TOSHKENT SHAHRIDAGI INHA UNIVERSITETI
INHA UNIVERSITY IN TASHKENT

STUDENT NAME:	X X X X X X X
STUDENT ID NUMBER:	XXXXX
DEPARTMENT:	XXXX

Solution of the recently held

FINAL EXAMINATION (FALL 2016)

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.**
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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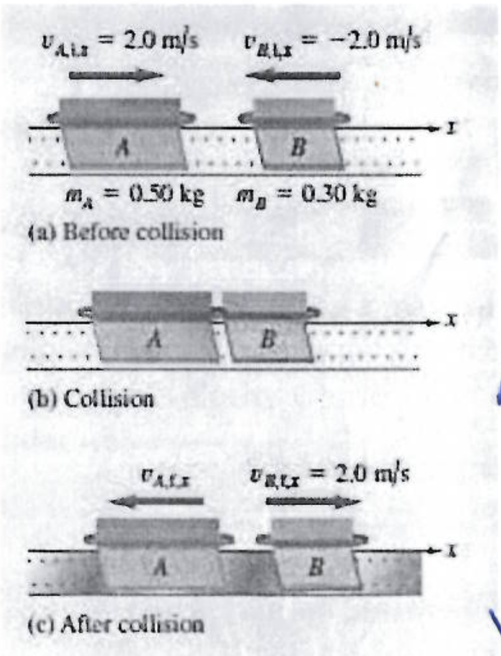
Important: Please, write your solutions inside rectangular boxes, drawn below each question. Please, write your final answers after the word "Answer", given in the last line of boxes. You can use the backside of pages for your intermediate calculations *etc*, <u>but you have to write your final answers after the word "Answer"</u>. There are 7 (seven) problems (questions) 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: 5 Points, Obtained:_______)



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.

$$\left.\begin{array}{l} P_{ix} = m_A \cdot V_{Ai} + m_B \cdot V_{Bi} \\ P_{fx} = m_A \cdot V_{Af} + m_B \cdot V_{Bf} \end{array}\right\} \Rightarrow$$

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

$$V_{Af} = \frac{0.5\,kg\,(2.0\ m/s) + 0.3\,kg \cdot (-2.0\ m/s) - 0.3\,kg \cdot (2.0\ m/s)}{0.5\ kg} =$$

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

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

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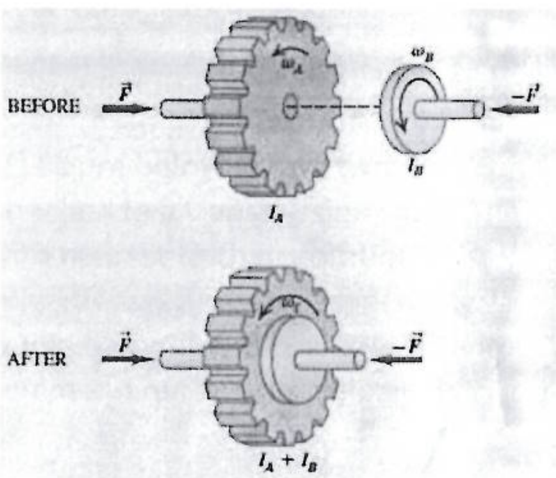
[2] Figure below shows two disks, one an engine flywheel, the other a clutch plate attached to a transmission shaft. Their moment of inertia are $\mathbf{I_A}$ and $\mathbf{I_B}$, respectively, with respect to their rotation axis. Initially they are rotating with constant angular velocities $\mathbf{w_A}$ and $\mathbf{w_B}$, respectively. We then push the disks together with the forces acting along the *x* axis only. Eventually the disks stick to each other and reach a common final angular velocity $\mathbf{w_f}$. Derive an expression for $\mathbf{w_f}$.

(Max: 4 Points, Obtained:________)



In this problem, the total angular momentum of the system is conserved.

Conservation of angular momentum gives

$$I_A \cdot \omega_A + I_B \cdot \omega_B = (I_A + I_B) \cdot \omega_f$$

$$\omega_f = \frac{I_A \cdot \omega_A + I_B \cdot \omega_B}{I_A + I_B}$$

Answer: $\omega_f = \dfrac{I_A \cdot \omega_A + I_B \cdot \omega_B}{I_A + I_B}$

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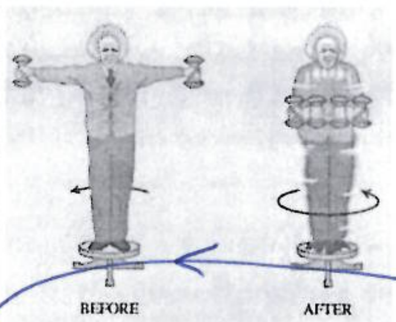
[3] An acrobatic physics professor stands at the center of a turntable, holding his arms extended horizontally, with a **5 kg** dumbbell in each hand (**mass of a one dumbbell is 5 kg.**). Initially he is rotating about a vertical axis, making one revolution in 2 seconds. **His moment of inertia (without the dumbbells)** is **3 kg 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 (w_f) (in both 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: 6 Points, Obtained:_______)

Note that Professor has only two dumbbells at both initial and final positions ("Before" and "After").



