SOLUTIONS

Istanbul Medipol University
School of Engineering and Natural Sciences
General Physics 1

Midterm

17 November 2019

Duration: 120 min

Name	
Student ID	
Department	
Signature	

- Closed book, closed notes, no calculators
- Write your student ID on every page in the spaces provided above.
- Show all your work. Your work and answers must be shown on the pages provided. You may write on the back side of the paper.
- Your grade will be based on the correctness of your solution and the clarity of your work leading up to the solution.
- Numerical answers must be given with correct SI units, and SI unit symbols must be used only.

Grade:

Question	Course Learning Outcome	Grade
1 (20 points)	1, 3	
2 (20 points)	1, 3	
3 (20 points)	1, 3	
4 (20 points)	1, 3	
5 (20 points)	1, 3	
	Total	

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Question 1 (from Young and Friedman)

An automobile and a truck start from rest at the same instant, with the automobile initially at some distance behind the truck. The truck has a constant acceleration of *2 m/s²*, and the automobile an acceleration of *3 m/s²*. The automobile overtakes the truck after the truck has moved *40 m*.

a. How much time does it take the automobile to overtake the truck?
b. How far was the automobile behind the truck initially?
c. What is the speed of each when the automobile catches the truck?

a.) Truck starts from rest with $a_T = 2\,m/s^2$ and moves 40m:

5

$$x = x_0 + v_0 t + \frac{1}{2} a_T t^2 \quad , x_0 = 0 \quad , v_0 = 0$$

$$x = \frac{1}{2} a_T t^2$$

$$40m = \frac{1}{2}(2m/s^2)t^2$$

10 $$t = 2\sqrt{10}\ s$$

b) The total distance that the automobile travels:

$$x_A = x_0 + v_0 t + \frac{1}{2} a_A t^2 \qquad x_0 = 0 \ , v_0 = 0 \qquad t = 2\sqrt{10}\ s$$

$$a_A = 3\,m/s^2$$

$$x_A = \frac{1}{2}(3m/s^2)(40s^2)$$

3 $$= 60m$$

5 2 $$x_A - x_T = 60\,m - 40m = 20m$$

c) $$v_A = v_{0A} + a_A t \qquad v_0 = 0$$

$$= (3m/s^2)2\sqrt{10}\ s$$

2.5 $$= 6\sqrt{10}\ m/s$$

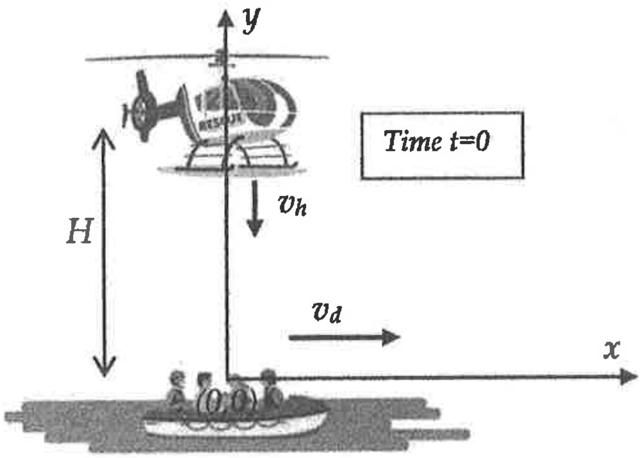
$$v_T = v_{0T} + a_T t \quad , v_0 = 0$$

$$= (2m/s^2)2\sqrt{10}\ s$$

2.5 $$= 4\sqrt{10}\ m/s$$

Question 2 (from Prof. Bordel)

A helicopter has constant vertical speed v_h downwards. When the helicopter is at a height H, right below it there is a boat that is moving horizontally with speed v_d. If at this instant, a package is thrown from the helicopter horizontally:



6 a. What should be the initial speed and direction (left or right) of the package with respect to the helicopter for it to land on the boat?

6 b. How long does it take for the package to reach the boat?

