Kuwait University — Physics Department

Physics 101

Summer Semester

Final Exam

Monday July 29, 2024

11:00 AM – 1:00 PM

Model Answer

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

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

Choose your Instructor's Name:

Instructors: Drs. Al Dosari, Al Jassar, Al Qattan, 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. An object has a position vector given by $\vec{r}(t) = [(2+t^3)\hat{\imath} + (3-4t^2)\hat{\jmath}]\ m$, where t is measured in seconds. **Find the magnitude of the object's acceleration at $t = 2\ s$.**

$$\vec{v} = \frac{d\vec{r}}{dt} = (3t^2\hat{\imath} - 8t\hat{\jmath})\ m/s$$

$$\vec{a} = \frac{d\vec{v}}{dt} = (6t\hat{\imath} - 8\hat{\jmath})\ m/s^2$$

$$\vec{a}(2s) = (6(2)\hat{\imath} - 8\hat{\jmath})\ m/s^2 = (12\hat{\imath} - 8\hat{\jmath})\ m/s^2$$

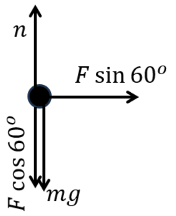
$$|\vec{a}(2s)| = \sqrt{12^2 + 8^2} = 14.4\ m/s^2$$

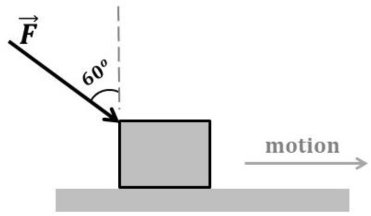
SP2. A 15 kg block is pushed to the right along a horizontal **frictionless** surface by a constant force $F = 120\ N$, as shown. **Draw the free body diagram of the block and find its acceleration.**

$$F\ sin\ 60 = ma_x$$

$$120\ sin\ 60 = 15a_x$$

$$a_x = 6.9\ m/s^2$$



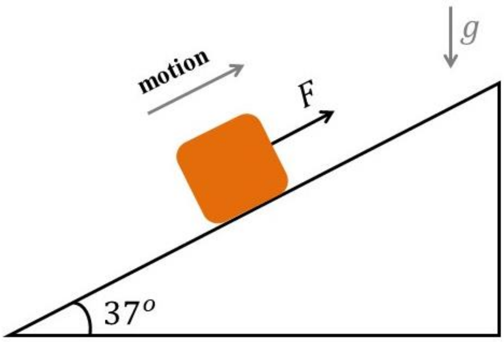


SP3. A 2 kg block is pulled across **a rough** inclined surface by a force $F = 18\ N$, as shown. The block **moves up** the incline with **constant speed**. **Find the coefficient of kinetic friction between the block and the surface.**

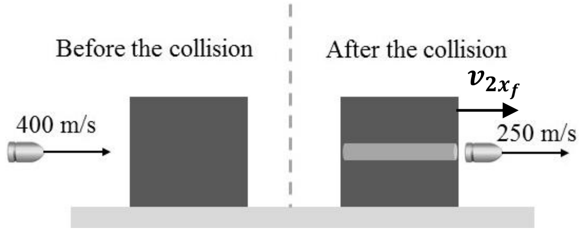
$$F - mg\sin\theta - f_k = 0$$

$$F - mg\sin\theta - \mu_k mg\ cos37^o = 0$$

$$\mu_k = \frac{F - mg\sin\theta}{mg\ cos37^o} = 0.37$$



SP4. A 2 kg block **rests** on a frictionless surface. A 50 g bullet moving at 400 m/s strikes the block and **emerges from it** with a speed of 250 m/s, as shown. **Find the speed of the block after the collision.**