There is no friction in the turntable and there are no external torques with respect to the vertical rotation axis, and so the angular momentum about this axis is conserved: $I_i \omega_i = I_f \omega_f$. In each case,

$\boxed{i = \text{initial},\ f = \text{final}}$

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

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

$$I_f = 2.2\ kg \cdot m^2 + 2 \cdot (5.0\ kg)\cdot(0.20\ m)^2 = 2.6\ kg \cdot m^2$$

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

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

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

Answer:

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

$$\boxed{K_i \simeq 64\ Joules}$$

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

$$\boxed{K_f \simeq 320\ Joules}$$

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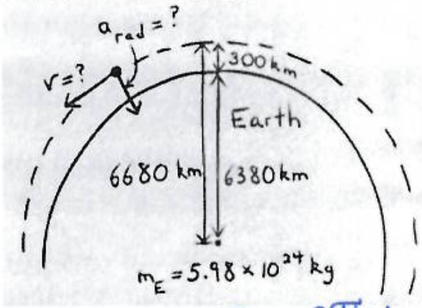
[4] Suppose we want to place a weather satellite into a circular orbit 300 km above the earth's surface (see Figure below). **What speed (v), period (*T*), and radial acceleration (a_r) must it have?** The Earth's radius is **6380 km = 6.38 x 10^6 m**, and its mass is **5.98 x 10^{24} kg**. You may use **G = 6.67 x 10^{-11} N m^2/kg^2**.

(Max: 6 Points, Obtained:_______)



$$\frac{G \cancel{m_s} \cdot m_E}{r^2} = \frac{\cancel{m_s} V^2}{r} \qquad r = (6.38\times10^6 + 0.3\times10^6)\,m$$

$$r = 6.68\times10^6\,m$$

$$V = \sqrt{\frac{G \cdot m_E}{r}} = \sqrt{\frac{6.67\times10^{-11} \cdot 5.98\times10^{24}}{6.68\times10^6}}\ m/s$$

$$V \simeq 7700\ m/s$$

$$T = \frac{2\pi r}{V} = \frac{2\pi \times 6.68\times10^6\,m}{7700\ m/s} \simeq 5400 \text{ seconds} \simeq 91 \text{ minutes}$$

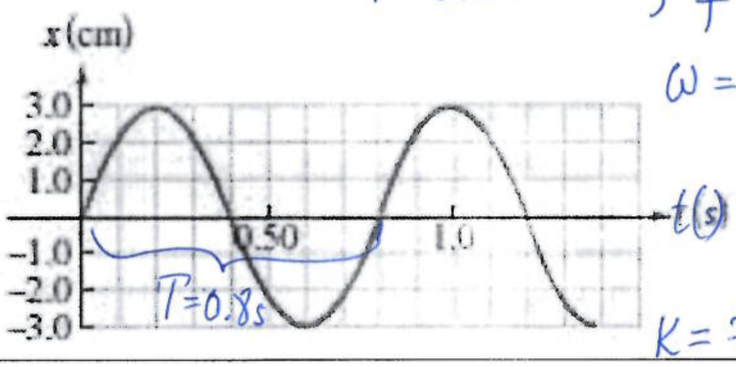
The radial acceleration $a_r = \frac{V^2}{r} = \frac{(7700\ m/s)^2}{6.68\times10^6\,m} \simeq 8.9\ m/s^2 \simeq 9\ m/s^2$

Answer: $V \simeq 7700\ m/s$; $T \simeq 5400$ seconds $\simeq 91$ minutes; $a_r \simeq 9\ m/s^2$

[5] A **2.40 kg** ball is attached to an unknown spring and is set to oscillate on a frictionless surface. Figure below shows a graph of the ball's position **x(t)** as a function of time (in seconds). **For this motion (SHM), find (a) its period (T), (b) its frequency (f), (c) its angular frequency (w), (d) its amplitude (x_m), and (e) the spring constant (k).**

(Max: 5 Points, Obtained:_______)

