Student Name : SOLUTION________________________

Student I.D. : ___________________________________

American University of Beirut

Faculty of Arts and Sciences

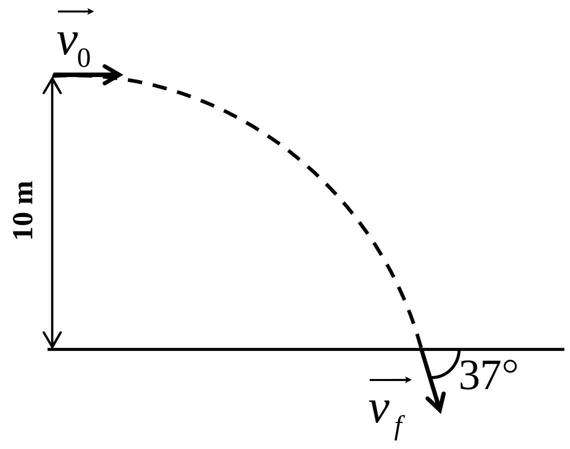
Course Name	: Introductory Physics I	**Course Code**	: PHYS 101
Exam	: Quiz-1	**Sections**	: All
Date	: March 6, 2015	**Time**	: 17:00 – 18:00
Semester	: Spring	**Year**	: 2014 - 2015
Instructor	: Dr. Hani Hamzeh	**Exam Weight**	: 20%

Instructions

- Time allowed: **60 minutes**
- Take g = **9.80 m/s^2**
- Cheating in any way will result in an **F** grade
- Read each question carefully before answering
- Answer questions that you are confident about first.
- This exam consists of **7 pages** including this page
- Only standard (not programmable) calculators are allowed
- No documents are allowed
- Borrowing any instrument is forbidden

Problem #	Grade
Problem 1	/15
Problem 2	/5
Problem 3	/10
Problem 4	/10
Problem 5	/10
Problem 6	/10
Total	/100

Problem-1 (15 points) (~ 15 min)



A ball is thrown horizontally with a speed v_o from a height of 10 m. It reaches the ground with an angle of 37° below the horizontal as shown in the figure. Neglect air resistance.

(a) Find the initial speed v_o of the ball.

(b) How long does it take the ball to reach the ground?

a) $v_{f_x} = v_f \cos 37 = v_{o_x} = v_o \Rightarrow v_f = v_o / \cos 37$

$v_{f_y} = -v_f \sin 37 = -v_o \tan 37$

constant acceleration, projectile motion $\Rightarrow$

$v_{f_y}^2 = v_{i_y}^2 + 2a_y \Delta y = 0 + 2(-9.80)(-10) = 196 \Rightarrow v_{f_y} = -14 \text{ m/s}$

$$\boxed{v_o = \frac{-v_{f_y}}{\tan 37} = \frac{14}{\tan 37} = 18.6 \text{ m/s}}$$

b) $$\boxed{t = \frac{v_{f_y} - v_{i_y}}{a} = \frac{-14 - 0}{-9.80} = 1.43 \text{ s}}$$

If the ball were thrown instead with an initial velocity of 9 m/s at an angle of 30° above the horizontal, from the same initial height:

(c) What would then be the maximum height reached by the ball with respect to the ground?

(d) How far from the initial horizontal position would it reach the ground?

c) $v_{i_y} = v_i \sin 30 = 9 \sin 30 = 4.5 \text{ m/s}$

$v_{f_y}^2 = v_{i_y}^2 + 2a_y \Delta y \Rightarrow \Delta y = y_{max} - y_i = \frac{v_{f_y}^2 - v_{i_y}^2}{2a_y} = \frac{0 - 4.5^2}{2(-9.80)} = 1.03 \text{ m} \Rightarrow \boxed{y_{max} = 11.03 \text{ m}}$

d) $\Delta y = v_{i_y} t - \frac{1}{2} g t^2$ the total time of the flight can be found:

$-10 = 4.5t - 4.9t^2 \Rightarrow 4.9t^2 - 4.5t - 10 = 0 \Rightarrow t = 1.96 \text{ s}$ (only the positive solution is possible)

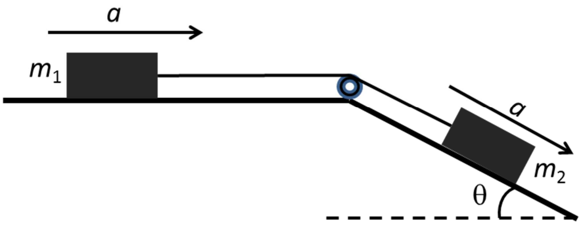
$$\boxed{\Delta x = v_{i_x} t = (v_i \cos 30) t = (9 \cos 30) 1.96 = 15.3 \text{ m}}$$

Problem-2 (5 points) (~ 5 min)

Two blocks of masses m_1 = 3 kg and m_2 = 5 kg are connected by a string of negligible mass that passes over a frictionless mass-less pulley. Block m_1 moves on a horizontal frictionless surface, while block m_2 moves on a frictionless inclined plane making an angle θ = 30° with the horizontal.

