UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3
MIDTERM EXAM

October 19, 2017 Time: 90 minutes

NAME: SOLUTIONS MASTER STUDENT NO.: ____________

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

LECTURE SECTION (please check):

- ❑ 01 Dr. D. Janzen
- ❑ 02 Dr. R. Pywell
- ❑ 03 B. Zulkoskey
- ❑ 97 Dr. A. Farahani
- ❑ C15 Dr. A. Farahani

INSTRUCTIONS:

1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card 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 name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

QUESTION NUMBER	MAXIMUM MARKS	MARKS OBTAINED
A1-12	12	
B1-4	8	
B5-8	8	
B9-12	8	
B13-16	8	
MARK	out of 36:	

PART A

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

A1. Vector $\vec{A}$ has horizontal and vertical components of 2.0 cm and 1.5 cm respectively. Vector $\vec{B}$ has horizontal and vertical components of 2.0 cm and −1.5 cm respectively. The vector $\vec{C} = \vec{A} + \vec{B}$ has a magnitude of…

B

$C_x = A_x + B_x = 2.0\text{cm} + 2.0\text{cm} = 4.0\text{cm}$

(A) 3.0 cm. (B) 4.0 cm. (C) 5.0 cm. (D) 8.0 cm. (E) 16 cm.

$C_y = A_y + B_y = 1.5\text{cm} + (-1.5\text{cm}) = 0$

A2. You measure the length and width of a rectangle with a ruler and you arrive at the values 1.245 m and 0.344 m respectively. You calculate the rectangle's perimeter with your calculator by adding the length and width and then multiplying the result by 2. The calculator display reads "3.1780". Wishing to express your answer to the proper number of significant figures, you should record your answer for the perimeter as…

B

$P = 2(l+w) = 2(1.245\text{m} + 0.344\text{m})$

(A) 3.1780 m. (B) 3.178 m. (C) 3.18 m. (D) 3.2 m. (E) 3.0 m.

$= 2(1.589\text{m})$
$= 3.178\text{m}$

A3. Given the following dimensions for the quantities H, v_0, and g: $[H] = L$; $[v_0] = L/T$; $[g] = L/T^2$, which one of the following equations is dimensionally correct?

A

(A) $H = \frac{v_0^2}{2g}\sin^2\theta$ (B) $H = \frac{v_0}{2g}\sin^2\theta$ (C) $H = \sqrt{\frac{v_0}{2g}\sin^2\theta}$

(D) $H = \frac{g}{2v_0}\sin^2\theta$ (E) $H = \frac{gv_0}{2}\sin^2\theta$

$\frac{(L/T)^2}{L/T^2} = \frac{L^2/T^2}{L/T^2} = \frac{L^2}{L} = L$ ✓

A4. A skateboarder starts from rest and moves down a hill with constant acceleration in a straight line, travelling for 6 s. In a second trial, he starts from rest and moves along the same straight line with the same acceleration for only 2 s. How does his displacement from his starting point in this second trial compare with the first trial?

C

$\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2 \Rightarrow \Delta x \propto t^2$

(A) one-third as large (B) three times larger (C) one-ninth as large
(D) nine times larger (E) $1/\sqrt{3}$ times as large

$\frac{\Delta x_2}{\Delta x_1} = \frac{t_2^2}{t_1^2} = \frac{(2s)^2}{(6s)^2} = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$

A5. A sailor drops a wrench from the top of a sailboat's vertical mast, a vertical distance of 10.0 m above the deck of the boat, while the boat is moving with constant velocity. Where will the wrench hit the deck? Ignore any effects due to air resistance.

B

(A) The wrench will hit the deck ahead of the base of the mast.
(B) The wrench will hit the deck at the base of the mast.
(C) The wrench will hit the deck behind the base of the mast.
(D) The answer depends on the mass of the wrench.
(E) The answer depends on the speed of the boat.

constant velocity $\Rightarrow \Sigma F = 0$ for sailboat.

Net force on wrench is only the vertical gravitational force.

∴ Horizontal motions of wrench and sailboat are the same.