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



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

$x_m = 3\ cm = 0.03\ m$

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

$K = 7.9^2 \times 2.40\ \frac{N}{m} \simeq 150\ \frac{N}{m}$

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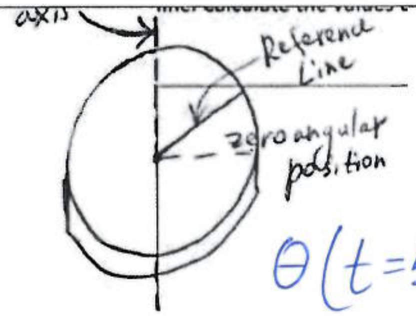
Answer: $T = 0.8$ seconds; $f = 1.25$ Hz; $\omega \approx 7.9 \frac{rad}{sec}$; $x_m = 3\ cm = 0.03\ m$;
$K \approx 150 \frac{N}{m}$

[6] The disk is rotating about its central axis like a merry-go-round. The angular position θ(t) of a reference line on the disk is given by θ(t)=−1−2t+5t^2, with t in seconds and θ in radians. **Determine the angular velocity function *w*(*t*) and angular acceleration function *α*(*t*) for the reference line. Calculate the values of θ(*t*) (in rad), *w*(*t*) (in *rad/s*), and *α*(*t*) (in *rad/s*²) at *t*=5 *s*.**

(Max: 4 Points, Obtained:_______)



$\omega(t) = \theta'(t) = -2 + 10t$

$\alpha(t) = \omega'(t) = 10$

$\theta(t=5\ s) = -1 - 2 \cdot 5 + 5 \cdot 5^2\ rad = 114$ radians

$\omega(t = 5\ s) = -2 + 10 \cdot 5\ \frac{rad}{s} = 48\ \frac{rad}{second}$

$\alpha(t = 5\ s) = 10\ \frac{rad}{s^2}$

Answer: $\omega(t) = -2 + 10 \cdot t$; $\alpha(t) = 10$; $\theta(t=5s) = 114$ radians;
$\omega(t=5s) = 48\ \frac{rad}{sec.}$; $\alpha(t=5s) = 10\ \frac{rad}{s^2}$

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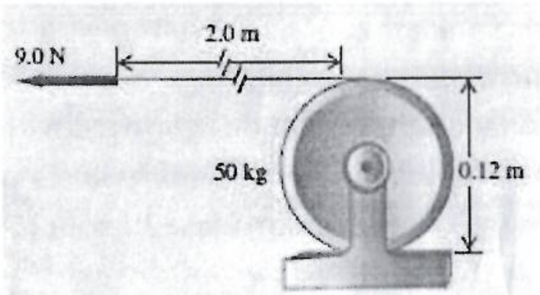
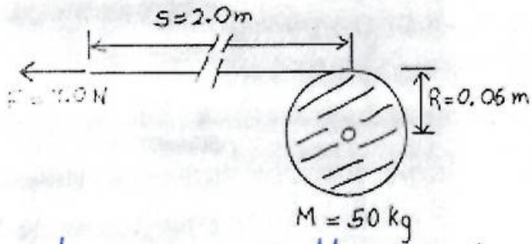
[7] A light, flexible, nonstretching cable (rope) is wrapped several times around a winch drum – a solid cylinder with mass **M = 50 kg** and diameter 0.12 m (**R = 0.06 m**), that rotates about a stationary horizontal axis that turns without a friction. The free end of the cable is pulled with a constant force of magnitude **F = 9.0 N** over a distance of **s = 2 meters** (see Figure below). It unwinds without slipping. **If the cylinder is initially at rest, find its final angular velocity (w_f) and the final speed (v_f) of the cable.**

You may use ***I*=(1/2)MR²** for a moment of inertia of the cylinder with respect to rotation axis.

(Max: 10 Points, Obtained:_______)





Acording to work-kinetic energy theorem:

$$F \cdot s = \frac{I\omega_f^2}{2} - \left(\frac{I\omega_i^2}{2}\right) = 0 \quad = \frac{I\omega_f^2}{2}$$

because it is initially at rest

$$\omega_f = \sqrt{\frac{2 \cdot F \cdot s}{I}} = \sqrt{\frac{2 \cdot F \cdot s}{\frac{1}{2} M \cdot R^2}} = \sqrt{\frac{4 \cdot F \cdot s}{M \cdot R^2}}$$

$$\omega_f = \sqrt{\frac{4 \cdot 9 \cdot 2}{50 \cdot (0.06)^2}} \ \frac{\text{rad}}{\text{second}} = 20 \ \frac{\text{rad.}}{\text{sec.}}$$

$$V_f = \omega \cdot R = \left(20 \ \frac{\text{rad}}{s}\right) \cdot (0.06 \text{ m}) = 1.2 \text{ m/s}$$

Answer: $\omega_f = 20 \ \frac{\text{rad}}{\text{sec}}$; $V_f = 1.2$ m/s