TOSHKENT SHAHRIDAGI INHA UNIVERSITETI
INHA UNIVERSITY IN TASHKENT

STUDENT NAME:	
STUDENT ID NUMBER:	
DEPARTMENT:	

Solution of the recently held

FINAL EXAMINATION FALL 2018

COURSE NAME:	**PHYSICS 1**
COURSE NUMBER:	MSC1021
EXAMINATION DATE:	
TIME:	
EXAMINATION DURATION:	90 Minutes
ADDITIONAL MATERIALS ALLOWED TO USE:	Own brain, own memory and logics. **CALCULATORS ARE ALLOWED**
SPECIAL INSTRUCTIONS:	No Cheating and Good Luck!

Please do not open the examination paper until directed to do so.

READ INSTRUCTIONS FIRST:

Desks should be free from all unnecessary items (books, notes, technology, food, water, clothes);

Use of any electronic device (Phone, iPod, iPad, laptop) is not allowed during the examination;

Cheating, talking to fellow students, singing, turning back are not allowed;

Write your Name (*capital letters*), ID number and Department name in each page of your examination paper;

Final answers must be written by only blue or black, non-erasable pen. Do not use highlighters or correction pen;

All answers should be written in the space provided for each question, unless specified the other way;

If additional space is required, you should notify Proctors;

If you have a problem please raise your hand and wait quietly for a Proctor;

You are not allowed to leave the examination room until you submit the examination papers.

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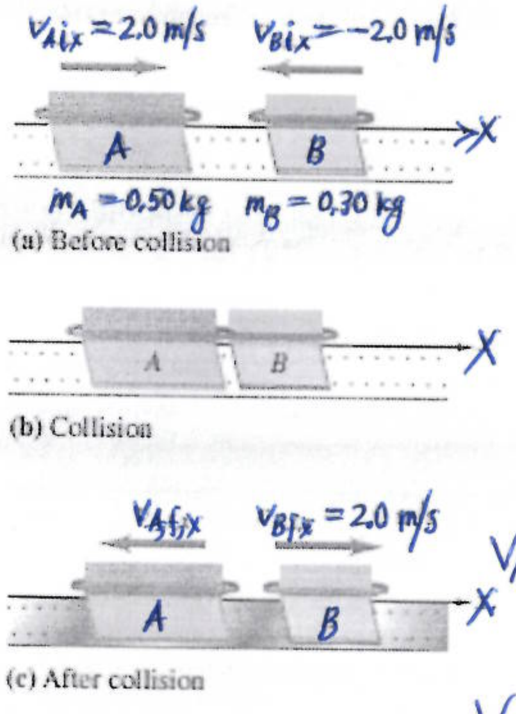
Important: Please, write your solutions inside rectangular boxes, drawn below each question. <u>You have to write your final answers after the word "Answer", given in the last line of boxes.</u> You can use the backside of pages for your intermediate calculations *etc*. There are 8 problems in the paper.

(Total: 40 Points, Obtained:_______)

[1] Two gliders move toward each other on a linear air track, which we assume is frictionless. Glider **A** has a mass of **0.5 kg**, and glider **B** has a mass of **0.3 kg**; both gliders move with an initial speed of **2 m/s**. After they collide, glider **B** moves away with a final velocity whose *x* component is **+2 m/s**. What is the final velocity of glider **A**?

(Max: 4 Points, Obtained:_______)



(a) Before collision

(b) Collision

(c) After collision

Let us write a total momentum conservation law for X axis:

$P_{ix} = P_{fx}$, where i and f stand for initial and final total momenta, respectively.

