Kuwait University Physics Department

Physics 101

Fall Semester

Final Exam

Wednesday, December 27, 2023

8:00 AM – 10:00 AM

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

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

Choose your Instructor's Name:

Instructors: Drs. Al Dosari, Al Jassar, Al kurtas, Al Qattan, Al Refai, Al Smadi, Askar, Demir, Salameh

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 as arranged in the above table.
3. **Give your final answer in the correct units.**
4. Assume g = 10 m/s².
5. Mobiles are **<u>strictly prohibited</u>** 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. A 1.5 kg object moves in the xy plane with a velocity of $\vec{v} = (4\hat{\imath} - 3\hat{\jmath})\ m/s$. Calculate t**he angular momentum of the object relative to the origin in unit vector notation, given that its position vector is** $\vec{r} = (5\hat{\imath} + 2\hat{\jmath})\ m$.

$$\vec{L} = \vec{r} \times \vec{p} = m\,\vec{r} \times \vec{v}$$

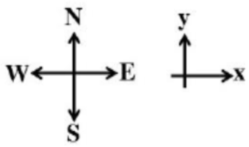
$$\vec{r} \times \vec{v} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ 5 & 2 & 0 \\ 4 & -3 & 0 \end{vmatrix}$$

$$= 0i + 0j + [5(-3) - (2)(4)]\,\hat{k}$$

$$= -23\,\hat{k}\ m^2/s$$

$$\vec{L} = m\,\vec{r} \times \vec{v} = 34.5\,\hat{k}\ \ kg \cdot m^2/s$$

SP2. Two forces act on a block of mass m. The forces are: $F_1 = 8\ N$ along the positive x-axis and $F_2 = 12\ N$ in a direction 53° north of east. **Find the mass m if the magnitude of its acceleration is 6 m/s^2.**



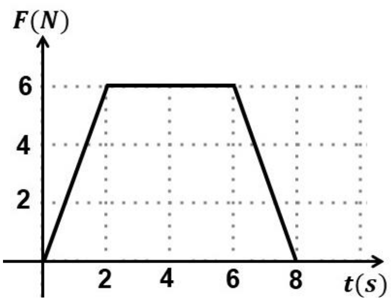
$$\sum F_x = 8 + 12\cos 53° = 15.2\ N$$

$$\sum F_y = 12 \sin 53° = 9.6\ N$$

$$\left|\sum \vec{F}\right| = \sqrt{(15.2)^2 + (9.6)^2} = 18\ N$$

$$\left|\sum \vec{F}\right| = ma \Rightarrow m = \frac{\left|\sum \vec{F}\right|}{a} = \frac{18}{6} = 3\ kg$$

SP3. A2 kg object starts moving at $t = 0\ s$ with an initial velocity of $3\ m/s$ along the $+x$-axis. If the net force exerted on the object **varies with time** as shown in the figure, **use the impulse momentum theorem to find the speed of the object at $t = 8\ s$.**



$$J = \Delta p = Area = 6 + 24 + 6 = 36\ kg \cdot m/s$$

$$m(v_f - v_i) = 36\ kg \cdot m/s$$

$$v_f = v_i + \frac{\Delta p}{m} = 3 + \frac{36}{2} = 21\ m/s$$

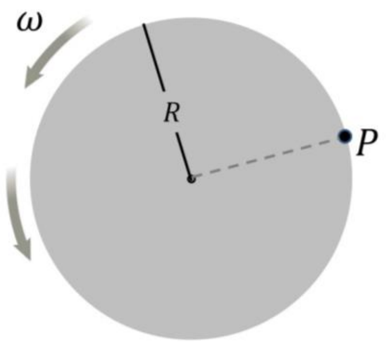
SP4. A 3 kg stone initially moving with velocity $\vec{v} = \left(5\hat{\imath} + 4\hat{\jmath} - 8\hat{k}\right) m/s$, it explodes into two pieces. **After the explosion**, the first piece ($m_1 = 2\ kg$) has a velocity of $\vec{v}_1 = \left(7\hat{\imath} + 2\hat{\jmath} - 14\hat{k}\right) m/s$. **Find the velocity of the second piece ($m_2 = 1\ kg$) after the explosion, in unit vector notation.**

$$M\vec{v}_i = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$3\left(5\hat{\imath} + 4\hat{\jmath} - 8\hat{k}\right) = 2\left(7\hat{\imath} + 2\hat{\jmath} - 14\hat{k}\right) + 1(\vec{v}_2)$$

$$\vec{v}_2 = \left(15\hat{\imath} + 12\hat{\jmath} - 24\hat{k}\right) - \left(14\hat{\imath} + 4\hat{\jmath} - 28\hat{k}\right) = \left(\hat{\imath} + 8\hat{\jmath} + 4\hat{k}\right) m/s$$