(a) Draw a free body diagram for each block.

(b) Find the tension in the string.



Newton's second law on block $m_1: \vec{T_1} + m_1\vec{g} + \vec{n_1} = m_1\vec{a_1}$

Newton's second law on block $m_2: \vec{T_2} + m_2\vec{g} + \vec{n_2} = m_2\vec{a_2}$

Since the two blocks are connected by a taut string and the pulley is frictionless and mass-less $\Rightarrow a_1 = a_2$

since the string is also of negligible mass $\Rightarrow T_1 = T_2$

Considering the system comprised of the two blocks and the string connecting them and using the "system approach" we first find a

Newton's second law for the system is $m_1\vec{g} + m_2\vec{g} + \vec{n_1} + \vec{n_2} = (m_1 + m_2)\vec{a}$

If we take the projection along the direction of motion, with rightward as the positive direction:

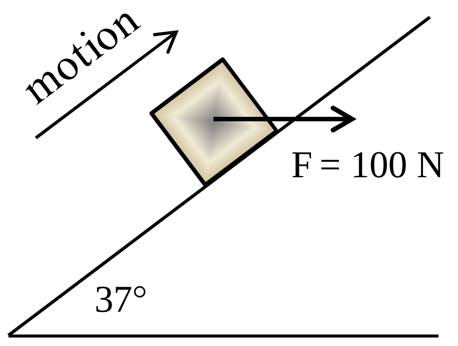
$$m_2 g \sin 30 = (m_1 + m_2)a \Rightarrow a = \frac{m_2 g \sin 30}{(m_1 + m_2)} = \frac{5 \times 9.80 \times \sin 30}{8} = 3.06 \text{ m/s}^2$$

If we isolate the block of mass m_1 and project Newton's second law along the horizontal direction:

$\boxed{T = m_1 a = 3 \times 3.06}$

Problem-3 (10 points) (~ 10 min)

A 4 kg block is pushed upward over a 37° rough incline by a constant horizontal force of 100 N (see figure). The block moves up the incline with a constant acceleration a = 3 m/s^2. Find the magnitude of the coefficient of kinetic friction between the incline and the object (μ_k = ?).



Newton's second law

$$\sum \vec{F} = \vec{F} + \vec{n} + m\vec{g} + \vec{f_k} = m\vec{a}$$

Projection along x (x axis taken parallel to the incline and positive upwards)

$$F\cos 37 + 0 - mg\sin 37 - f_k = ma \quad (1)$$

and $f_k = \mu_k n$

Projection along y

$$-F\sin 37 + n - mg\cos 37 + 0 = 0 \Rightarrow n = F\sin 37 + mg\cos 37 = 91.5 \text{ N}$$

$$\Rightarrow f_k = \mu_k\left(F\sin 37 + mg\cos 37\right)$$

if we replace in equation (1)

$$F\cos 37 - mg\sin 37 - \mu_k\left(F\sin 37 + mg\cos 37\right) = ma$$

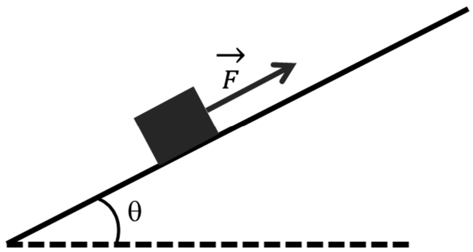
$$\Rightarrow \mu_k = \frac{F\cos 37 - mg\sin 37 - ma}{F\sin 37 + mg\cos 37} = 0.48$$

Problem-4 (10 points) (~ 10 min)

An object of weight 80 N is on an inclined plane that makes an angle $\theta = 20°$ with the horizontal. An upward force $\vec{F}$ is applied on the object parallel to the inclined plane (see figure). The coefficient of static friction between the object and the inclined plane is $\mu_s = 0.25$.