D

A6. A blue ball is thrown horizontally from the roof of a building and at exactly the same time a green ball is dropped from rest. You may assume that the building and the ground around it are level and that air resistance effects are negligible. Which ball reaches the ground first, and what can be said about their speeds on impact? Vertical motions are the same ($v_{oy} = 0$, $a_y = g$ down)

(A) The blue ball reaches the ground first and it is moving faster than the green ball throughout its motion. so times are the same.

(B) The green ball reaches the ground first and it is moving faster than the blue ball throughout its motion. Blue ball is always moving faster

(C) Both balls reach the ground at the same time, and with the same speed. than green ball.

(D) Both balls reach the ground at the same time, and the blue ball is moving faster on impact.

(E) The answer depends on the masses of the balls.

A7. If a constant non-zero net force acts on an object during a given period of time, which one of the following statements **must** be true during that time?

E

$\Sigma\vec{F} \neq 0 \Rightarrow \vec{a} \neq 0 \Rightarrow$ changing velocity

(A) The object does not move.

(B) The acceleration of the object is increasing.

(C) The object's speed remains constant.

(D) The magnitude of the object's velocity increases.

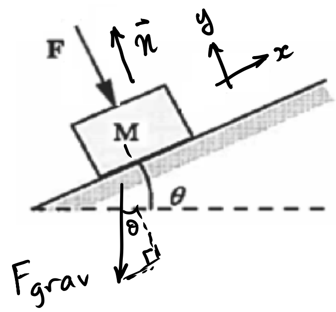
(E) The object accelerates.

changing velocity $\Rightarrow$ change in speed or change in direction or change in both speed and direction

Constant net force $\Rightarrow$ constant acceleration

A8. A block of mass M is on an inclined surface that makes an angle θ with the horizontal. A force $\vec{F}$, perpendicular to the surface, acts on the block as shown in the figure. Which one of the following is the correct expression for the magnitude of the normal force of the surface of the incline on the block?

B



(A) $Mg\cos\theta$ (B) $F + Mg\cos\theta$ (C) $F - Mg\cos\theta$

(D) $Mg\cos\theta + F\cos\theta$ (E) $Mg\cos\theta - F\cos\theta$

$\Sigma F_y = 0$

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

A9. Two objects, 1 and 2, with masses $m_1 = m$ and $m_2 = 2m$, respectively, are initially positioned so that their centres are a distance r apart. The magnitude of the gravitational force of object 2 on object 1 is F. Object 2 is now replaced with object 3, of mass $m_3 = 4m$, and it is positioned so that its centre is a distance $2r$ from the centre of object 1. The magnitude of the gravitational force of object 1 on object 3 is…

E

$F_{21} = \frac{G(m)(2m)}{r^2} = 2\frac{Gm^2}{r^2}$; $F_{13} = G\frac{(m)(4m)}{(2r)^2} = \frac{Gm^2}{r^2} = \frac{1}{2}(F_{21}) = \frac{1}{2}F$

(A) F. (B) $2F$. (C) $4F$. (D) ¼ F. (E) ½ F.

A10. A car has a mass m and is moving with speed V. A truck has a mass $2m$ and is moving with speed $2V$. Which equation correctly relates the kinetic energy of the truck, KE_{truck}, to the kinetic energy of the car, KE_{car}?

D

(A) $KE_{truck} = KE_{car}$ (B) $KE_{truck} = 2KE_{car}$ (C) $KE_{truck} = 4KE_{car}$.

(D) $KE_{truck} = 8KE_{car}$ (E) $KE_{truck} = 16KE_{car}$

$KE_{truck} = \frac{1}{2}(2m)(2v)^2 = \frac{1}{2}(2m)(4V^2) = \frac{1}{2}(8mV^2)$

$KE_{truck} = 8\left(\frac{1}{2}mV^2\right) = 8\,KE_{car}$

A11. A box, of mass *m*, resting stationary on the floor, is lifted up and put on a table top where it then remains stationary. The table top is a height *h* above the floor. What is the net work done on the box during this process? Ignore any effects due to air resistance. $W_{net} = \Delta KE = 0$

D

(A) *mgh* (B) *mg* (C) *–mgh* (D) zero

(E) The net work cannot be determined without knowing the details of how fast the box was moved and what path it took.

