University of Turkish Aeronautical Association
PHY 101
MIDTERM EXAMINATION
Saturday, 17 November, 2018

TIME:
13:40-15:30
110 minutes

Check student's ID card and write his/her initials here:

Fill in this part completely. Use pen, not pencil:

LAST NAME	FIRST NAME	NO	SECT	DEPT	SIGNATURE

GRADING:

Problem No.	Points	Grader's Name	Grade	Grade Change (If any after objection.)
1	20	SB		
2	25	ÇŞ		
3	30	SD		
4	25	MAO		
Total =	100	Total =		

Solutions

- This examination has 4 classical type problems. Solve all of them.
- Check the exam. If there are any missing pages, missing problems, or printing errors, inform the proctor immediately.
- **Use of calculator and asking questions to the proctor is not allowed.**
- If you think that a problem is wrong, do not spend time. Skip it and continue, and see the coordinator after the exam.
- There might be corrections during the exam. Listen carefully and do the corrections on the exam paper.
- If a problem has quantities given like x, y, V, E, r, q, ... etc. with no numerical values, then express your answers in terms of some or all of the given quantities and the related constants like the permittivity of empty space ε_0, etc.
- **Write all steps in answering a problem in the space provided under each problem. If the solution steps are not shown, no credits will be given. Write clearly all formulas you use. SI units must be given for all numerical answers.**
- **Students <u>cannot</u> leave the exam room during the first 15 minutes. Any student who comes late more than 15 minutes cannot take the exam. No extra time is given to the student who comes late during the first 15 minutes.**
- **Keep your solutions very carefully away from other eyes around you by keeping the exam papers folded at all times. Otherwise another student may look at your solution and copy it. If that happens, then you will also be questioned.**

<u>Instructors:</u> Assoc. Prof. Dr. S. BADOĞLU, Assoc. Prof. Dr. Ç. ŞENTÜRK, Asst. Prof. Dr. S. DENGİZ, Dr. M. A. OLPAK

PROBLEM 1 (20 points)

At $t = 0$, a particle starts from rest at $x = 0, y = 0$. The position of the particle is given as a function of time as $r = (2.0\,t^2\mathbf{i} + 1.5t^2\mathbf{j})m$. Determine (a) the x and y components of velocity, (b) the speed and (c) the acceleration of the particle, all as a function of time. (d) Express position and velocity vectors at t=2 s, and evaluate all the above at t=2 s.

(a) $\vec{v} = \frac{d\vec{r}}{dt} = \frac{d}{dt}\left[(2.0t^2\hat{i} + 1.5t^2\hat{j})m\right] = (4.0t\hat{i} + 3.0t\hat{j})\,m/s$

Hence $v_x = (4.0\,t)\,m/s$, $v_y = (3.0t)\,m/s$

(b) $v = \sqrt{v_x^2 + v_y^2} = \sqrt{16.0\,t^2 + 9.0\,t^2} = \sqrt{25.0\,t^2} = (5t)\,m/s$

(c) $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}\left[(4.0t\hat{i} + 3.0t\hat{j})\,m/s\right] = (4.0\hat{i} + 3.0\hat{j})\,m/s^2$

(d) $\vec{r}(t=2.0s) = (8.0\hat{i} + 6.0\hat{j})\,m$

$\vec{v}(t=2.0s) = (8.0\hat{i} + 6.0\hat{j})\,m/s$

$\vec{a}(t=2.0s) = (4.0\hat{i} + 3.0\hat{j})\,m/s^2$

$v_x(t=2.0s) = 8.0\,m/s$

$v_y(t=2.0s) = 6.0\,m/s$

All parts are 5 pts.

Point cuts:

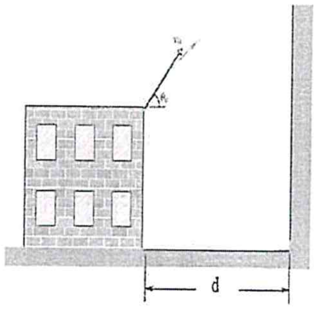
- -1 for every part with missing units.
- -1 for every part with missing vector notation.
- -1 if derivation is not shown.
- -1 if calculation of speed is not shown per components.

PROBLEM 2 (25 points)

A ball is thrown from the roof of a building toward a wall at speed $v_0 = 25\ \frac{m}{s}$ and at angle $\theta_0 = 37^\circ$ above the horizontal, as shown in the figure. If the ball hits the wall $2s$ after the throw,

a) (6 points) Find the distance d between the wall and the base of the building,
b) (6 points) How far above the roof of the building does the ball hit the wall?
c) (10 points) What are the horizontal and vertical components of the ball's velocity, as it hits the wall?
d) (3 points) When the ball hits the wall, has it passed the heighest point on its trajectory?

