Kuwait University **Physics Department**

Physics 101

Summer Semester

Final Exam

Monday, July 24, 2023

2:00 PM – 4:00 PM

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

Model Answer

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

Instructors: Drs. Al Dosari, Al Jassar, Al Smadi, 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/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. The angular position of a rotating disc is described by $\boldsymbol{\theta(t) = 2t^3 - 6t^2}$, where θ is in $radians$ and t is in $seconds$. **Find the angular acceleration of the disc at $\boldsymbol{t = 5s}$.**

$$\omega(t) = \frac{d\theta(t)}{dt} = 6t^2 - 12t$$

$$\alpha(t) = \frac{d\omega(t)}{dt} = 12t - 12$$

$$\alpha(t = 5s) = 12(5) - 12 = 48\, rad/s^2$$

SP2. A constant force $\vec{F} = (20\hat{\imath} + 35\hat{\jmath} - 40\hat{k})\ N$ acts on a 4 kg block while it is moving along the $x - axis$. **Calculate the work done by the force $\vec{F}$ when the block moves from $\boldsymbol{x = 2\ m}$ to $\boldsymbol{x = 9\ m}$.**

$$\Delta\vec{r} = +7\hat{\imath}\, m$$

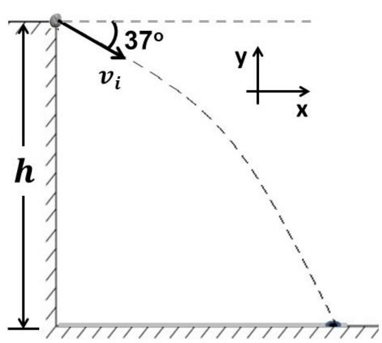
$$W = \vec{F}\cdot\Delta\vec{r} = (20)(7) + 0 + 0 = +140\, J$$

SP3. A stone is projected from the edge of a vertical cliff and hits the ground 2 s later. The stone's **initial velocity is $\boldsymbol{v_i = 20\ m/s}$ directed at 37° below the horizontal**, as shown. **Find the height ($\boldsymbol{h}$) of the cliff.**

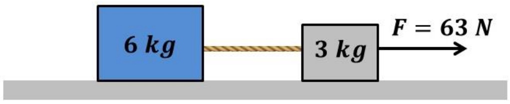
$$v_{y_i} = -v_i \sin(37^o) = -20\sin(37^o) = -12\, m/s$$

$$\Delta y = v_{y_i}t - \frac{1}{2}gt^2 = -12(2) - 5(2^2) = -44\, m$$

$$h = |\Delta y| = 44\, m$$



SP4. A constant force $F = 63\ N$ is applied to a $3\ kg$ block, which is connected to a $6\ kg$ block by a light rope, as shown. The two blocks accelerate together on **a rough horizontal** surface ($\mu_k = 0.4$). **Find the magnitude of the <u>net force</u> on the 3 kg block**.



$$F - \mu_k (m_1 + m_2)\ g\ = (m_1 + m_2)\ a$$

$$a = \frac{F - \mu_k (m_1 + m_2)\ g}{(m_1 + m_2)} = 3\ m/s^2$$

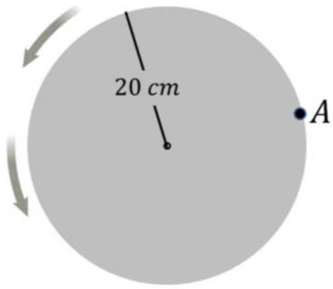
$$F_{net}(on\ m_1) = m_1 a = 9\ N$$

SP5. A disc starts **from rest** and rotates with **constant angular acceleration**. The disc completes 225 revolutions during the first $6\ s$. **Find the tangential acceleration of point A at $t = 6\ s$.**

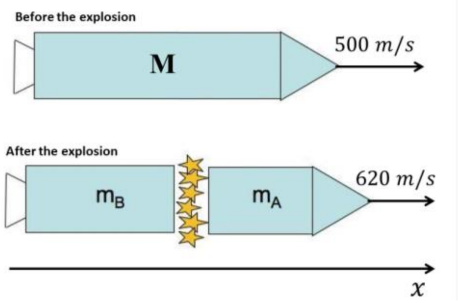
$$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$$

$$225(2)(3.14) = 0 + \frac{1}{2}\alpha(6)^2 \Rightarrow \alpha = 78.5\ rad/s^2$$

$$a_{tan} = R\alpha = 0.2(78.5) = 15.7\ m/s^2$$



SP6. A rocket ($M = 80\ kg$) initially moves at $500\ m/s$. Due to an explosion, the rocket separates into two parts ($m_A = 50\ kg$ and $m_B = 30\ kg$). After the explosion part A moves at a speed of 620 m/s to the right, as shown. **Find the velocity of part B.**