$$m_1 v_{1x_i} + m_2 v_{2x_i} = m_1 v_{1x_f} + m_2 v_{2x_f}$$

$$0.05\,(400) + 0 = 0.05\,(250) + 2 v_{2x_f}$$

$$v_{2x_f} = \frac{0.05\,(400) - 0.05(250)}{2}$$

$$= 3.75\ m/s$$

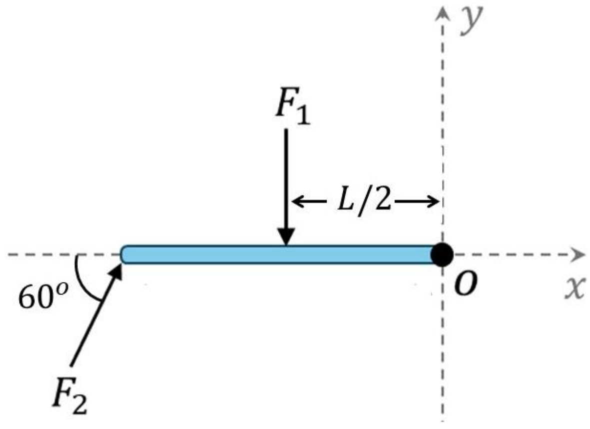
SP5. Two forces, $F_1 = 30\ N$ and $F_2 = 40\ N$, are applied on **<u>a massless</u> rod** with a length of $L = 3\ m$, as shown. **Calculate the net torque about point *O* due to these forces.**

$$\vec{\tau}_1 = +r_1 F_1 \sin 90^o\,\hat{k} = +(1.5)(30)\hat{k}$$
$$= +45\,\hat{k}\ N.m$$

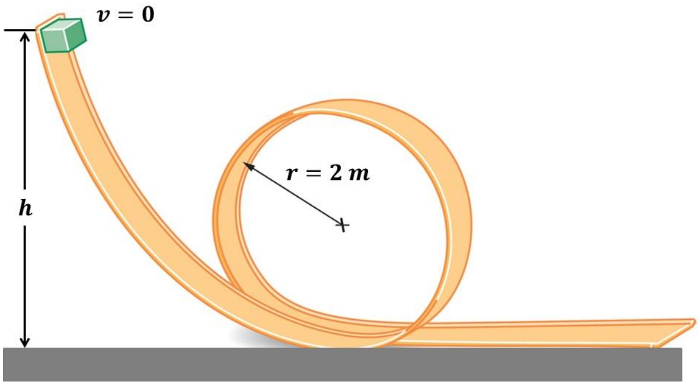
$$\vec{\tau}_2 = -r_2 F_2 \sin 120^o\,\hat{k}$$

$$= -(3)(40)\sin 120^o\,\hat{k} = -103.9\,\hat{k}\ N.m$$

$$\vec{\tau} = \vec{\tau}_1 + \vec{\tau}_2 = -58.9\,\hat{k}\ N.m$$



SP6. A block of mass m slides **from rest** on a frictionless loop-the-loop track, as shown. What is the **minimum** release height (h) required for the block to **stay in contact with the surface at the top of the circular portion of the track**?



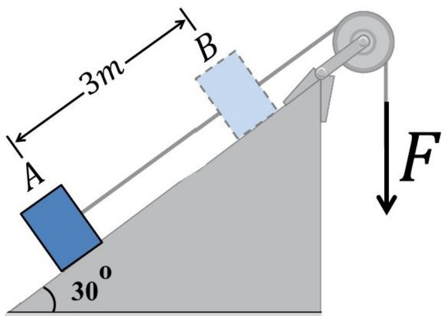
at the top of the circular portion

$$mg + n = m\frac{v^2}{r}$$

$$n = 0 \Rightarrow v = \sqrt{rg} = \sqrt{20}\,m/s$$

$$mg(h-4) = \frac{1}{2}mv^2 \Rightarrow h = \frac{1}{2}\frac{v^2}{g} + 4 = 5\,m$$

SP7. A 2 kg box **rests** on **a frictionless inclined surface** and attached to a light rope that passes over a frictionless pulley ($R = 0.1\,m,\ I = 0.01\,kg \cdot m^2$), as shown. The rope is pulled from its lower end by a constant force ($F = 25\,N$). If the block **starts from rest at point A**, **find its speed at point B.**



$$E_f - E_i = W_F$$

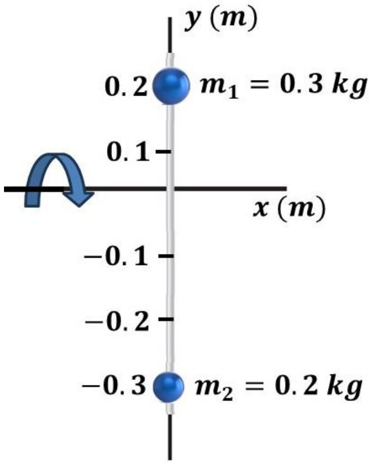
$$mgh + \frac{1}{2}mv^2 + \frac{1}{2}I(\frac{v}{R})^2 - 0 = F(d)$$

$$2(10)(3\sin(30^o)) + \frac{1}{2}(2)v^2 + \frac{1}{2}(\frac{0.01}{0.1^2})v^2 = 25(3)$$

$$v = 5.5\,m/s$$

Part II: Long Problems (5 points each)