SP5. A disk of radius $0.2\ m$ is rotating with **constant angular acceleration** around an axis passing through its center, as shown. It starts rotating at $t = 0\ s$ with angular velocity of $12\ rad/s$. After making $20\ revolutions$, its angular velocity becomes $40\ rad/s$. **Find the tangential acceleration ($in\ m/s^2$) of point p on the disk.**



$$\Delta\theta = 20(2\pi) = 125.6\ rad$$

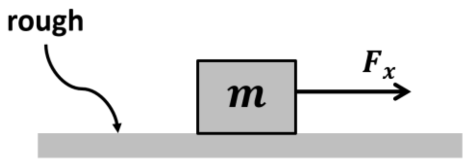
$$\omega_f^2 = \omega_i^2 + 2\alpha\ \Delta\theta$$

$$40^2 = 12^2 + 2(\alpha)(125.6)$$

$$\alpha = 5.8\ rad/s^2$$

$$a_{tan} = R\alpha = 0.2(5.8) = 1.16\ m/s^2$$

SP6. A 3 kg block **rests on a rough horizontal surface**. A variable force $F(x) = 6x^2 + 2$, where $F(x)$ is measured in N and x is measured in m, starts acting on the block. **The block starts from rest at the origin** and achieves a speed of 8 m/s when reaching the position $x = 4\,m$. **Find the work done on the block <u>by friction</u> during this motion.**

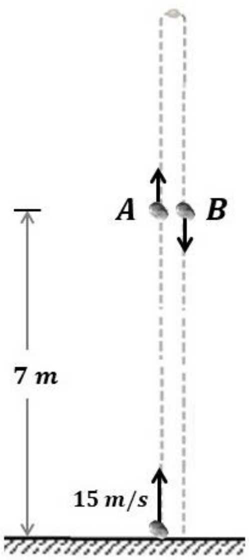


$$w_{F_x} = \int_{x_i}^{x_f} F_x\,dx = \int_0^4 (6x^2 + 2)dx = 2x^3 + 2x]_0^4 = 136\ J$$

$$\Delta K = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = \frac{1}{2}(3)(8^2 - 0) = 96\,J$$

$$w_{F_x} + w_{f_k} = \Delta K \ \Rightarrow\ w_{f_k} = \Delta K - w_{F_x} = 96 - 136 = -40\,J$$

SP7. You throw a stone straight up with an initial speed of 15 m/s. It passes point A on the way up at a height of 7 m. **What is the time required for the stone to travel from point A to point B?**



$$\Delta y = v_{yi}t - \tfrac{1}{2}gt^2$$

$$7 = (15)t - \tfrac{1}{2}(10)t^2 \Longrightarrow t_1 = 0.58\,s, t_2 = 2.42\,s$$

$$\Delta \mathrm{t} = t_2 - t_1 = 1.84\,s$$

OR

From the ground to point A

$$v_{y_f}^2 = v_{y_i}^2 - 2g\Delta y = 15^2 - 2(10)(7) = 85 \ \Rightarrow\ v_{y_f} = \pm 9.2\,m/s$$

From A to B

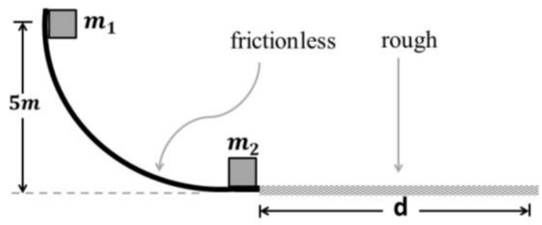
$$v_{y_f} = v_{y_i} - gt$$

$$-9.2 = 9.2 - 10t \ \Rightarrow t = 1.84\,s$$

Part II: Long Problems (5 points each)

LP1. Block 1 ($m_1 = 4\ kg$) slides **from rest** along a **frictionless** ramp from a height of $5\ m$, and block 2 ($m_2 = 6\ kg$) rests on a frictionless horizontal surface, as shown. The two blocks collide at the bottom of the ramp and **stick together**, then they slide into **a rough region ($\mu_k = 0.25$) and come to a stop in distance d.**

(a) Find the speed of block 1 just before the collision.