$$\left.\begin{aligned} P_{ix} &= m_A \cdot V_{Ai} + m_B \cdot V_{Bi} \\ P_{fx} &= m_A \cdot V_{Af} + m_B \cdot V_{Bf} \end{aligned}\right\} \Longrightarrow$$

$$V_{Af} = \frac{m_A \cdot V_{Ai} + m_B \cdot V_{Bi} - m_B \cdot V_{Bf}}{m_A}$$

$$V_{Af} = \frac{0.5\,kg\left(2\,\frac{m}{s}\right) + 0.3\,kg\left(-2\,\frac{m}{s}\right) - 0.3\,kg\left(2\,\frac{m}{s}\right)}{0.5\,kg}$$

$$V_{Af} = -0.4\ m/s$$

Answer: $\mathbf{V_{A,f,x}} =$ -0.4 m/s

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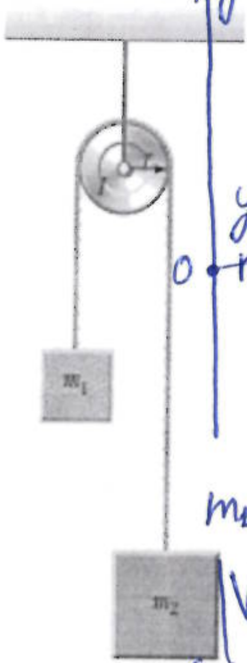
[2] Two blocks with masses m_1=**2.0** ***kg*** and m_2=**9.0** ***kg*** are attached over a pulley with mass ***M*=3.0 kg**, hanging straight down as in Atwood's machine (see Figure below). The pulley is a solid cylinder with radius ***R*=0.05** ***m***, and there is some friction in the axle. The system is released from rest, and the string moves without slipping over the pulley. **If the larger mass is traveling at a speed of 2.5** ***m/s*** **when it has dropped 1.0** ***m*****, how much mechanical energy was lost due to friction in the pulley's axle?** The moment of inertia of a solid cylinder of radius ***R*** and mass ***M*** with respect to rotation axis going through its center is $I = 0.5(MR^2)$. Use **g=9.8** m/s^2.

(Max: 8 Points, Obtained:_______)

$V=\omega R \Rightarrow \omega = \frac{V}{R} = \left(\frac{\frac{5}{2} m/s}{0.05\,m}\right) = 50\,\frac{rad}{s}$ $\quad I=\frac{1}{2}MR^2 = 0.00375\,kg\cdot m^2$



initial time — final time

U_{disk} $\quad U_{disk}$

$y_{1i}=y_{2i}=0$ $\quad y_{1f}=+1m$

m_1 m_2 $\quad$ 1m $\quad$ 1m

$y_{2f}=-1m$

The easy way is to use conservation of energy:

conservation of energy

$$\boxed{E_i = E_f + |W_{frict}|}$$

We will use conservation of energy

$E_{lost}=|W_{friction}|$, where $W_{frict.}$ = work done by friction force

$m_1 \cdot g \cdot y_{1i} + m_2 \cdot g \cdot y_{2i} + \cancel{U_{disk}} = \frac{m_1V^2}{2} + \frac{m_2V^2}{2} + \frac{I\omega^2}{2} + m_1 g y_{1f} + m_2 g y_{2f} + |W_{frict}| + \cancel{U_{disk}}$

$|W_{frict}| = E_{Lost} = -\left(\frac{m_1V^2}{2} + \frac{m_2V^2}{2} + \frac{I\omega^2}{2} + m_1 \cdot g \cdot y_{1f} + m_2 \cdot g \cdot y_{2f}\right)$

$E_{Lost} = -\left(\frac{2\cdot(2.5)^2}{2}J + \frac{9(2.5)^2}{2}J + \frac{0.00375\cdot(50)^2}{2}J + 2\cdot 9.8\cdot 1J - 9\cdot 9.8\cdot 1J\right) =$

$E_{Lost} = -\left(6.25J + 28.125J + 4.6875J + 19.6J - 88.2J\right) \approx 30$ Joules

Answer: $E_{Lost} \approx$ 30 Joules $\quad (\approx 30$ Joules$)$

[3] An acrobatic physics professor stands at the center of a turntable, holding his arms extended horizontally, with a **5 kg** dumbbell in each hand (**mass of a one dumbbell is 5 kg.**). **Initially** he is rotating about a vertical axis, **making one revolution in 2 seconds. His moment of inertia (without the dumbbells)** is **3 kg**

