Kuwait University **Physics Department**

جامعة الكويت
KUWAIT UNIVERSITY

Physics 101

Spring Semester
Final Exam
Monday, May 8, 2023
5:00 PM – 7:00 PM

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

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

Choose your Instructor's Name:

Dr. Abdulmuhsen Ali	Dr. Belal Salameh
Dr. Fatema Al Dosari	Dr. Nasser Demir
Dr. Tareq Al Refai	Dr. Ruqayyah Askar
Dr. Abdul Khaleq	Dr. Bedoor Alkurtass

For Instructors 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 arranged in the above table.
3. **Give your final answer in the correct units.**
4. Assume g = 9.8 m/s².
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. The position vector of an object moving in xy-plane is given by: $\vec{r}(t) = (t^2 - 1.2t)\hat{\imath} + (0.3t^3 + 1.5t)\hat{\jmath}$ where $\vec{r}$ is in meters and t is in seconds. **Find the magnitude of object's acceleration at $t = 2s$.**

$$\vec{v}(t) = \frac{d\vec{r}(t)}{dt} = [(2t - 1.2)\hat{\imath} + (0.9t^2 + 1.5)\hat{\jmath}]\ m/s$$

$$\vec{a}(t) = \frac{d\vec{v}(t)}{dt} = [(2)\hat{\imath} + (1.8t)\hat{\jmath}]\ m/s^2$$

$$\vec{a}(2) = [(2)\hat{\imath} + (3.6)\hat{\jmath}]\ m/s^2$$

$$|\vec{a}(2)| = \sqrt{2^2 + 3.6^2} = 4.1\ m/s^2$$

SP2. A force $\vec{F} = (2\hat{\imath} - 3\hat{\jmath})N$ is applied to an object located at the position $\vec{r} = (2\hat{\imath} - 3\hat{\jmath} + 4\hat{k})\ m$. **What are the magnitude and direction of the torque, with respect to the positive x-axis?**

$$\vec{\tau} = \vec{r} \times \vec{F} = \begin{bmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ 2 & -3 & 4 \\ 2 & -3 & 0 \end{bmatrix} = (0 - -12)\hat{\imath} - (0 - 8)\hat{\jmath} + (-6 - -6)\hat{k}$$

$$\vec{\tau} = (12\hat{\imath} + 8\hat{\jmath})\ N.m$$

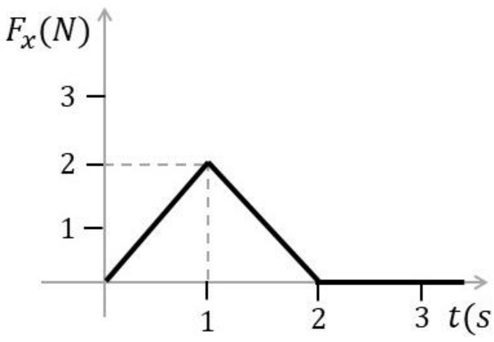
$$|\vec{\tau}| = \sqrt{12^2 + 8^2} = 14.4\ N.m$$

$$\theta = tan^{-1}\left(\frac{8}{12}\right) = 33.7°$$

SP3. The figure shows a plot of the **time dependent** force F_x acting on a particle in motion along the *x*-axis. **What is the change in the particle's linear momentum between $t = 0\ s$ and $t = 2\ s$ due to this force?**

$$\Delta\vec{P} = \vec{J} = \int_0^2 F\,dt = area\ under\ the\ curve$$

$$\Delta\vec{P} = \frac{1}{2} \times 2 \times 2 = 2\ kg \cdot m/s$$



SP4. A collision occurs between a particle with mass $m_1 = 2\,kg$ traveling with velocity $\vec{v}_1 = (-4\hat{\imath} - 3\hat{\jmath})\,m/s$ and another particle with mass $m_2 = 3\,kg$ traveling with velocity $\vec{v}_2 = (6\hat{\imath} - 2\hat{\jmath})\,m/s$. The two particles **stick together** after the collision. **What is the final (common) velocity just after the collision in unit vector notation?**