$U_i + K_i = U_f + K_f$

$m_1 g h + 0 = 0 + \frac{1}{2} m_1 v_1^2$

$v_1 = \sqrt{2gh} = 10\ m/s$

(b) Find the speed of the combined blocks immediately after the collision.

$m_1 v_1 + 0 = (m_1 + m_2) v_2$

$(4)(10) = (4 + 6) v_2 \Rightarrow v_2 = 4\ m/s$

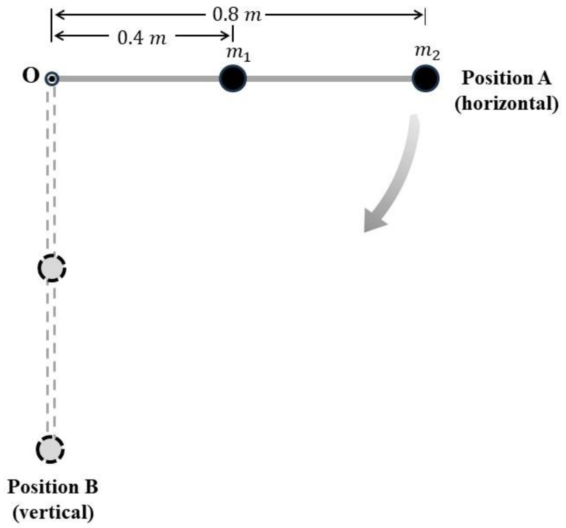
(c) What is the distance d?

$E_f - E_i = W_{f_k}$

$$0 - \frac{1}{2}(m_1 + m_2) v_2^2 = -\mu_k (m_1 + m_2) g d$$

$$d = \frac{v_2^2}{2\mu_k g} = \frac{(4)^2}{2(0.25)(10)} = 3.2\ m$$

LP2. An object consists of two small masses ($m_1 = 0.2\ kg\ and\ m_2 = 0.3\ kg$) joined by **a massless** rigid rod of length 0.8 m, as shown. The object is pivoted about an axis through point O so that it can rotate in a vertical circle. The object starts **from rest** from the horizontal position (position A).



(a) Find the moment of inertia of the object about the rotation axis (point O).

$$I = m_1 r_1^2 + m_2 r_2^2 = 0.2(0.4^2) + 0.3(0.8^2)$$
$$= 0.224\ kg \cdot m^2$$

(b) Find the angular speed of the object <u>at the vertical position (position B).</u>

$$E_i = E_f$$

$$m_1 g y_{1_i} + m_2 g y_{2_i} = \frac{1}{2} I \omega_f^2$$

$$0.2(10)(0.4) + 0.3(10)(0.8) = \frac{1}{2}(0.224)\omega_f^2 \Rightarrow \omega_f = 5.35\ rad/s$$

(c) If v_1 is the speed of m_1 and v_2 is the speed of m_2 at the vertical position, then:

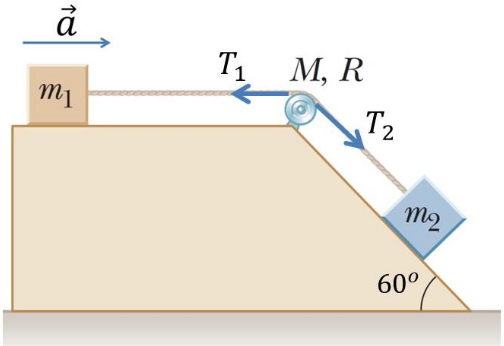
* $v_1 = v_2$ * $v_1 > v_2$ * $v_1 < v_2$

(d) As the object rotates from the horizontal to the vertical position, the angular acceleration will

* increase * decrease * remain constant

LP3. Two blocks ($m_1 = 2\ kg$ and m_2) are connected by a massless string over a pulley ($R = 0.25\ m$, $I = 0.05\ kg \cdot m^2$), as shown. Block 1 slides to the right on **a frictionless horizontal surface** with acceleration of $a = 4\ m/s^2$ and block 2 slides down **a frictionless incline**.

(a) Find the angular acceleration of the pulley.



$$\alpha = \frac{a_{tan}}{R} = \frac{4}{0.25} = 16\ rad/s^2$$

(b) Find the tensions (T_1 and T_2) in the string.