$$Mv_{x_i} = m_A v_{Ax_f} + m_B v_{Bx_f}$$

$$v_{Bx_f} = \frac{Mv_{x_i} - m_A v_{Ax_f}}{m_B}$$

$$= \frac{(80)(500)-(50)(620)}{30} = +300\ m/s \quad \text{(To the right)}$$

SP7. Starting at $t = 0\ s$, a net external force $\vec{F}(t) = (4t\hat{\imath} - 9t^2\hat{\jmath})$, where F is in $newtons$ and t is in $seconds$, is applied to a box that has an initial momentum $\vec{p}_i = (-3i + 4j)\ kg \cdot m/s$. **Find the momentum of the box at $t = 2\ s$ in unit vector notation.**

$$\vec{J} = \int_{t_i}^{t_f} \vec{F}(t)dt = \int_0^2 (4t\hat{\imath} - 9t^2\hat{\jmath})\ dt = [(2t^2\hat{\imath} - 3t^3\hat{\jmath})]_0^2 = (8\hat{\imath} - 24\hat{\jmath})\ kg \cdot m/s$$

$$\vec{J} = \vec{p}_f - \vec{p}_i \Rightarrow \vec{p}_f = \vec{J} + \vec{p}_i$$

$$\vec{p}_f = \vec{J} + \vec{p}_i = (8\hat{\imath} - 24\hat{\jmath}) + (-3i + 4j) = (5\hat{\imath} - 20\hat{\jmath})\ kg \cdot m/s$$

Part II: Long Problems (5 points each)

LP1. Two **identical** objects ($m_1 = m_2 = 2\ kg$) move on **a frictionless** horizontal surface with velocities $\vec{v}_{1_i} = (4\hat{\imath} - 6\hat{\jmath})\ m/s$ and $\vec{v}_{2_i} = (8\hat{\imath} + 2\hat{\jmath})\ m/s$. The two objects collide, **stick together, and move with velocity** $\vec{v}_f$.

(a) Find the total kinetic energy of the system before the collision.

$$\sum K_i = \frac{1}{2}m_1 v_{1_i}^2 + \frac{1}{2}m_2 v_{2_i}^2$$

$$= \frac{1}{2}(2)(4^2 + 6^2) + \frac{1}{2}(2)(8^2 + 2^2) = 120\,J$$

(b) Find the common velocity of the two objects after the collision ($\vec{v}_f$) in unit vector notation.

$$m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i} = (m_1 + m_2)\vec{v}_f$$

$$\vec{v}_f = \frac{m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i}}{(m_1 + m_2)} = \frac{2(4\hat{\imath} - 6\hat{\jmath}) + 2(8\hat{\imath} + 2\hat{\jmath})}{4} = (6\hat{\imath} - 2\hat{\jmath})\ m/s$$

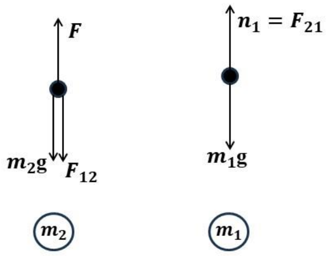
(c) Find the change in kinetic energy due to the collision.

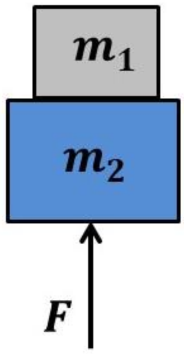
$$\Delta K = \frac{1}{2}(m_1 + m_2)v_f^2 - \left(\frac{1}{2}m_1 v_{1_i}^2 + \frac{1}{2}m_2 v_{2_i}^2\right)$$

$$= \frac{1}{2}(4)(6^2 + 2^2) - (120) = -40\,J$$

LP2. Two blocks ($m_1 = 3\ kg, m_2 = 5\ kg$) are raised vertically by a force $F = 96\ N$, as shown.

(a) Draw a Free body diagram for each block.





(b) Find the contact force between the two blocks.

$$F - (m_1 + m_2)g = (m_1 + m_2)a$$

$$a = \frac{F - (m_1 + m_2)g}{(m_1 + m_2)} = \frac{96 - (80)}{8} = 2\ m/s^2$$

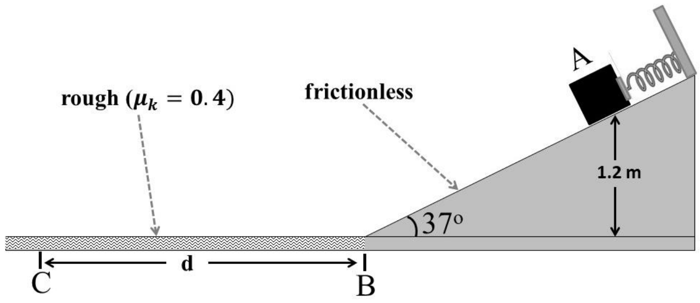
$$F_{21} - m_1 g = m_1 a \Rightarrow F_{21} = m_1(g + a) = 36\ N$$

OR $F - F_{12} - m_2 g = m_2 a \Rightarrow F_{12} = F - m_2 g - m_2 a = 96 - 50 - 10 = 36\ N$

(c) If the surface between the two blocks is rough with coefficients of friction (μ_s *and* μ_k), then the friction force acting on m1 equals (ignore air resistance).