LP1. Two small balls are connected by **a very light** rigid rod, as shown. The system rotates around the $x - axis$.



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

$$I = m_1 y_1^2 + m_2 y_2^2 = (0.3)(0.2)^2 + (0.2)(0.3)^2 = 0.03 \; kg \cdot m^2$$

b) The system starts to rotate **from rest** with a constant angular acceleration of $20\, rad/s^2$. Find the rotational kinetic energy of the system at $t = 3\ s$.

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

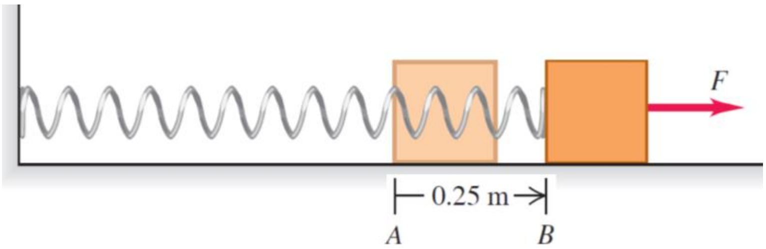
$$= 0 + 20(3) = 60\, rad/s$$

$$K_{rot} = \frac{1}{2} I\omega^2 = \frac{1}{2}(0.03)(60)^2 = 54\, J$$

c) Find the tangential speed of m_1 at $t = 3\ s$.

$$v = R\omega = 0.2(60) = 12\, m/s$$

LP2. A $2\,kg$ block **rests** on **a frictionless horizontal** surface is attached to a spring of force constant $k = 40\ N/m$, as shown. **The spring is relaxed at point A**, you move the block by pulling with a constant horizontal force $F = 20\ N$.



(a) Find the **total** **work** done on the block as it moves **from point A to point B.**

$$\sum W = W_F + W_{F_s} = F(d) + \frac{1}{2}k(x_i^2 - x_f^2)$$

$$= 20(0.25) + \frac{1}{2}(40)(0_i^2 - 0.25^2) = 3.75\,J$$

(b) Find the block's speed when it reaches point B.

$$\sum W = \Delta K$$

$$3.75 = \frac{1}{2}m(v_f^2 - v_i^2) = \frac{1}{2}(2)(v_f^2 - 0^2) \Rightarrow v_f = 1.9\ m/s$$

(c) If the surface was rough, then the **total** **work** done on the block as it moves **from point A to point B** will be

(*) **less than the value obtained in part a.**

* **greater than the value obtained in part a.**

* **equal to the value obtained in part a.**

LP3. block 1 ($m_1 = 3\ kg$) moves on **a horizontal frictionless surface** with an initial velocity $\vec{v}_{1_i} = (5\hat{\imath} - 4\hat{\jmath})\ m/s$. It collides with block 2 ($m_2 = 2\ kg$), which **is initially at rest**. After the collision, the velocity of m_1 is $\vec{v}_{1_f} = (4\hat{\imath} - 2\hat{\jmath})\ m/s$.

(a) Find the velocity of block 2 after the collision in unit vector notation.

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

$$3(5\hat{\imath} - 4\hat{\jmath}) + 0 = 3(4\hat{\imath} - 2\hat{\jmath}) + 2\vec{v}_{2_f}$$

$$\vec{v}_{2_f} = \frac{(15\hat{\imath} - 12\hat{\jmath}) - (12\hat{\imath} - 6\hat{\jmath})}{2} = (1.5\hat{\imath} - 3\hat{\jmath})\ m/s$$

(b) If the collision lasts for $0.1s$, find the average net force exerted **on block 1** during the collision in unit vector notation.