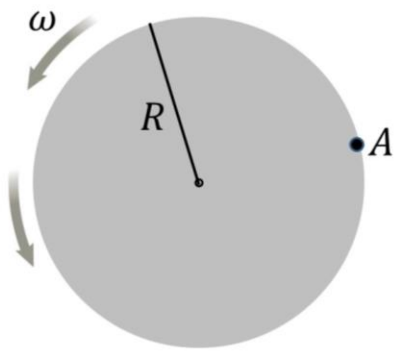
$$\sum \vec{P}_i = \sum \vec{P}_f$$

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_{total}\vec{v}_f$$

$$2(-4\hat{\imath} - 3\hat{\jmath}) + 3(6\hat{\imath} - 2\hat{\jmath}) = 5\vec{v}_f$$

$$\vec{v}_f = (2\hat{\imath} - 2.4\hat{\jmath})\,m/s$$

SP5. A wheel with a radius of $R = 0.3\,m$ starts to rotate **from rest** about an axis through its center. It accelerates with **a constant angular acceleration** of $\alpha = 0.8\,rad/s^2$. **Find the magnitude of the total acceleration (in m/s^2) of point A at $t = 2s$.**



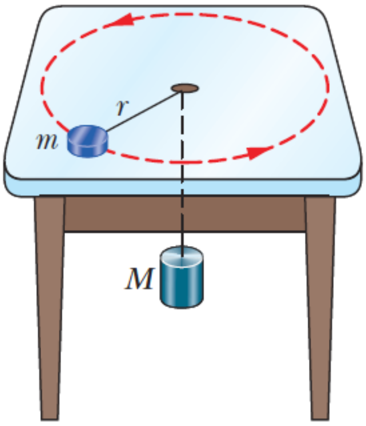
$$\omega_f = \omega_i + \alpha t = 0 + 0.8(2) = 1.6\,rad/s$$

$$a_r = R\omega_f^2 = 0.3(1.6)^2 = 0.77\,m/s^2$$

$$a_{tan} = R\alpha = (0.3)(0.8) = 0.24\,m/s^2$$

$$|\vec{a}_{tot}| = \sqrt{a_r^2 + a_{tan}^2} = \sqrt{0.77^2 + 0.24^2} = 0.81\,m/s^2$$

SP6. A puck of mass $m = 1.5\ kg$ rotates in a circle of radius $r = 0.2\ m$ on a **frictionless table** while attached to a hanging cylinder of mass $M = 3\ kg$ by a **light cord** that extends through a hole in the table, as shown. **The cylinder M is at rest**. **Find the speed of the puck (m).**

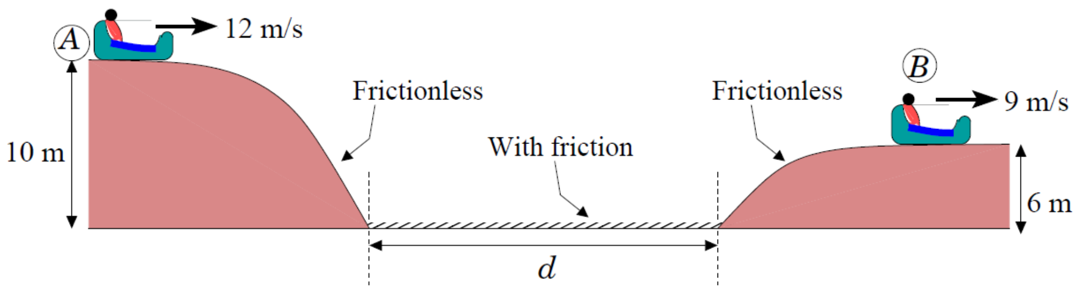


for m: $T = \frac{mv^2}{r}$

for M: $T = Mg$

$$\Rightarrow \frac{mv^2}{r} = Mg \quad \Rightarrow v = \sqrt{\frac{M}{m}Rg} = \sqrt{\frac{3}{1.5}(0.2)(10)} = 2\ m/s$$

SP7. A roller-coaster track is shown. Between two frictionless hills, the horizontal track of length d is **rough** with $\mu_k = 0.1$. At position A, the sled has a speed of $v_A = 12\ m/s$ and when it reaches position B, its speed becomes $v_B = 9\ m/s$. **Find the length d.**



$$E_f - E_i = W_{other}$$

$$(\frac{1}{2}mv_f^2 + mgy_f) - \left(\frac{1}{2}mv_i^2 + mgy_i\right) = W_{f_k}$$