(a) If the object is not moving and if the force of static friction f_s is not equal to its maximum value, find an expression for f_s.

(b) Calculate the minimum magnitude of the applied force $\vec{F}$ that will start the object to move up the incline.



a) Newton along the incline:

$F - f_s - mg\sin\theta = 0$

$\boxed{f_s = F - mg\sin\theta}$

b) the minimum magnitude of the force F that will start the object moving up the incline is the one which causes the static friction force to reach its maximum value $f_{s,\max} = \mu_s n$

$F_{\min} - mg\sin\theta = f_{s,\max} = \mu_s n$

Newton along the perpendicular to the incline:

$n - mg\cos\theta = 0 \Rightarrow n = mg\cos\theta$ and we replace this value in the equation giving us $F_{\min}$

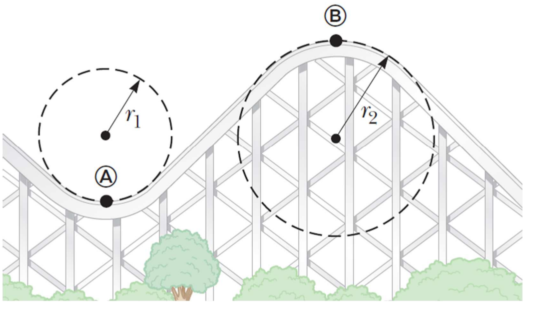
$\Rightarrow \boxed{F_{\min} = \mu_s mg\cos\theta + mg\sin\theta = 0.25\times 80\times\cos 20° + 80\times\sin 20° = 46.16\text{ N}}$

Problem-5 (10 points) (~ 10 min)

A roller-coaster car has a mass of 500 kg when fully loaded with passengers. Assume the roller-coaster tracks at points A and B are parts of vertical circles of radius r_1 = 10.0 m and r_2 = 15.0 m, respectively.

(a) If the vehicle has a speed of 20.0 m/s at point A, what is the force exerted by the track on the car at this point?

(b) What is the maximum speed the vehicle can have at point B and still remain on the track?



a) We apply Newton's second law at point A, with $v = 20.0$ m/s, $n =$ force of track on roller coaster, and $R = 10.0$ m:

$$\sum F = \frac{Mv^2}{R} = n - Mg$$

From this we find

$$n = Mg + \frac{Mv^2}{R} = 2.49\times10^4\,\text{N}$$

b) At point B, the centripetal acceleration is now downard and Newton's second law now gives

$$\sum F = n - Mg = -\frac{Mv^2}{R}$$

The maximum speed at B corresponds to the case where the rollercoaster begins to fly off the track, or when $n = 0$. Then,

$$-Mg = -\frac{Mv_{\text{max}}^2}{R} \;\Rightarrow v_{\text{max}} = \sqrt{Rg} = 12.1\text{ m/s}$$

Problem-6 (10 points) (~ 10 min)

A skydiver of mass 80.0 kg jumps from a slow-moving aircraft and reaches a terminal speed of 50.0 m/s.

(a) What is her acceleration when her speed is 30.0 m/s?

(b) What is the drag force on the skydiver when her speed is

i. 50.0 m/s?

ii. 30.0 m/s?

Given $m = 80.0$ kg, $v_T = 50.0$ m/s, we can write

If we apply Newton's second law along the vertical direction to the skydiver we have:

$$D - mg = -ma \Rightarrow \frac{1}{2}C\rho Av^2 - mg = -ma$$

When the skydiver reaches her terminal speed, $a = 0$

$$\Rightarrow mg = \frac{C\rho Av_T^2}{2} \Rightarrow \frac{C\rho A}{2} = \frac{mg}{v_T^2} = 0.314 \text{ kg/m}$$

a) At $v = 30.0$ m/s

$$a = g - \frac{C\rho Av^2/2}{m} = 9.80 \text{ m/s}^2 - \frac{(0.314\,\text{kg/m})(30.0 \text{ m/s})^2}{80.0 \text{ kg}} = 6.27 \text{ m/s}^2 \text{ downward}$$

b) i) At $v = 50.0$ m/s, terminal velocity has been reached

$$\sum F_y = 0 = mg - D \Rightarrow D = mg = (80.0 \text{ kg})(9.80 \text{ m/s}^2 = 785 \text{ N directed upward}$$

ii) At $v = 30.0$ m/s

$$\frac{C\rho Av^2}{2} = (0.314 \text{ kg/m})(30.0 \text{ m/s})^2 = 283 \text{ N directed upward}$$