Kuwait University **Physics Department**

Physics 121

Mid-Term Exam II
Spring Semester (2022-2023)

April 29, 2023
Time: 15:00 – 16:30

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

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

Instructors: Drs. Alotaibi, Hadipour, Kokkalis, Razee, Salameh, Zaman

Important:

1. Answer all questions and problems (No solution = no points).
2. Full mark = 28 points as arranged in the table below.
3. **Give your final answer in the correct units.**
4. Assume g = 9.8 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.**

For use by instructors

Grades:

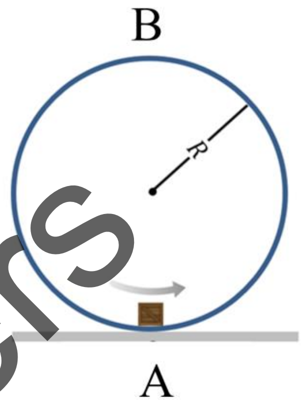
#	P1	P2	P3	P4	P5	P6	P7	Total
Pts	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**28**

GOOD LUCK

P1. A vertical hoop of radius (R) is fixed to the ground. A small block of mass $m = 0.2$ kg is sliding along the inside rough surface of the hoop, as shown. At the **lowest point (point A)**, the block has a speed 6 m/s and the normal force exerted on it is $F_N = 12$ N.

a. Find the radius R of the hoop. (2 points)

b. Find the minimum speed of the block at the top of the hoop (point B), in order for it to continue moving in a circular path without falling. (2 points)



(a) at point A

$$F_N - mg = m\frac{v_A^2}{R}$$

$$R = \frac{mv_A^2}{F_N - mg} = 0.72\ m$$

(b) $F_N + mg = m\frac{v_B^2}{R}$ (Eq. 1)

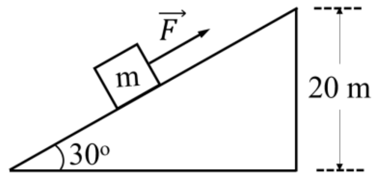
For the minimum speed required for circular motion at B,

$F_N = 0$ and (Eq. 1) $v_B^{min} = \sqrt{Rg} = 2.7$ m/s

P2. A force F pulls a 30 kg block along **a frictionless incline** with **constant speed,** as shown.

a. Find the work done by F as the block moves from bottom to the top of the incline. (3 points)

b. Find the average power of the force F if it takes 1 minute to reach the top of the incline. (1 point)



(a)

$$F - mg\,sin(30^o) = 0 \quad \Rightarrow \quad F = mg\,sin(30^o) = 147\,N$$

$$sin(30^o) = \frac{20}{d} \Rightarrow d = 40\,m$$

$$W_F = |F||d|\cos(\theta) = 147(40)\cos(0) = 5880\,J$$

OR

$$\sum W = \Delta KE = 0$$

$$W_{mg} + W_F = 0 \quad \Rightarrow W_F = -W_{mg} = mgh = 30(9.8)(20) = 5880\,J$$

(b)

$$\bar{P} = \frac{W}{t} = \frac{5880}{60} = 98\,watt$$

OR

$$\bar{v} = \frac{d}{t} = \frac{40}{60} = \frac{2}{3}\,m/s$$

$$\bar{P} = F\bar{v}\cos(\theta) = 147\frac{2}{3}\cos(0^o) = 98\,watt$$

P3. A spring ($k = 200$ N/m) is compressed by x from its natural length and has a 2 kg mass at one end. The spring is released (at point A) and the mass moves from rest along the horizontal surface and enters (at point B) a semicircular loop or radius $R = 1$ m. **Ignore friction forces.**

a. Find the compression (x) of the spring so that the mass pass from point C with 3 m/s. (2 points)

b. Find the work done by the force of gravity on the mass from B to C. (2 points)

(a) $\frac{1}{2}kx_A^2 + 0 = \frac{1}{2}mv_C^2 + mgR$

$$\rightarrow x_A = \sqrt{\frac{mv_C^2 + 2mgR}{k}} = 0.53\ m$$

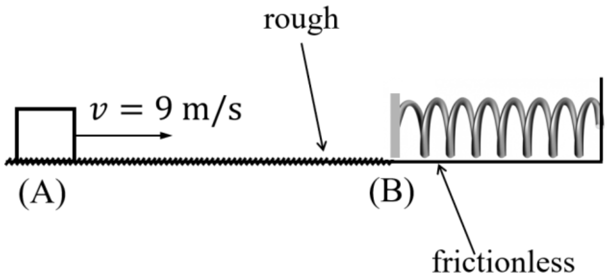
(b) $W_{mg} = -\Delta PE = -(PE_C - PE_B) = -mgR$

$$\rightarrow W_{mg} = -19.6\ J$$

P4. A block ($m = 2$ kg) is projected from point A with a speed of 9 m/s and strikes a relaxed spring at point B with a speed of 3 m/s. The block compresses the spring a maximum distance of 0.2 m.

a. Find the work done by friction on the block between points A and B. (2 points)

b. Find the spring stiffness constant (k). (2 points)