To find T_1

$$T_1 = m_1 a = 8\ N$$

To find T_2

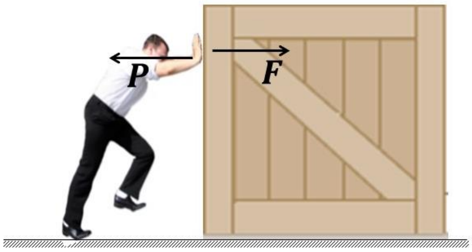
$$T_2 R - T_1 R = I\alpha \quad \Rightarrow \quad T_2 = \frac{I\alpha + T_1 R}{R} = \frac{0.05(16) + 8(0.25)}{0.25} = 11.2\ N$$

(c) Find the mass of block 2.

$$m_2 g \sin(30^o) - T_2 = m_2 a \quad \Rightarrow \quad m_2 = \frac{T_2}{g \sin(60^o) - a} = 2.4\ kg$$

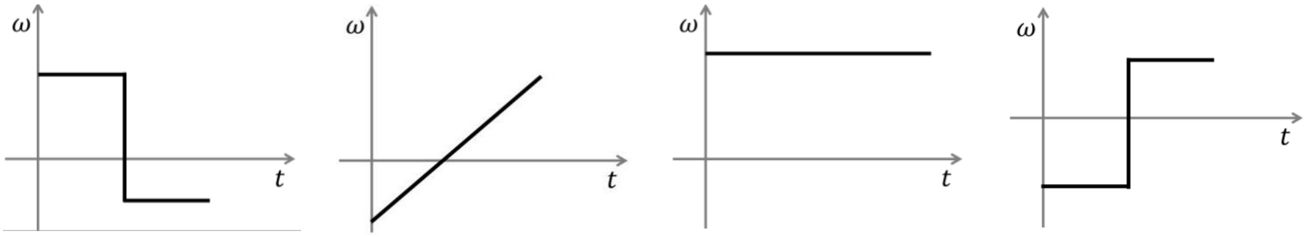
Part III: Questions (Choose the correct answer, one point each)

Q1. When a man exerts a force of magnitude ($\boldsymbol{F}$) to push a box of mass ($\boldsymbol{m}$) on **a rough horizontal surface**, the box, exerts a force of magnitude ($\boldsymbol{P}$) on the man's hand. **If the man and the box move with a constant acceleration of magnitude ($\boldsymbol{a}$)**, then



* $F = P + ma - f_k$
* $F = P + ma$
* $F = P + ma + f_k$
* $F = P$

Q2. A disk is rotating <u>at **a constant angular acceleration**</u> about a fixed axis. Initially, it rotates clockwise, then it changes its direction of rotation to be counterclockwise. **The graph which describes the object's angular velocity ($\boldsymbol{\omega}$) is:**



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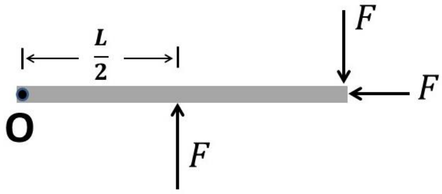
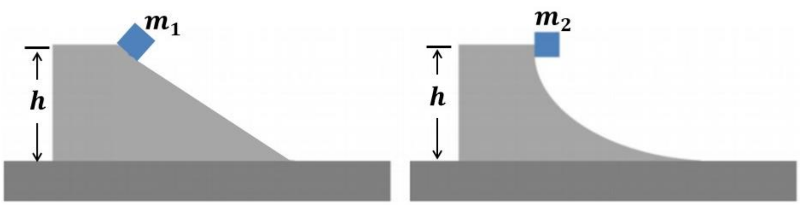
Q3. Three horizontal forces of equal magnitude are applied to a massless rod of length $\boldsymbol{L}$, which is free to rotate about a vertical axis passing through point O, as shown. **The magnitude of the net torque on the rod equals**



* $L\,F$
* $\frac{L}{2}F$
* $\frac{5L}{2}F$
* $\frac{3L}{2}F$

Q4. Two blocks ($m_1 > m_2$) slide from **rest** on two **frictionless slides,** as shown. **Both slides have the same height $\boldsymbol{h}$**. At the slides' end, the speed of block 1 is v_1 and the speed of block 2 is v_2. **Which of the following is correct?**



* $v_1 > v_2$
* $v_1 < v_2$
* $v_1 = v_2$
* The relation between v_1 *and* v_2 depends on the curvature of the curved slide.