Kuwait University   Physics Department

Physics 101

Fall Semester

Final Exam

Monday, January 24, 2022

6:00 PM – 8:00 PM

Student's Name: ………………..……………………..………………. Serial Number: …..…………

Student's Number: …..………………………………..……… Section: ……………………

Choose your Instructor's Name:

Dr. Ahmed Al-Jassar	Dr. Belal Salameh
Dr. Hala Al-Jassar	Dr. Nasser Demir
Dr. Tareq Al Refai	Dr. Ruqayyah Askar
Dr. Abdul Khaleq	Dr. Bedoor Alkurtass

For Instructor use only

Grades:

#	SP1	SP2	SP3	SP4	SP5	SP6	SP7	LP1	LP2	LP3	Q1	Q2	Q3	Q4	Total
Pts	3	3	3	3	3	3	3	5	5	5	1	1	1	1	40

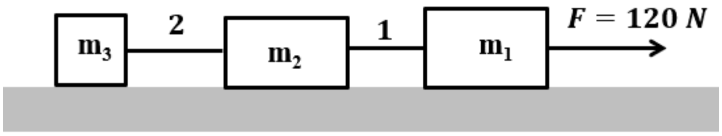
Important:

1. Answer all questions and problems (No solution = no points).
2. Full mark = 40 points as arranged in the above table.
3. **Give your final answer in the correct units.**
4. Assume g = 10 m/s^2.
5. Mobiles are **strictly prohibited** during the exam.
6. Programmable calculators, which can store equations, are not allowed.
7. **Cheating incidents will be processed according to the university rules.**

GOOD LUCK

Part I: Short Problems (3 points each)

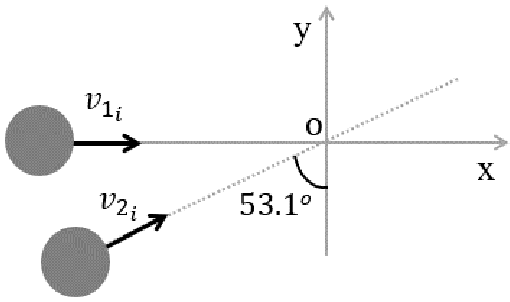
SP1: Three blocks ($m_1 = 20\ kg, m_2 = 15\ kg, m_3 = 5\ kg$) are connected by two light ropes, as shown. A constant horizontal force acts on block 1 and the three blocks move to the right on a **frictionless** horizontal surface. **Find the tension in rope 2.**



$$\sum F = m_{total}a \Rightarrow a = \frac{\sum F}{m_{total}} = \frac{120}{40} = 3\ m/s^2$$

$$T_2 = m_3 a = 15\ N$$

SP2. Two balls of **equal mass** moving with the same initial speed ($v_{1_i} = v_{2_i} = 3\ m/s$), as shown. The two balls collide at point O and **stick together**, **what is their common velocity in unit vector notation after the collision?**



$$\vec{v}_{1_i} = +3\ \hat{\imath}\, m/s$$

$$\vec{v}_{2_i} = (+3 \sin 53.1^o\ \hat{\imath} + 3 \cos 53.1^o\ \hat{\jmath})\ m/s$$

$$= (+2.4\hat{\imath} + 1.8\hat{\jmath})\ m/s$$

$$m\vec{v}_{1_i} + m\vec{v}_{2_i} = 2m\vec{v}_f$$

$$\vec{v}_f = \frac{\vec{v}_{1_i} + \vec{v}_{2_i}}{2} = (2.7\hat{\imath} + 0.9\hat{\jmath})\ m/s$$

SP3. A 0.3 kg ball is released **from rest**. If the magnitude of the ball's momentum just before it hits the ground is 2.4 $kg \cdot m/s$, **from what height was the ball released**? **(Ignore air resistance)**

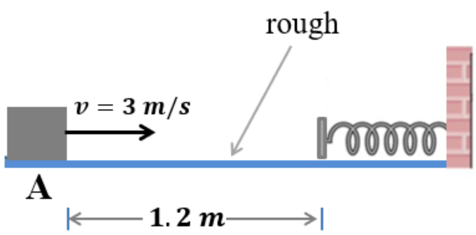
$$p_f = mv_f \Rightarrow v_f = \frac{p_f}{m} = \frac{2.4}{0.3} = 8\ m/s$$

$$v_f^2 = v_i^2 - 2g\Delta y \Rightarrow v_f^2 = 2gh \Rightarrow h = \frac{v_f^2}{2g} = 3.2\ m$$