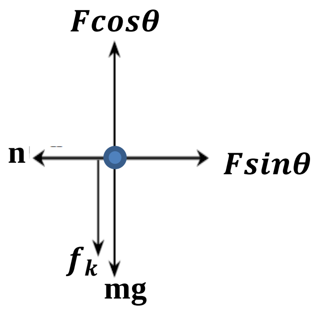
$$\frac{1}{2}m \times 81 + m \times 10 \times 6 - \left(\frac{1}{2}m \times 144 + m \times 10 \times 10\right) = -0.1 \times m \times 10 \times d$$

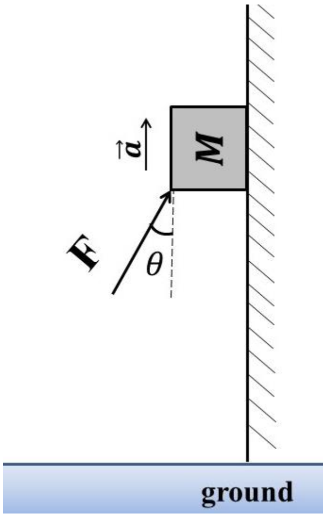
$$d = 71.5\ m$$

Part II: Long Problems (5 points each)

LP1. A block of mass $M = 5\ kg$ is placed against a **rough vertical wall** ($\mu_k = 0.3$) and a constant force $F = 80\ N$ is applied on the block at an angle $\theta = 30°$, as shown. The block starts moving **upward with constant acceleration**.

(a) Draw a clear free-body diagram for the block.





(b) What is the magnitude of the normal force exerted on the block by the wall?

$$\sum F_x = 0$$

$$n - F\ sin\theta = 0$$

$$n = Fsin\theta = 80\ sin30° = 40N$$

(c) What is the magnitude of the block's acceleration?

$$\sum F_y = Ma$$

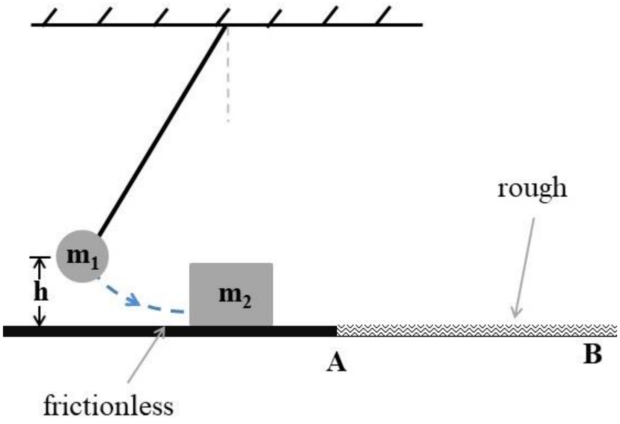
$$F\ cos\theta - Mg - f_k = Ma$$

$$80\ cos30^o - 50 - \mu_k(40) = 5a$$

$$a = 1.46\ m/s^2$$

LP2. A ball ($m_1 = 0.25\ kg$), suspended on the end of a wire, is **released from rest** from height $h = 0.45\ m$ and collides with a block ($m_2 = 0.5\ kg$) which is at **rest** on a **frictionless** horizontal surface, as shown. After the collision the block moves on a **rough portion of the surface** (between A and B) and **stops at B**.

a) Find the ball's speed just before it collides with the block.



$$E_i = E_f$$

$$m_1 g h = \frac{1}{2} m_1 v_i^2$$

$$v_i = \sqrt{2gh} = \sqrt{9} = 3\ m/s$$

b) If the ball rebounds back at a speed of 1 m/s after the collision, find the speed of the block after the collision.

$$\sum P_{xi} = \sum P_{xf}$$

$$m_1(+3) = m_1(-1) + m_2 v_{2xf}$$

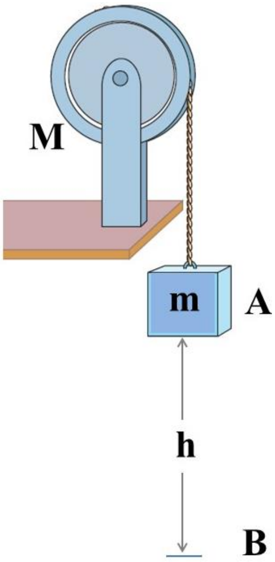
$$0.75 = -0.25 + 0.5 v_{2xf}$$

$$v_{2xf} = +2\ m/s$$

c) Find the work done by friction on the block between points A and B.