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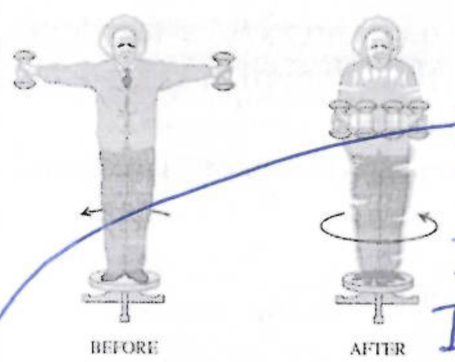
m² when his **arms are outstretched**, and **his moment of inertia (without the dumbbells)** is **2.2 kg m²** when his **arms are pulled in close to his chest.** Each dumbbell is **1 m** from the axis of rotation initially (**when arms are outstretched**) and is **0.2 m** from the axis of rotation at the end (**when arms are pulled in close to the chest**). Neglect the friction in turntable and find professor's final angular velocity (in revolutions/sec and in rad/sec) when he pulls dumbbells close to his chest. **Calculate the initial (rotational) kinetic energy and final (rotational) kinetic energy (in Joules).**

(Max: 4 Points, Obtained:_______)

Because no friction in the turntable and no external torques with respect to the vertical axis $\Rightarrow$ the angular momentum about this axis is conserved:



$I_i \cdot \omega_i = I_f \cdot \omega_f$. In each case $\boxed{i = \text{initial},\ f = \text{final}}$

$I = I_{prof.} + I_{dumb}$, thus,

$I_i = 3 kg \cdot m^2 + 2 \cdot (5.0 kg) \cdot (1.0 m)^2 = 13 kg \cdot m^2$

$I_f = 2.2 kg \cdot m^2 + 2 \cdot (5.0 kg) \cdot (0.2 m)^2 = 2.6 kg \cdot m^2$

$\omega_i = 2\pi \frac{1 \text{ rev.}}{2.0 s} = \pi \text{ rad/s.}$

$(13 kg \cdot m^2) \cdot (\pi \frac{rad}{s}) = (2.6 kg \cdot m^2) \cdot \omega_f$

$\omega_f = 5.0 \pi \frac{rad}{s} = 2.5 \text{ rev/s}$

$K_i = \frac{1}{2} I_i \omega_i^2 = \frac{1}{2} (13 kg \cdot m^2) \cdot (\pi \frac{rad}{s})^2$

$K_i \approx 64$ Joules

$K_f = \frac{1}{2} I_f \cdot \omega_f^2 = \frac{1}{2} (2.6 kg \cdot m^2) \cdot (5.0 \pi \frac{rad}{s})^2$

$K_f \approx 320$ Joules

Answer: $K_{rot}i$ = 64 Joules $K_{rot}f$ = 320 Joules

[4] ***a)*** Find the position of the center of mass (x_{com}=?) of the three objects located in a coordinate system as shown in Figure **(a)** below. ***b)*** Find the position of the

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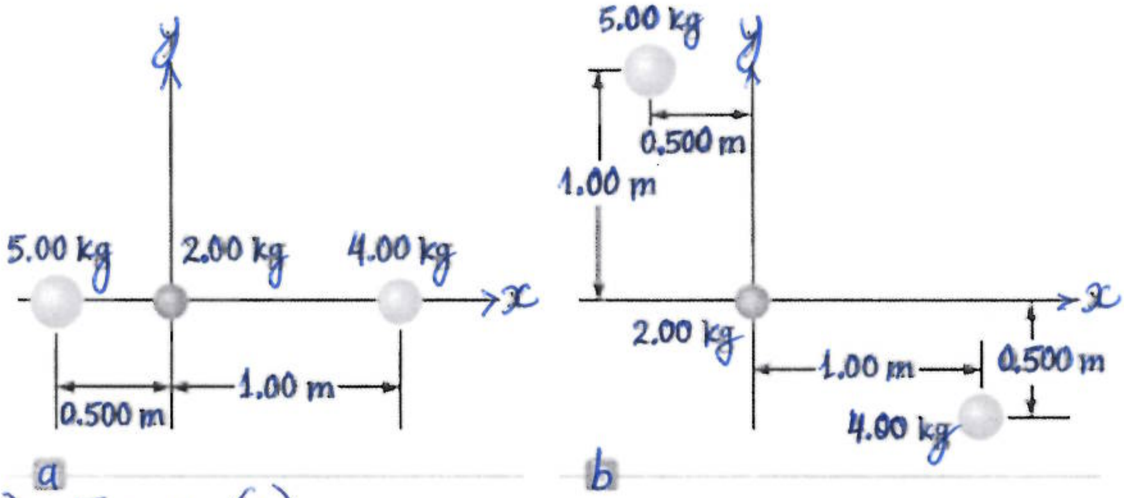
center of mass (x_{com}=?; y_{com}=?) of the three objects located in a coordinate system as shown in Figure **(b)** below. Treat the objects as point particles.