3 c. What is the trajectory y(x) of the package for an observer on the shore?

3 d. What is the horizontal distance traveled by the package?

2 e. When the package lands on the boat, which way does its velocity point? What is the angle between the velocity and the horizontal?

a) Its ~~velo~~ horizontal velocity should match the velocity of the boat. Since it's thrown horizontally, it should be thrown with $\vec{V_d}$ to the right.

b) $y = y_0 + V_{y_0} t - \frac{1}{2} g t^2$

$0 = H - V_h t - \frac{1}{2} g t^2$

$g t^2 + 2 V_h t - 2H = 0$

solve for t: $\dfrac{-2V_h \pm \sqrt{4V_h^2 + 8Hg}}{2g} = \dfrac{-V_h \pm \sqrt{V_h^2 + 2gH}}{g}$

c) $x = V_d t \Rightarrow t = \dfrac{x}{V_d}$

$y = H - \dfrac{V_h}{V_d} x - \dfrac{g}{2V_d^2} x^2$

d) $x = v_d t$

$$= \frac{v_d}{g}\left(-v_h + \sqrt{v_h^2 + 2gH}\right)$$

e) $\tan\theta = \dfrac{v_{y_{final}}}{v_{x_{final}}}$

$v_{x_{final}} = v_d \hat{i}$

$v_{y_{final}} = v_{y_0} - gt$

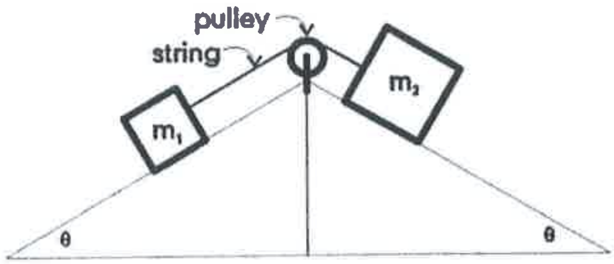
$$= -v_h - g\left(\frac{-v_h \pm \sqrt{v_h^2 + 2gH}}{g}\right)$$

$$= -\sqrt{v_h^2 + 2gH}\ \hat{j}$$

$$\theta = \arctan\left(\frac{-\sqrt{v_h^2 + 2gH}}{v_d}\right)$$

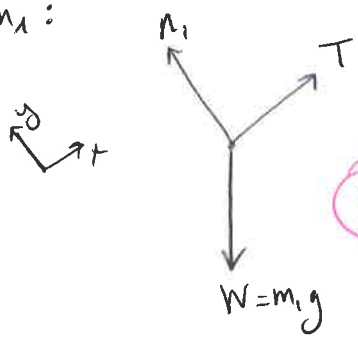
Question 3 (from Prof. Chiao)

Two masses $m_1 = 5kg$ and $m_2 = 10\ kg$ are on opposite sides of a double incline that has an angle of $\theta = 30^o$ with respect to the ground on both sides. The masses are attached by a spring over a pulley that sits at the top of the incline. The spring and pulley are massless and the incline is frictionless. (You can take $g = 10\ m/s^2$)



a. Draw free body diagrams for both masses
b. Find the acceleration of the two masses
c. Find the tension in the string

a) FBD for m_1:



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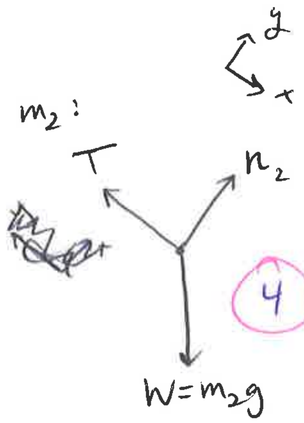
FBD for m_2:



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b) m_1: $\Sigma F_y = 0 : -m_1 g\cos\theta + n_1 = 0$

$\Sigma F_x = m_1 a = T - m_1 g\sin\theta \rightarrow T = m_1(a + g\sin\theta)$

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m_2: $\Sigma F_y = 0 : -m_2 g\cos\theta + n_2 = 0$