SP4. A particle moves in the xy-plane under the influence of a net **conservative** force. The potential energy associated with this force is given by $U(x, y) = 3(x^4 + y^4)$, where x and y are measured in m and U is measured in J. **Find the work done by the net force on the particle when moving from (2 m, 3 m) to (4 m, 5 m).**

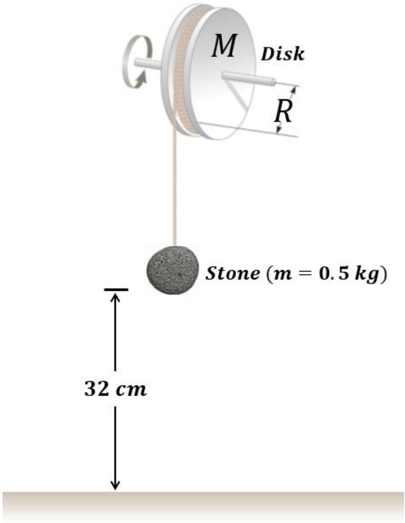
$$W_F = -\Delta U$$
$$= U_i - U_f = 3(2^4 + 3^4) - 3(4^4 + 5^4)$$
$$= 291 - 2643 = -2352\ J$$

SP5. A 7 kg block starts moving at point A with a speed of 3 m/s on a **rough horizontal surface** ($\mu_k = \mathbf{0.25}$), as shown. The block moves to the right and compresses a spring **a maximum distance of 0.2 m, find the force constant of the spring**.



$$E_f - E_i = W_{f_k}$$
$$\frac{1}{2}kx_{max}^2 - \frac{1}{2}mv^2 = -\mu_k(mg\ (1.4))$$
$$\frac{1}{2}k(0.2^2) - 31.5 = -24.5 \Rightarrow k = 350\ N/m$$

SP6. A light rope is wrapped around the rim of a solid disk that is free to rotate about a horizontal axis through its center. We tie the free end of the rope to a stone and **release the stone from rest at a height 32 cm** from the floor, as shown. **Find the speed of the stone just before it touches the floor if the rotational kinetic energy of the disk at this instant is $0.6\,J$.**

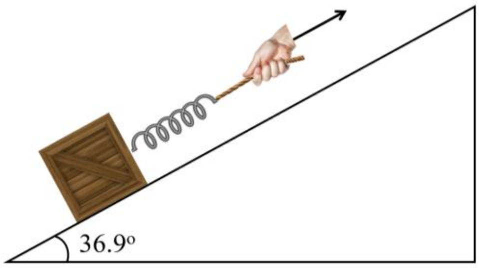


$$mgh = \frac{1}{2}mv_f^2 + K_{rot}$$

$$v_f = \sqrt{\frac{2}{m}(mgh - K_{rot})}$$

$$= \sqrt{\frac{2}{0.5}((0.5)(10)(0.32) - 0.6)} = 2\ m/s$$

SP7. A 20 kg block rests on **a rough incline** ($\mu_s = 0.4$). A spring of force constant $k = 1150\ N/m$ is connected to the block, as shown. The spring is pulled with a gradually increasing force. **Find the extension in the spring when the block <u>starts moving up the incline</u>.**



$$kx = mg\sin(36.9^o) + f_{s_{max}}$$

$$kx = mg\ sin(36.9^o) + \mu_s\ mg\cos(36.9^o)$$

$$x = \frac{mg\ sin(36.9^o) + \mu_s\ mg\cos(36.9^o)}{k} = \frac{184}{1150}$$

$$= 0.16\ m = 16\ cm$$

Part II: Long Problems (5 points each)

LP1. **Only two forces** $\vec{F}_1$ and $\vec{F}_2$ act on a block of mass $m = 0.5\ kg$ that is moving in the xy-plane. The velocity of the block is given by $\vec{v}(t) = [40\hat{\imath} + (20 - 10t)\hat{\jmath}]\ m/s$, where t is measured in seconds.

a) Find the net force on the block in unit vector notation.