(Max: 4 Points, Obtained:_______)



1) Figure (a)

$$x_{com} = \frac{\sum_i m_i \cdot x_i}{\sum_i m_i} = \frac{m_1 \cdot x_1 + m_2 \cdot x_2 + m_3 \cdot x_3}{m_1 + m_2 + m_3}$$

$$x_{com} = \frac{(5\,kg)\cdot(-0.5\,m) + (2\,kg)\cdot(0\,m) + (4\,kg)\cdot(1.0\,m)}{11\,kg} = \frac{1.5\,kg \cdot m}{11\,kg} = 0.136\,m$$

$$x_{com} = 0.136\,m$$

2) Figure (b)

$$x_{com} = 0.136\,m$$

$$y_{com} = \frac{\sum_i m_i \cdot y_i}{\sum_i m_i} = \frac{m_1 \cdot y_1 + m_2 \cdot y_2 + m_3 \cdot y_3}{m_1 + m_2 + m_3}$$

$$y_{com} = \frac{(5\,kg)\cdot(1\,m) + (2\,kg)\cdot(0\,m) + (4\,kg)\cdot(-0.5\,m)}{5\,kg + 2\,kg + 4\,kg} = 0.273\,m$$

Answer: *a)* x_{com}= 0.136 m *b)* x_{com}= 0.136 m ; y_{com}= 0.273 m

[5] A **2.40 kg** ball is attached to an unknown spring and is allowed to oscillate. Figure below shows a graph of the ball's position ***x(t)*** as a function of time (in

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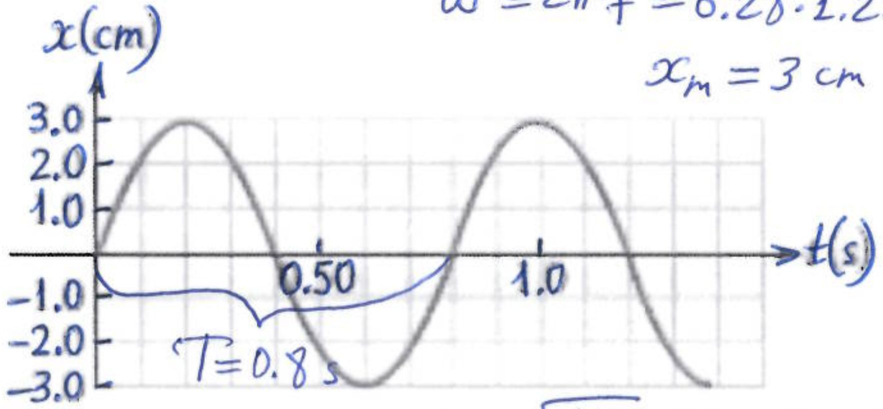
seconds). **For this motion (SHM), find (a) its period (*T*), (b) its frequency (*f*), (c) its angular frequency (*w*), (d) its amplitude (x_m) (in meters), and (e) the spring constant (*k*).**

(Max: 4 Points, Obtained:_______)