A12. You hold a slingshot at arm's length, pull the light elastic band back to your chin, and release it to launch a pebble horizontally with speed 200 cm/s. With the same procedure, you fire a bean with speed 600 cm/s. What is the ratio of the mass of the bean to the mass of the pebble?

A

(A) 1/9 (B) 1/3 (C) 1 (D) 3 (E) 9

In both cases, the work done by the elastic band is the same.

$$\therefore W_{\substack{elastic\\band}} = \Delta KE_{pebble} = \Delta KE_{bean}$$

$$\therefore \frac{1}{2}m_p v_p^2 = \frac{1}{2}m_b v_b^2$$

$$\frac{m_b}{m_p} = \left(\frac{v_p}{v_b}\right)^2 = \left(\frac{200\text{cm/s}}{600\text{cm/s}}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$$

PART B

WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.

WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).

IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE HALF-MARKS (1/2).

IF YOU STILL DO NOT HAVE THE CORRECT ANSWER, BUT REWORK YOUR SOLUTION AND REVEAL A STAR WITH YOUR THIRD SCRATCH, THEN YOU RECEIVE 0.2/2.

REVEALING THE STAR WITH YOUR FOURTH OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

YOU MAY ANSWER ALL FOUR PART B QUESTION GROUPINGS (1-4, 5-8, 9-12, AND 13-16) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 3 GROUPINGS.

USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

Grouping B1-B4

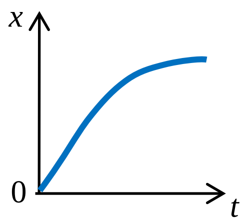
A car is travelling along a straight road at a speed of 52.0 km/h. The driver sees that the traffic lights at an intersection up ahead change to red. He then applies his brakes and brings the car to a stop at a distance of 45.1 m from where he starts applying the brakes. While the car is slowing down its acceleration is constant. We choose the $+x$ direction to be in the direction of the car's velocity at the time when the brakes are first applied.

$$v_0 = \frac{52.0\,\text{km}}{\text{h}} \times \frac{1\,\text{h}}{3600\,\text{s}} \times \frac{1000\,\text{m}}{\text{km}}$$

$$v_0 = 14.4\,\text{m/s}$$

B1. What is the initial speed of the car in m/s?

B2. Which one of the following graphs best represents the position of the car as a function of time from when it first starts braking to when it comes to rest? (We choose $x = 0$ to be the position of the car when it first starts braking.)



$$\Delta x = v_0 t + \tfrac{1}{2} a t^2$$

$$\Delta x = v_0 t - \tfrac{1}{2} |a| t^2$$

Also, note that speed decreases steadily with time. ∴ Car moves shorter distances in equal time intervals

B3. Calculate the magnitude of the acceleration of the car while it is slowing down.

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

$$a = \frac{v^2 - v_0^2}{2\Delta x} = \frac{0 - (14.4\,\text{m/s})^2}{2(45.1\,\text{m})} = -2.30\,\text{m/s}^2 \Rightarrow |a| = 2.30\,\text{m/s}^2$$

B4. Calculate the time interval between when the driver first applies the brakes and when the car comes to rest.

$$v = v_0 + at \Rightarrow t = \frac{v - v_0}{a} = \frac{0 - 14.4\,\text{m/s}}{-2.30\,\text{m/s}^2} = 6.26\,\text{s}$$

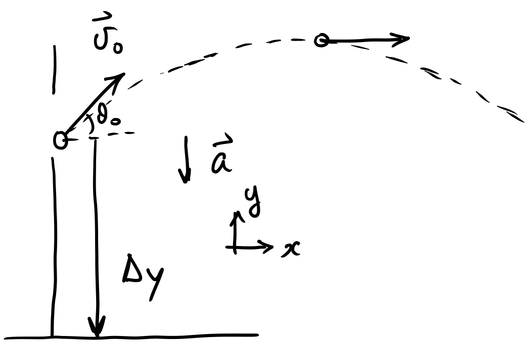
Grouping B5-B8

From the window of a building, a ball is tossed from a height h above the ground with an initial velocity of $\upsilon_0 = 8.90$ m/s at an angle of $\theta_0 = 23.0°$ above the horizontal. It strikes the ground 4.00 s later.