$$\vec{a} = \frac{d\vec{v}}{dt} = -10\ \hat{\jmath}\ m/s^2$$

$$\sum \vec{F} = \vec{F} = m\vec{a} = 0.5(-10\hat{\jmath}) = -5\hat{\jmath}\ N$$

b) If $\vec{F}_1 = 15\hat{\imath}\ N$, find the magnitude of $\vec{F}_2$.

$$\vec{F}_2 = \sum \vec{F} - \vec{F}_1 = (-5\hat{\jmath} - 15\hat{\imath})\ N$$

$$\vec{F}_2 = (-15\hat{\imath} - 5\hat{\jmath})\ N$$

$$|\vec{F}_2| = \sqrt{15^2 + 5^2} = 15.8\ N$$

c) Find the total work done on the block during the time interval from $t = 0\ s\ to\ t = 2\ s$.

$$\Sigma w = \Delta k = \frac{1}{2} m\left(v^2(2\ s) - v^2(0\ s)\right)$$

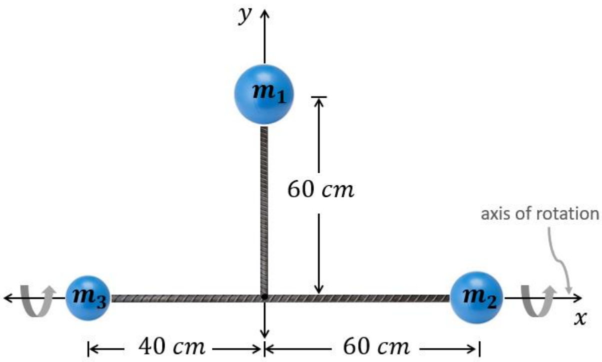
$$\vec{v}(2\ s) = 40\ \hat{\imath} + (20 - 20)\hat{\jmath} = 40\ \hat{\imath}\ m/s \Longrightarrow v^2(2\ s) = 1600\ \left(\frac{m}{s}\right)^2$$

$$\vec{v}(0\ s) = (40\hat{\imath} + 20\ \hat{\jmath})\frac{m}{s} \Longrightarrow v^2(0\ s) = 2000\ \left(\frac{m}{s}\right)^2$$

$$\Sigma W = \frac{1}{2}(0.5)(1600 - 2000) = -100\ J$$

LP2. Three small balls ($m_1 = 0.5\ kg, m_2 = 0.3\ kg, and\ m_3 = 0.2\ kg$) are connected by **massless** rigid rods, as shown. The system starts to rotate **from rest** about the x-axis with **a constant angular acceleration of 2 rad/s²**.

a) Find the moment of inertia of the system about the axis of rotation.



$$I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 = (0.5)(0.6)^2 + (0.3)(0)^2 + (0.2)(0)^2 = 0.18\ kg \cdot m^2$$

b) Find the angular speed of the system at $t = 4\ s$.

$$\omega_f = \omega_i + \alpha t$$

$$= 0 + 2(4) = 8 \text{ rad/s}$$

c) Find the rotational kinetic energy of the system at $t = 4\ s$.

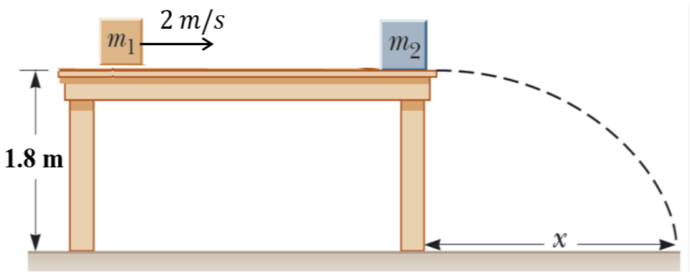
$$K_{rot} = \frac{1}{2} I\omega^2 \quad = \frac{1}{2}(0.18)(8)^2 = 5.76 \text{ J}$$

d) Find the net torque exerted on the system about the axis of rotation.

$$\sum \tau = I\alpha = 0.18\ (2) = 0.36\ N \cdot m$$

LP3. Block 1 moves with a speed of 2 m/s on a **frictionless** tabletop, as shown. It collides **elastically** with block 2 ($m_2 = 0.7\ kg$) that is initially at rest. After the collision block 2 moves horizontally **to the right at a speed of 0.8 m/s** and leaves the table and then land on the ground.

