a) Draw a free body diagram for the child when at the bottom of the swing. (*2 marks*)

(b) Calculate the magnitude of the radial acceleration and the instantaneous angular speed of the child when at the bottom of the swing. (*4 marks*)

$$a_r = \frac{v^2}{r} = \frac{(4.20\,\text{m/s})^2}{6.50\,\text{m}}$$

$a_r =$ $\boxed{2.71\ \text{m/s}^2}$

$\omega =$ $\boxed{0.646\ \text{rad/s}}$

$$a_r = 2.71\ \text{m/s}^2$$

$$\omega_{inst} = \frac{v_{inst}}{r} = \frac{4.20\,\text{m/s}}{6.50\,\text{m}} = 0.646\ \text{rad/s}$$

(c) Calculate the tension in the rope when the child is at the bottom of the swing. (*4 marks*)

$\boxed{438\,\text{N}}$

Newton II for circular motion:

$$\Sigma F_r = ma_r$$

$$T - W = ma_r$$

$$T = ma_r + W = ma_r + mg$$

$$T = m(a_r + g) = 35.0\,\text{kg}(2.71\,\text{m/s}^2 + 9.80\,\text{m/s}^2)$$

$$T = 438\,\text{N}$$

END OF EXAMINATION