B5. Which one of the following is the correct expression for the speed of the ball when it reaches maximum height?

At max. height, $v_y = 0 \Rightarrow v = v_x = v_{0x} = v_0 \cos\theta_0$

B6. How far horizontally from the base of the building does the ball strike the ground?



$\Delta x = \bar{v}_x t = v_{0x} t = (v_0 \cos\theta_0) t$

$\Delta x = (8.90\,\text{m/s})(\cos 23.0°)(4.00\,\text{s})$

$\Delta x = 32.8\,\text{m}$

B7. Calculate the height from which the ball was thrown.

$\Delta y = v_{0y} t + \frac{1}{2} a_y t^2 = (v_0 \sin\theta_0) t + \frac{1}{2}(-g) t^2$

$\Delta y = (8.90\,\text{m/s})(\sin 23.0°)(4.00\,\text{s}) - \frac{1}{2}(9.80\,\text{m/s}^2)(4.00\,\text{s})^2 = -64.5\,\text{m}$

$\therefore$ height of building $=$ 64.5m

B8. How long does it take the ball to reach a point 10.0 m below the level of launching?

$\Delta y = v_{0y} t + \frac{1}{2} a_y t^2$; $v_{0y} = v_0 \sin\theta_0$

$\Delta y = v_{0y} t - \frac{1}{2} g t^2$ $\quad v_{0y} = 3.48\,\text{m/s}$

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

$(4.90\,\text{m/s}^2) t^2 - (3.48\,\text{m/s}) t - 10.0\,\text{m} = 0$

$t = \dfrac{3.48 \pm \sqrt{(3.48)^2 - 4(4.90)(-10.0\,\text{m})}}{2(4.90)}\,\text{s}$

$t = \dfrac{3.48 \pm 14.43}{9.80}\,\text{s} \Rightarrow t = 1.83\,\text{s}$

Alternate Solution:

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

$v_y = \left[(3.48\,\text{m/s})^2 + 2(-9.80\,\text{m/s}^2)(-10.0\,\text{m})\right]^{1/2}$

$v_y = -14.43\,\text{m/s}$

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

$t = \dfrac{v_y - v_{0y}}{a} = \dfrac{-14.43\,\text{m/s} - 3.48\,\text{m/s}}{-9.80\,\text{m/s}^2}$

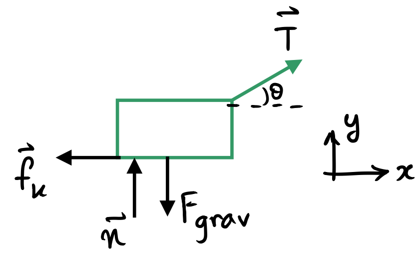
$t = 1.83\,\text{s}$

Grouping B9-B12

A child pulls a sled across horizontal ground, applying a constant tension through a rope held at an angle $\theta = 40.0°$ above the horizontal. The loaded sled has a mass of 15.0 kg, and the coefficient of kinetic friction between the sled and the ground is $\mu_k = 4.00 \times 10^{-2}$. The wagon moves with a constant speed $v_x = 1.44$ m/s. Constant speed in one direction $\Rightarrow \vec{a} = 0 \Rightarrow \Sigma \vec{F} = 0 \Rightarrow \Sigma F_x = 0$

B9. What is the ratio f_k / T of the friction force to the tension in the rope? $T\cos\theta - f_k = 0 \Rightarrow \frac{f_k}{T} = \cos\theta$

B10. Which one of the following free body diagrams most accurately represents the forces acting on the sled?