a) Find the velocity of block 1 immediately after the collision.



$$v_{2_{xf}} - v_{1_{xf}} = v_{1_{xi}} - v_{2_{xi}}$$

$$0.8 - v_{1_{xf}} = 2 - 0$$

$$v_{1_{xf}} = -1.2\ m/s$$

b) Find the impulse on block 2?

$$\vec{J} = \Delta\vec{p} = m_2\vec{v}_{2_f} - m_2\vec{v}_{2_i} = 0.7(0.8\hat{\imath}) - 0 = +0.56\,\hat{\imath}\ kg\cdot\frac{m}{s}$$

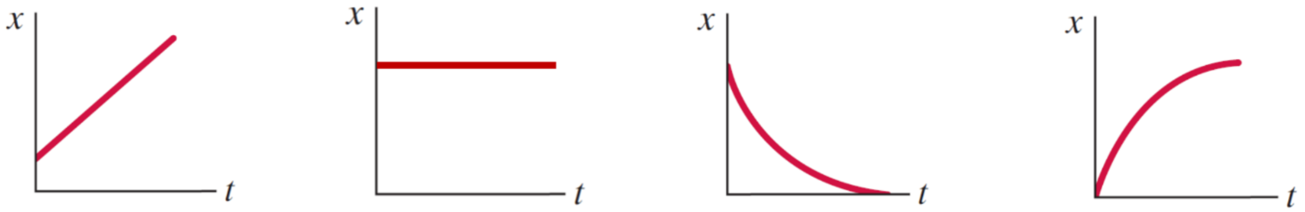
c) How far away (x) from the bottom of the table does block 2 land?

$$\Delta y = v_{y_i}t - \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{-2\Delta y}{g}} = \sqrt{\frac{3.6}{10}} = 0.6\ s$$

$$\Delta x = v_{x_i}t = 0.8(0.6) = 0.48\ m$$

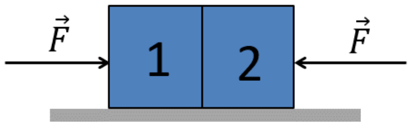
Part III: Questions (Choose the correct answer, one point each)

Q1. A car travels along the x-axis **with constant speed**. Which of the following graphs represents the motion of the car?



* * * *

Q2. Two horizontal forces of equal magnitude (F) act on two blocks, as shown. **The blocks remain at rest on a frictionless horizontal surface**. The magnitude of the **contact force** between the two blocks is F_{12}. **Which of the following is true?**



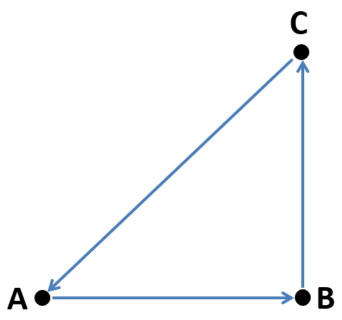
* $\boldsymbol{F_{12} = 0}$

* $\boldsymbol{F_{12} = 2F}$

* $\boldsymbol{F_{12} = F/2}$

* $\boldsymbol{F_{12} = F}$

Q3. Consider the path ABCA shown in the figure. If the work done by **a conservative force $\vec{F}$** from A to B is 6 J, and the work done by $\vec{F}$ from B to C is 8 J, **then the work done by $\vec{F}$ from C to A is:**



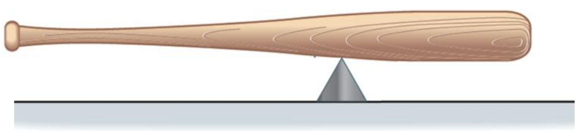
* $\boldsymbol{0\,J}$

* $\boldsymbol{-10\,J}$

* $\boldsymbol{-14\,J}$

* $\boldsymbol{10\,J}$

Q4. A baseball bat balances when placed on a stand, as shown. The relation between the mass of the bat to the left of the stand (m_{left}) and its mass to the right of the stand (m_{right}) is:



* $\boldsymbol{m_{left} > m_{right}}$

* $\boldsymbol{m_{left} = m_{right}}$

* $\boldsymbol{m_{left} < m_{right}}$