$\Sigma F_x = m_2 a = m_2 g\sin\theta - T$

$$m_2 a = m_2 g\sin\theta - m_1(a + g\sin\theta)$$

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$$(m_1 + m_2)a = (m_2 - m_1) g\sin\theta$$

$$a = \frac{m_2 - m_1}{m_1 + m_2} g\sin\theta = \left(\frac{10kg - 5kg}{5kg + 10kg}\right)(10 m/s^2)\sin 30^\circ$$

$$= \frac{50}{30} m/s^2 = \frac{5}{3} m/s^2$$

c) $T = m_1 (a + g\sin\theta)$

$$= m_1 \left(\frac{m_2 - m_1}{m_1 + m_2} g\sin\theta + g\sin\theta \right)$$

$$= g\sin\theta \left[m_1 + \frac{m_1 m_2 - m_1^2}{m_1 + m_2} \right]$$

$$= g\sin\theta \left[\frac{m_1^2 + m_1 m_2 + m_1 m_2 - m_1^2}{m_1 + m_2} \right]$$

$$= g\sin\theta \left(\frac{2 m_1 m_2}{m_1 + m_2} \right)$$

$$= (10\,m/s^2)\,\frac{1}{2} \left(\frac{2(5kg)(10kg)}{15kg} \right)$$

$$= \frac{100}{3}\,N$$

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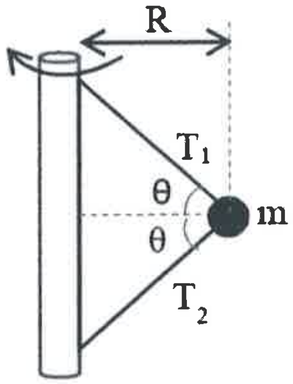
Question 4 (from Prof. Tonguc)

A point object with mass m is tied to a vertical rod with two massless ropes as shown in the figure. If m is uniformly turning in the horizontal plane around the rod;

a. Draw the free body diagram for m and write the relevant equations.
b. Given the values listed below, find the tension T_1 and the linear velocity of m.



$T_2 = 50$ N
$R = 2$ m
$m = 8$ kg
$g = 10$ m/s^2
$\theta = 53°$
$\sin 53° = 0.8$
$\cos 53° = 0.6$

a) FBD for m:

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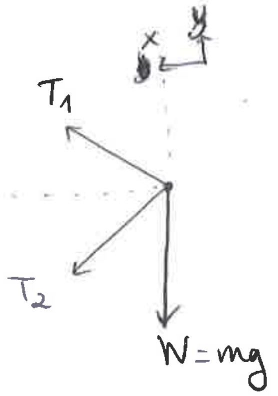

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$$y: \; T_1 \sin\theta - T_2 \sin\theta - mg = 0$$

$$x: \; T_1 \cos\theta + T_2 \cos\theta = m\frac{v^2}{R}$$

4

b) $T_1 \sin 53° - T_2 \sin 53° - mg = 0$

$T_1(0.8) - (50\text{ N})(0.8) - (8\text{ kg})(10\text{ m/s}^2) = 0$

$T_1 = \dfrac{120\text{ N}}{0.8} = 150$ N

4

$(T_1 + T_2)\cos\theta = m\dfrac{v^2}{R}$

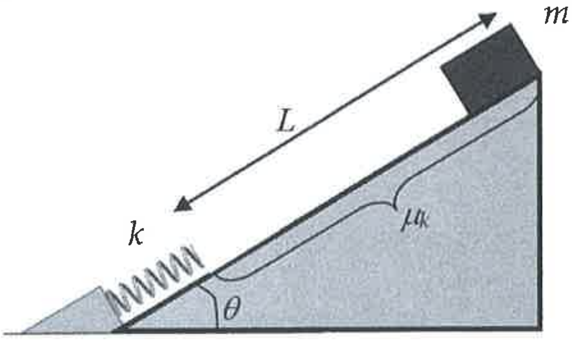
$(150\text{ N} + 50\text{ N})\, 0.6 = (8\text{ kg})\dfrac{v^2}{2\text{m}}$