$T = 0.8$ seconds, $f = \frac{1}{T} = \frac{1}{0.8s} \approx 1.25\ Hz$

$\omega = 2\pi \cdot f = 6.28 \cdot 1.25 \approx 7.9\ \frac{rad}{s}$

$x_m = 3\ cm = 0.03\ m$



$\omega = \sqrt{\frac{k}{m}} \Rightarrow k = \omega^2 \cdot m$

$k = 7.9^2 \times 2.40\ \frac{N}{m} \approx 150\ \frac{N}{m}$

Answer: $T = 0.8\ s$ $f = 1.25\ Hz$ $w = 7.9\ \frac{rad}{sec}$ $x_m = 3\ cm = 0.03\ m$ $k = 150\ \frac{N}{m}$

[6] An astronaut standing on the surface of Ceres, the largest asteroid, drops a rock from a height of **10.0** ***m*** (assume it travels in a vacuum). It takes **8.06 seconds** for the rock to hit the ground. **(a)** Calculate the acceleration of gravity (g_c=?) **(in** ***m/s²*****)** on the surface of Ceres. **(b)** Find the mass of Ceres (M_c=?) **(*in kg*)** if the radius of Ceres is **$R_c = 5.10 \times 10^5$ *m*.** **(c)** Calculate the gravitational acceleration **(in** ***m/s²*****)** at the height of **50** ***km*** above the surface of Ceres (g_c'=?).

(Max: 6 Points, Obtained:_______)

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a) Apply the kinematics displacement equation to the falling rock to solve for the gravitational acceleration on Ceres, g_c:

$\Delta x = \frac{1}{2}at^2 + V_0 \cdot t \Rightarrow -10\,m = -\frac{1}{2} g_c \cdot (8.06\,s)^2 \Rightarrow g_c = 0.308\ m/s^2$ $\boxed{a = -g_c}$

b) Find the mass of Ceres, M_c, equating the weight of the rock on Ceres to the gravitational force acting on the rock:

$\cancel{m} g_c = G \frac{M_c \cdot \cancel{m}}{R_c^2} \Rightarrow M_c = \frac{g_c \cdot R_c^2}{G} = 1.20 \times 10^{21}\ kg$ $G = 6.67 \times 10^{-11} \frac{m^3}{kg \cdot s^2}$

c) Calculate the acceleration of gravity at a height of 50 km above the surface of Ceres, equating the weight at 50 km to the gravitational force:

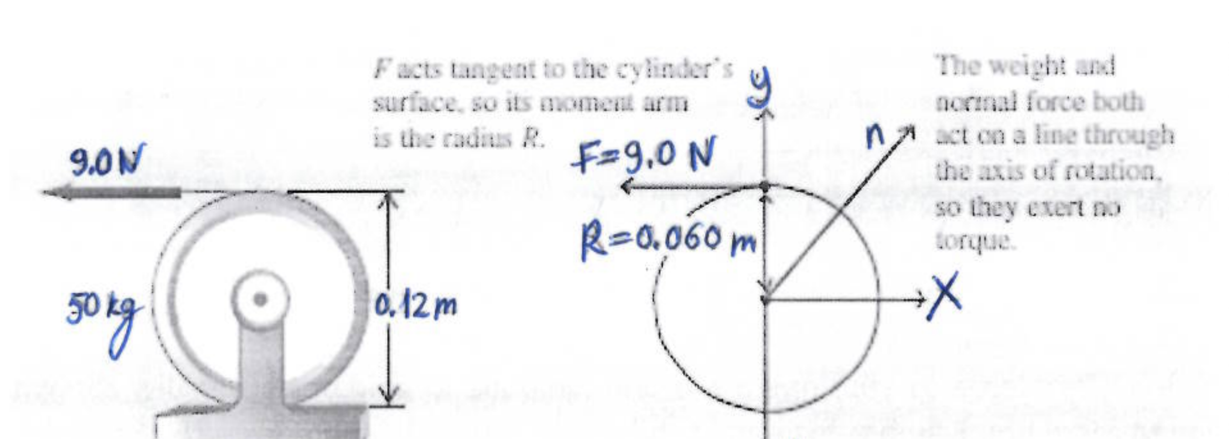
$\cancel{m} \cdot g_c' = G \frac{\cancel{m} M_c}{r^2} \Rightarrow g_c' = G \frac{M_c}{r^2} = (6.67 \times 10^{-11}\ kg^{-1} \cdot m^3 \cdot s^{-2}) \frac{1.20 \times 10^{21}\ kg}{(5.60 \times 10^5\ m)^2}$