[Take g=10 $\frac{m}{s^2}$, and $\sin(37^\circ) = \cos(53^\circ) = \frac{3}{5}$; $\sin(53^\circ) = \cos(37^\circ) = \frac{4}{5}$]



(Let's choose $\overset{y}{\perp}_{x}$ with the orgin at the release point) $\Rightarrow \boxed{x_0 = y_0 = 0}$

a) (For the x-motion, $a_x = 0$) $\Rightarrow d = v_{0x} t = v_0 \cos\theta_0 t$

$= 25 \cdot \frac{4}{5} \cdot 2 = 40m$ //

b) (For the y-motion, $a_y = -g$) $\Rightarrow y = \overset{0}{\cancel{y_0}} + v_{0y} t - \frac{1}{2} g t^2$ $(v_{0y} = v_0 \sin\theta_0)$

$= 25 \cdot \frac{3}{5} \cdot 2 - \frac{1}{2} \cdot 10 \cdot 2^2 = 10m$ //

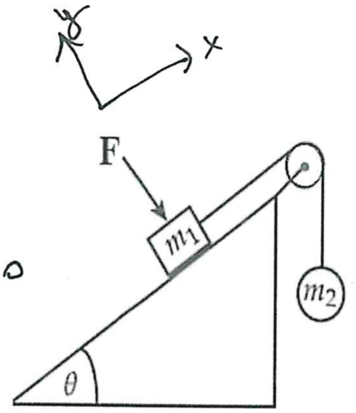
c) $v_x = v_0 \cos\theta_0 = 25 \cdot \frac{4}{5} = 20\ \frac{m}{s} = \text{Const.}$

$v_y = v_{0y} - gt = v_0 \sin\theta_0 - gt = 25 \cdot \frac{3}{5} - 10 \cdot 2 = -5\ \frac{m}{s}$

d) Since $v_y < 0$ when the ball hits the wall, it has passed the highest point on its trajectory.

PROBLEM 3 (30 points)

A block of mass $m_1 = 1kg$ placed on a rough surface ($\mu_k = 0.5$) inclined at an angle $\theta = 53^\circ$ is connected by a light cord over a massless and frictionless pulley with a ball of mass $m_2 = 5kg$. A force $\boldsymbol{F}$ is exerted on mass m_1 in *perpendicular* direction to the incline as shown in the figure. The mass m_1 is moving with a <u>*constant*</u> speed upward the incline. $\Rightarrow a=0$

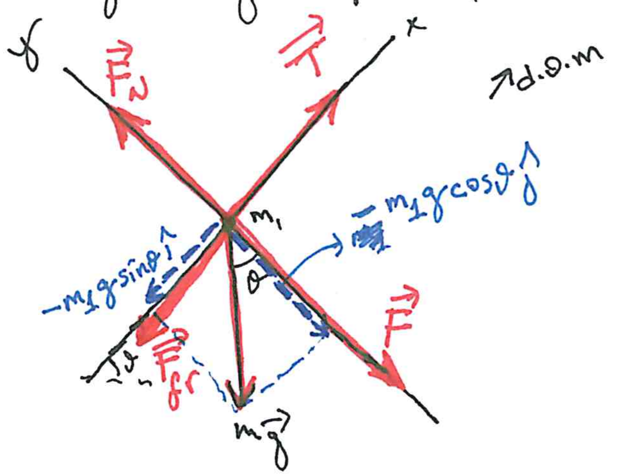


a) (5 points) Draw the Free Body Diagrams for the masses m_1 and m_2.
b) (5 points) Find the tension in the cord.
c) (10 points) Find the normal force $\boldsymbol{F_N}$ acting on m_1.
d) (10 points) Find the magnitude of the applied force $\boldsymbol{F}$ on m_1.

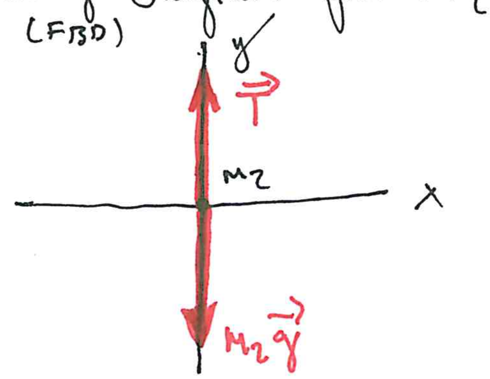
(**Note:** $\sin(53^\circ) = 0.8$; $\cos(53^\circ) = 0.6$; μ_k is the coefficient of kinetic friction.)

$\boxed{a=0}$

(a) Free-Body (FBD) Diagram for m_1:



Free-Body Diagram (FBD) for m_2



(b) From FBD for m_2, one gets: ~~a=0~~

$$\sum \vec{F}_2 = m_2 a = 0 \Rightarrow (T - m_2 g)\hat{j} = 0 \Rightarrow T = m_2 g = (5kg)(9.80\,m/s^2) = 49N$$

(c) From FBD for m_1, one arrives at:

$$\sum \vec{F}_1 = m_1 a = 0 \Rightarrow \underbrace{(T - m_1 g\sin\theta - F_{fr})}_{x\text{-component}}\hat{i} + \underbrace{(F_N - m_1 g\cos\theta - F)}_{y\text{-component}}\hat{j} = 0$$

with $F_{fr} = \mu_k F_N$.