(a) $E_B - E_A = W_{f_k}$

$$W_{f_k} = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 = -72\ J$$

(b) $\frac{1}{2}mv_B^2 = \frac{1}{2}kx_{max}^2$

$$k = \frac{mv_B^2}{x_{max}^2}$$

$$= \frac{2(3)^2}{0.2^2} = 450\ N/m$$

P5. The figure below shows the arm of a person bent at 90^o. The mass of each part of the arm is shown in the figure. The corresponding centers-of-mass are indicated by " × ". **Find the *x*-coordinate and *y*-coordinate of the center-of-mass of the entire arm, measured from the shoulder joint (point O).**

(4 points)

$$X_{CM} = \frac{x_u m_u + x_f m_f + x_h m_h}{m_u + m_f + m_h}$$

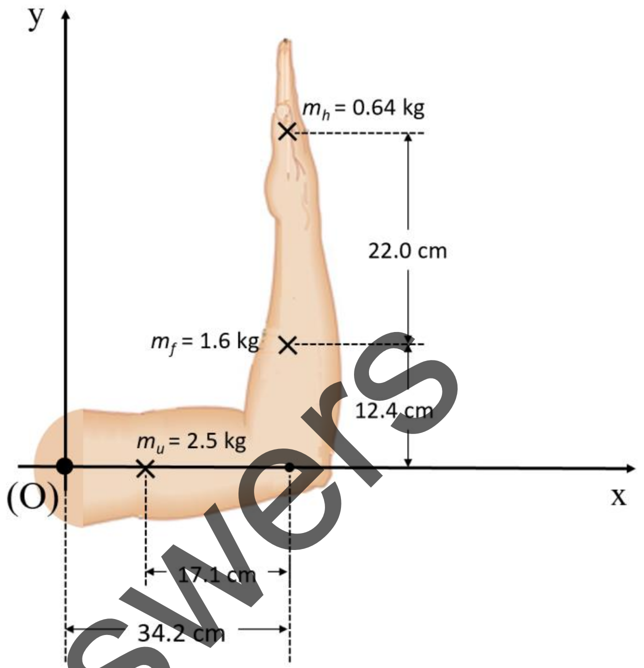
$$= \frac{(34.2 - 17.1) \times 2.5 + 34.2 \times 1.6 + 34.2 \times 0.64}{2.5 + 1.6 + 0.64}$$

$$\rightarrow X_{CM} = 25.2\ cm$$

$$Y_{CM} = \frac{y_u m_u + y_f m_f + y_h m_h}{m_u + m_f + m_h}$$

$$= \frac{0 \times 2.5 + 12.4 \times 1.6 + (12.4 + 22) \times 0.64}{2.5 + 1.6 + 0.64}$$

$$\rightarrow Y_{CM} = 8.83\ cm$$



P6. A rotating wheel is slowing down at a rate of $1.5\ \mathrm{rad/s^2}$. At $t = 0$, the angular velocity of the wheel is $12\ \mathrm{rad/s}$.

a. Find the linear velocity of a point which is 40 cm from the rotation axis at $t = 6$ s. (2 points)

b. Find the number of revolutions needed for the wheel to come to rest (from $t = 0$). (2 points)

(a) $\omega = \omega_o + \alpha t = 12 - 1.5 \times 6 = 3\, rad/s$

$v = r\omega = 0.40 \times 3 = 1.2\, m/s$

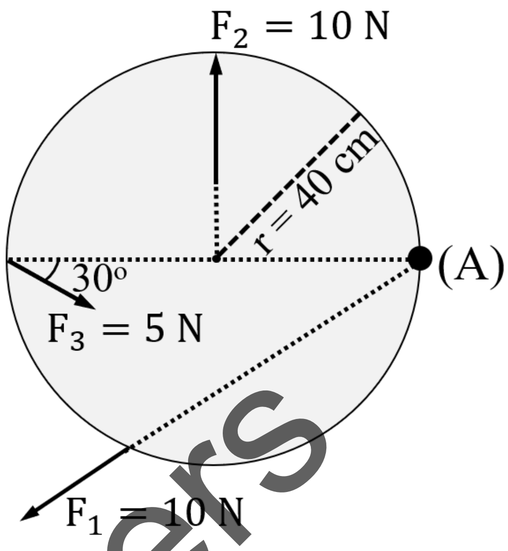
(b) $\omega^2 = \omega_o^2 + 2\alpha(\theta - \theta_o) \rightarrow \Delta\theta = \frac{\omega^2 - \omega_o^2}{2\alpha} = \frac{0^2 - 12^2}{2(-1.5)} = 48\, rad$

$N = \frac{\Delta\theta}{2\pi} = \frac{48}{2\pi} = 7.64\, rev$

P7. The figure shows three forces acting on a disk of radius $r = 40$ cm.

a. Find the initial torque by each force, about the pivot point A. **(3 points)**

b. Find the initial net torque, about the pivot point A. **(1 point)**



(a) $\tau_{F_1}^{(A)} = 0\ N.m$

$\tau_{F_2}^{(A)} = -r\ F_2 = -4\ N.m$

$\tau_{F_3}^{(A)} = (2r)\ F_3 \sin(30^o) = 2\ N.m$

(b) $\tau_{net}^{(A)} = \tau_{F_1}^{(A)} + \tau_{F_2}^{(A)} + \tau_{F_3}^{(A)} = 0 - 4 + 2 = -2\ N.m$