$g_c' = 0.255\ m/s^2$

Answer: $g_c = 0.308\ m/s^2$ $M_c = 1.20 \times 10^{21}\ kg$ $g_c' = 0.255\ m/s^2$

[7] A cable is wrapped several times around a uniform solid cylinder with diameter **0.12 *m*** and mass ***M*=50 *kg*** that can rotate freely about its axis (see Figure below). The cable is pulled by a force with magnitude ***F*=9.0 *N***. Assuming that the cable unwinds without stretching or slipping, find the magnitude of acceleration of the cable (*a*=?). The moment of inertia of a solid cylinder of radius ***R*** and mass ***M*** with respect to rotation axis going through its center is ***I* = 0.5(*MR*²)**.

(Max: 6 Points, Obtained:_______)



The torque of the force F relative to axis of rotation is $\tau = F \cdot R = (9\,N) \cdot (0.060\,m) = 0.54\ N \cdot m$ $\tau = 0.54\ N \cdot m$

The moment of inertia of a solid cylinder with respect to axis of rotation is $I = \frac{1}{2} MR^2 = \frac{1}{2}(50\,kg) \cdot (0.060\,m)^2 = 0.090\ kg \cdot m^2$

$I = 0.090\ kg \cdot m^2$

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Using $\tau = I\cdot\alpha$, we can find the angular acceleration α:

$$\alpha = \frac{\tau}{I} = \frac{0.54\ N\cdot m}{0.090\ kg\cdot m^2} = 6.0\ \frac{rad}{s^2}$$

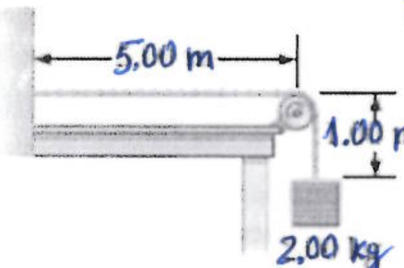
The magnitude of acceleration a of the cable is given by

$$a = R\cdot\alpha = (0.060\ m)\cdot(6.0\ rad/s^2) = 0.36\ m/s^2 \quad a = 0.36\ m/s^2$$

Answer: a = $0.36\ m/s^2$

[8] A uniform string has a mass M=**0.03 kg** and a length L=**6.0 m**. Tension is maintained in the string by suspending a block of mass m=**2.0 kg** from one end (see Figure below). a) Find the speed **v** of a transverse wave pulse on this string. (b) Find the time t it takes the pulse to travel from the wall to the pulley. Neglect the mass of the hanging part of the string. Use **g=9.8** m/s^2.

(Max: 4 Points, Obtained:_______)



Apply Newton's 2nd Law to find tension force F_τ in the string:

tension force $F_\tau = mg$

Speed of the wave on a stretched string is found using $V = \sqrt{\frac{F_\tau}{\mu}}$,

where $\mu = \frac{M}{L}$ = linear mass density of the string.

$$\text{Hence } V = \sqrt{\frac{F_\tau}{\mu}} = \sqrt{\frac{mg}{M/L}} = \sqrt{\frac{2\ kg\cdot 9.8\ m/s^2}{0.03\ kg/(6\ m)}} =$$

$$V = \sqrt{\frac{19.6\ N}{0.005\ kg/m}} = 62.6\ m/s \quad V = 62.6\ m/s$$

The time it takes the pulse to travel from the wall to the pulley: $t = \frac{d}{V} = \frac{5\ m}{62.6\ m/s} = 0.0799\ s$

Answer: **V** = $62.6\ m/s \simeq 63\ m/s$ $\quad$ t = $0.0799\ s \simeq 0.08\ s$

GOOD LUCK!