$\Sigma \vec{F} = 0$ $\qquad \Sigma F_y = 0$

$\Sigma F_x = 0 \qquad n + T\sin\theta - F_{grav} = 0$

$T\cos\theta - f_k = 0 \qquad n = F_{grav} - T\sin\theta$

$T\cos\theta = f_k \qquad n = mg - T\sin\theta$

$T\cos\theta = \mu_k n = \mu_k(mg - T\sin\theta)$

B11. Calculate the magnitude of the tension in the rope.

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

$T(\cos\theta + \mu_k \sin\theta) = \mu_k mg \rightarrow T = \frac{\mu_k mg}{\cos\theta + \mu_k \sin\theta}$

$$T = \frac{(0.0400)(15.0\text{ kg})(9.80\text{ m/s}^2)}{(\cos 40.0°) + (0.0400 \sin 40.0°)} = 7.43\text{ N}$$

B12. If the child lets go of the rope, how far will the sled slide before coming to a complete stop? Neglect any added obstruction due to the rope.

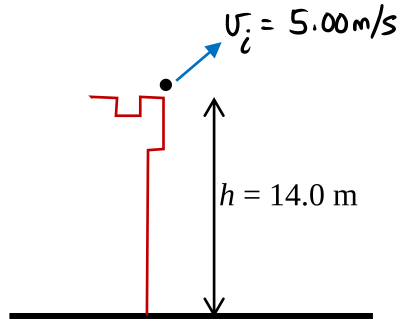
$\Sigma F_x = ma'_x \Rightarrow a'_x = -\frac{f'_k}{m} = \frac{-\mu_k n'}{m} = \frac{-\mu_k(mg)}{m} = -\mu_k g$ (T is now 0)

$$v_x^2 = v_{0x}^2 + 2a_x\Delta x \Rightarrow \Delta x = \frac{v_x^2 - v_{0x}^2}{2a_x} = \frac{-v_{0x}^2}{2(-\mu_k g)} = \frac{-(1.44\text{ m/s})^2}{2(-(0.0400)(9.80\text{ m/s}^2))}$$

$\Delta x = 2.64$ m

Grouping B13-B16

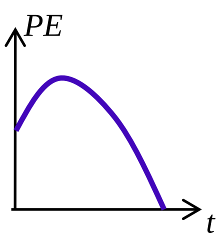
To repel attackers, a rock is thrown from the top of a castle wall and it eventually hits the horizontal ground below (narrowly missing an attacking knight). The rock is thrown at an angle above the horizontal, from a height *h* = 14.0 m above the ground. The initial speed of the rock is 5.00 m/s. The mass of the rock is $\underbrace{\text{312 g}}_{= 0.312\,\text{kg}}$.



B13. At what point in the rock's flight is the kinetic energy of the rock the smallest?

speed, and ∴ KE, is smallest at max. height.

B14. Which one of the following graphs best represents the gravitational potential energy of the rock as a function of time during its flight?



Since $PE_{grav} = mgh$ and v_x is constant, PE_{grav} vs. t will have the same shape as the actual trajectory of the rock.

B15. Calculate the speed of the rock just before it hits the ground (ignoring air resistance).

$$E_f = E_i \Rightarrow \tfrac{1}{2}mv_f^2 + 0 = \tfrac{1}{2}mv_i^2 + mgh \Rightarrow v_f = \sqrt{v_i^2 + 2gh} = 17.3\,\text{m/s}$$

B16. In real life (when air resistance is not ignored) it is found that the speed of the rock just before it hits the ground is exactly 10.0% smaller than the value you calculated in B15. Calculate the work done by the air resistance force on the rock during its motion.

Now $v_f' = (0.90)(17.3\,\text{m/s}) = 15.57\,\text{m/s}$; $E_i + W_{nc} = E_f' \Rightarrow W_{nc} = E_f' - E_i$

$$W_{nc} = \tfrac{1}{2}mv_f'^2 - \left(\tfrac{1}{2}mv_i^2 + mgh\right)$$

$$W_{nc} = -8.89\,\text{J}$$

END OF EXAMINATION