* $\mu_k m_1 g$ * $\mu_s m_1 g$ * $\mu_s(m_1 + m_2)g$ * zero

LP3. A 4 kg block is **released from rest** at point A when the spring ($k = 600\ N/m$) is compressed $20\ cm$. The block leaves the spring and slides down **a frictionless incline**, and then **a rough horizontal surface**, as shown. Finally, the block **stops at point C**.



(a) Find the total work done on the block between points A and B.

$$W_{total}(A \longrightarrow B) = W_{mg} + W_{F_s}$$

$$= mgh + \frac{1}{2}k(x_i^2 - x_f^2)$$

$$= 4(10)(1.2) + \frac{1}{2}(600)(0.2^2 - 0) = 60\ J$$

(b) Find the speed of the block at point B.

$$W_{total}(A \longrightarrow B) = \frac{1}{2}m(v_B^2 - v_A^2)$$

$$60 = \frac{1}{2}(4)(v_B^2 - 0) \Rightarrow v_B = 5.48\ m/s$$

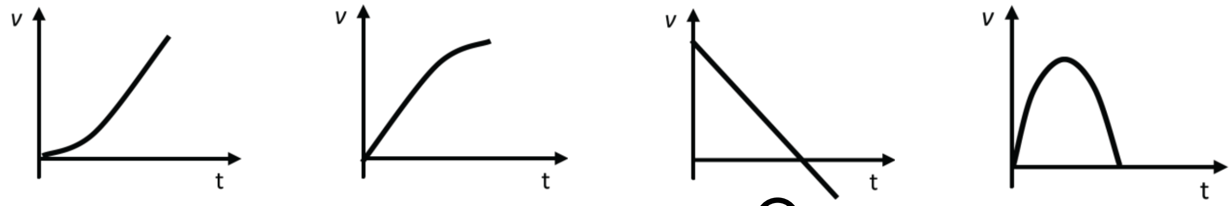
(c) Find the distance (d) between points B and C.

$$W_{total}(B \longrightarrow C) = \frac{1}{2}m(v_C^2 - v_B^2)$$

$$-\mu_k mgd = \frac{1}{2}m(0 - v_B^2) \Rightarrow d = \frac{v_B^2}{2\mu_k g} = 3.75\ m$$

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

Q1. A stone is thrown **vertically up**. Which of the following graphs correctly represents its **velocity**?

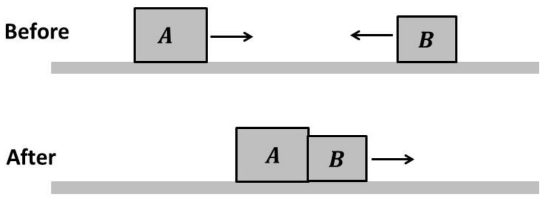


* * ⊛ *

Q2. Three blocks with masses $m_1 > m_2 > m_3$ rest on **a frictionless** table at position **A**. Three forces of equal magnitude **(F)** act on the blocks, and the blocks move the same distance to position **B,** as shown. **Which block will have the highest kinetic energy at position B.**

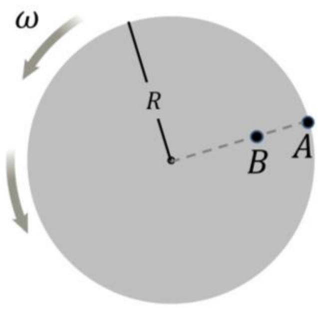
* m_1
* m_2
* m_3
* ⊛ all the same

Q3. For the **completely inelastic collision** shown in the figure, what can be said about the kinetic energy (K) of the system.



* $K_{before} = K_{after}$
* ⊛ $K_{before} > K_{after}$
* $K_{before} < K_{after}$
* $K_{before} + K_{after} = 0$

Q4. A solid disc is rotating about its center with angular velocity ω. Points A and B are two points on the disc's surface. **Which one of the following statements is correct?**



* ⊛ $\omega_A = \omega_B$
* $v_A = v_B$
* $\omega_A > \omega_B$
* $v_A < v_B$