$\dfrac{240}{8} = v^2 \quad \rightarrow v = \sqrt{30}$ m/s

4

Question 5 (from Prof. Bordel)

A block of mass m is released from rest at the top of an incline forming an angle θ with the horizontal. After traveling a distance L, the block hits a spring of stiffness constant k which is initially in its equilibrium configuration. The surface of the incline is rough above the spring - with a coefficient of kinetic friction μ_k between the block and the ramp - but smooth under the spring as seen in Figure.



a. Without any calculation, explain whether or not the block reaches the top of the incline after being pushed by the spring.
b. Determine the speed of the block when it reaches the spring
c. Determine the length of the compression l.
d. Determine the distance d traveled by the block on the way back, from the point where it loses contact with the spring to where it reaches its maximum height.
e. Determine the kinetic friction coefficient that allows the block to get to a stop after traveling a distance $L/2$ on the way back.

4 a) Because of energy dissipation due to 2 friction, the block 2 cannot reach the top again.

5 b) $W_{other} + K_1 + U_{grav_1} + U_{el_1} = K_2 + U_{grav_2} + U_{el_2}$ $\quad [H = L\sin\theta]$

$$-\mu_k n L + mgH = \frac{1}{2} m v_2^2$$

$$-\mu_k mg\cos\theta\, L + mgH = \frac{1}{2} m v_2^2$$

$$-gL\mu_k\cos\theta + gL\sin\theta = \frac{1}{2} v_2^2$$

$$\sqrt{2gL[\sin\theta - \mu_k\cos\theta]} = v_2$$

5 c) $W_{other} + K_2 + U_{grav_2} + U_{el_2} = K_1 + U_{grav_1} + U_{el_1}$

$$\frac{1}{2} m v_2^2 + l\sin\theta\, mg = \frac{1}{2} k l^2$$

$$l^2 - \frac{2mg}{k}\sin\theta\, l - \frac{m}{k} v_2^2 = 0 : l = \frac{2mg}{k}\sin\theta \pm \sqrt{\frac{4m^2g^2}{k^2}\sin^2\theta + \frac{4mv_2^2}{k}}$$

$$\frac{1}{2} m_2 v_2^2 + l\, mg\sin\theta = \frac{1}{2} k l^2$$

$$\frac{1}{2} m\left[2gL(\sin\theta - \mu_k\cos\theta)\right] + l\, mg\sin\theta = \frac{1}{2} k l^2$$

$$mgL\sin\theta - mgL\mu_k\cos\theta + l\, mg\sin\theta - \frac{1}{2} k l^2 = 0$$

$$l = \frac{-mg\sin\theta \pm \sqrt{m^2g^2\sin^2\theta + 2kmgL(\sin\theta - \mu_k\cos\theta)}}{-k}$$

d)

$$W_{other} + K_2 + U_{grav_2} + \cancel{U_{el_2}} = K_4 + U_{grav_2} + \cancel{U_{el_4}}$$

$$-\mu_k mg\cos\theta \frac{L}{2} + \frac{1}{2} m v_2^2 = mg\frac{L}{2}\sin\theta$$

$$v_2^2 - gL\sin\theta = \mu_k gL\cos\theta$$

$$\cancel{\frac{v_2^2}{gL\cos\theta} - \tan\theta = \mu_k}$$

2

$$2gL(\sin\theta - \mu_k\cos\theta) - gL\sin\theta = \mu_k gL\cos\theta$$

$$gL\sin\theta - 2gL\mu_k\cos\theta = \mu_k gL\cos\theta$$

$$\sin\theta - 2\mu_k\cos\theta = \mu_k\cos\theta$$

$$\mu_k = \frac{\tan\theta}{3}$$