$$\left(\sum F\right)_{av_{on\ block\ 1}} = \frac{\Delta\vec{p}_1}{\Delta t} = \frac{m_1\left(\vec{v}_{1_f} - \vec{v}_{1_i}\right)}{\Delta t} =$$

$$\frac{3((4\hat{\imath} - 2\hat{\jmath}) - (5\hat{\imath} - 4\hat{\jmath}))}{0.1} = (-30i + 60j)\ N$$

(c) Find the change in kinetic energy of the two blocks system due to the collision.

$$v_{1_i}^2 = 5^2 + 4^2 = 41\ (m/s)^2$$

$$v_{1_f}^2 = 4^2 + 2^2 = 20\ (m/s)^2$$

$$v_{2_f}^2 = 1.5^2 + 3^2 = 11.25\ (m/s)^2$$

$$\Delta K = (\frac{1}{2}m_1v_{1_f}^2 + \frac{1}{2}m_2v_{2_f}^2) - (\frac{1}{2}m_1v_{1_i}^2 + \frac{1}{2}m_2v_{2_i}^2)$$

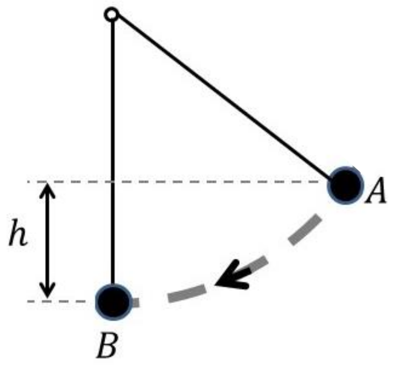
$$= \left(\frac{1}{2}(3)(20) + \frac{1}{2}(2)(11.25)\right) - \left(\frac{1}{2}(3)(41) + 0\right) = -20.25\ J$$

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

Q1. A box starts **from rest at $t = 0\ s$** and moves along the positive x-axis with **constant acceleration**. If the speed of the box at $t = 1\ s$ is v, then its speed at $t = 3\ s$ is:

* v * $2v$ * $3v$ * $9v$

Q2. When the bob ($mass\ = m$) of a simple pendulum moves from point A to point B, as shown, the work done on the bob by the **tension** is equal to



* $zero$

* $\frac{1}{2}m(v_B^2 - v_A^2)$

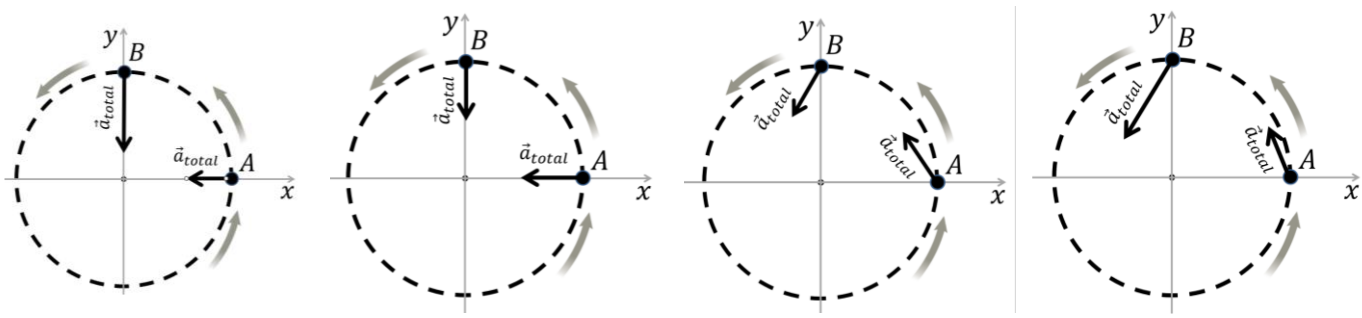
* $-mgh$

* mgh

Q3. An object is **initially moving to the right** along $+x$-axis with velocity v_{xi}. A net force is exerted on the object giving it **an impulse towards the left**. After the impulse, which of following statements is always true about the final velocity of the object v_{xf}:

- v_{xf} is negative.
- v_{xf} is zero.
- v_{xf} is positive.
- All the above are possible.

Q4. An object is moving in a circular path counterclockwise and **speeding up at a constant rate**. The object passes point A and then point B. Which figure represents the total acceleration of the object at these two points?



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