$$W_{f_k} = \Delta K = \frac{1}{2} m_2 \left(v_f^2 - v_i^2\right) = \frac{1}{2}(0.5)(0^2 - 2^2) = -1\ J$$

LP3. The figure shows a uniform solid disk, with ($M = 8\,kg$, $R = 0.3\,m$, $I = 0.36\,kg.m^2$), mounted on a fixed frictionless horizontal axle. A block of mass $m = 0.6\,kg$ hangs from a massless cord that is wrapped around the rim of the disk. The system is released **<u>from rest</u>** and the block moves vertically **<u>downward</u>** a distance $h = 1.5\,m$ with **a constant acceleration** of $a = 1.3\,m/s^2$.



a) What is the rotational kinetic energy of the disk when the block reaches point B?

$$E_A = E_B$$
$$mgh = \frac{1}{2}mv_B^2 + \frac{1}{2}I\omega_B^2$$
$$6(1.5) = 0.3(R^2\omega_B^2) + 0.18(\omega_B^2)$$
$$\omega = 6.59\,rad/s$$
$$K_R = \frac{1}{2}I\omega_B^2 = \frac{1}{2}\times 0.36 \times 6.59^2$$
$$= 7.82\,J$$

OR

$$v_f^2 = v_i^2 + 2a\Delta y$$
$$= 0 + 2(1.3)(1.5) = 3.9\,(m/s)^2$$
$$\omega_f = \frac{v_f}{R} = \frac{\sqrt{3.9}}{0.3} = 6.59\,rad/s$$
$$K_R = \frac{1}{2}I\omega_B^2 = \frac{1}{2}\times 0.36 \times 6.59^2$$
$$= 7.82\,J$$

b) Find the tension in the cord.

$$\sum F_y = ma$$
$$mg - T = ma$$
$$6 - T = 0.6(1.3)$$
$$T = 5.22\,N$$

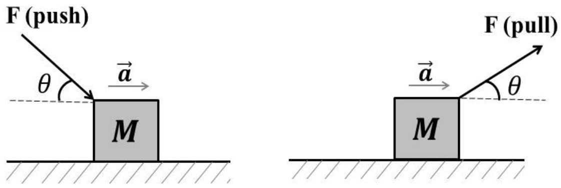
c) Find the work done by the cord's tension on the block as it moves the distance h.

$$W_T = \vec{T}.\vec{S} = |T|(h)\cos 180^o = -5.22 \times 1.5 = -7.83\,J$$

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

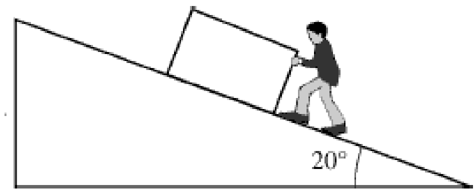
Q1. It always requires less force to pull a block of mass M on **a rough horizontal surface** instead of pushing it, as shown.

Why $F_{(pull)} < F_{(push)}$?



* Because the normal force becomes less while pulling
* Because the normal force becomes more while pulling
* Because the normal force becomes zero while pulling
* Because the gravitational force becomes less while pulling

Q2. A man pushes a box up **a rough** inclined plane at **constant speed**. Which one of the following statements is **FALSE?**



* The gravitational potential energy of the box increases.
* The work done on the box by the gravitational force is zero.
* The net work done by all the forces acting on the box is zero.
* The man does positive work in pushing the box up the incline.

Q3. The **linear momentum** of a system of colliding particles **is conserved only if**:

* The external forces equal to the internal forces.
* The kinetic energy is conserved.
* The collision is elastic.
* The net external force acting on the system is zero.

Q4. The figure shows **a circular path** taken by a particle traveling **counterclockwise**. If the instantaneous velocity of the particle is $\vec{v} = -2\hat{\imath} + 2\hat{\jmath}$, **through which quadrant is the particle moving at that instant?**

* First quadrant
* Second quadrant
* Third quadrant
* Fourth quadrant