From x-component, we get

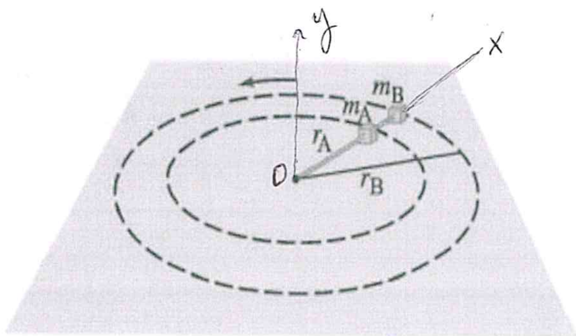
$$T - m_1 g\sin\theta - \mu_k F_N = 0 \Rightarrow F_N = \frac{T - m_1 g\sin\theta}{\mu_k} = \frac{49N - (1kg)(9.80\,m/s^2)\sin 53^\circ}{0.5} = 82.34N$$

(d) From y-component of the net force for m_1, one has

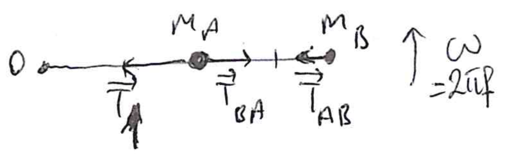
$$F_N - m_1 g\cos\theta - F = 0 \Rightarrow F = F_N - m_1 g\cos\theta = 82.34N - (1kg)(9.80\,m/s^2)\cos 53^\circ = 76.45N$$

PROBLEM 4 (25 points)

Two blocks, with masses m_A and m_B, are connected to each other and to a central post by cords as shown in the figure. They rotate about the post at frequency f (revolutions per second) on a frictionless horizontal surface at r_A and r_B from the post. Derive an algebraic expression for the tension in each segment of the cord (assumed massless) (**Hint:** for an object revolving around a fixed point at radius r with frequency f, the speed of the object is given by $v = 2\pi f r$.)

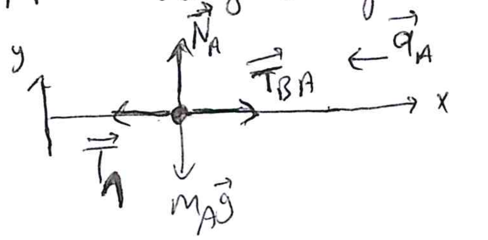


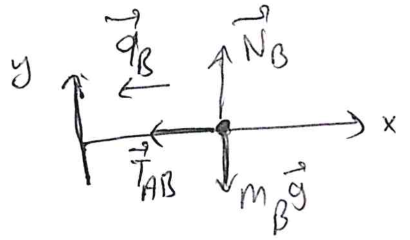
At a generic instant, we take a photograph of the system:



The masses are rotating with the same angular speed.

Free body diagrams:





$|\vec{T}_{BA}| = |\vec{T}_{AB}| \equiv T_2$

$|\vec{T}_1| \equiv T_1$

$|\vec{a}_A| = a_A$; $|\vec{a}_B| = a_B$

$\vec{T}_{AB}$ is the force pulling m_B, and $\vec{T}_{AB}$ is the force pulling m_A on the second rope. Their magnitudes are equal, but directions are opposite. So they are different forces, and are given different names.

Equations of motion:

$N_A - m_A g = 0$; $|\vec{T}_{BA}| - |\vec{T}_1| = -m_A |\vec{a}_A| \longrightarrow T_1 - T_2 = m_A a_A = m_A \frac{v_A^2}{r_A}$

$N_B - m_B g = 0$; $-|\vec{T}_{AB}| = -m_B |\vec{a}_B| \longrightarrow T_2 = m_B a_B = m_B \frac{v_B^2}{r_B}$

there is no friction; these equations give no new info.

$v_A = \omega r_A = 2\pi f r_A$

$v_B = \omega r_B = 2\pi f r_B$

$\Rightarrow T_2 = m_B \cdot \frac{(2\pi f r_B)^2}{r_B} = \boxed{4\pi^2 f^2 m_B r_B}$

for T_1, see the other page

$$T_1 - T_2 = m_A \frac{(2\pi f r_A)^2}{r_A} = 4\pi^2 f^2 m_A r_A \rightarrow T_1 = T_2 + 4\pi^2 f^2 m_A r_A$$

$$T_2 = 4\pi^2 f^2 m_B r_B \Rightarrow \boxed{T_1 = 4\pi^2 f^2 (m_A r_A + m_B r_B)}$$