Kuwait University | Physics Department

Physics 121

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

July 15, 2023
Time: 15:00 – 16:30

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

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

Instructors: Drs. Abdulmuhsen, Alotaibi, Lajko, Kokkalis, Razee

Important:

1. Answer all questions and problems (No solution = no points).
2. Full mark = 30 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:

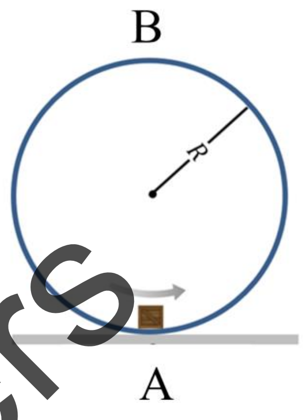
#	P1	P2	P3	P4	P5	P6	P7	Total
Pts	**4**	**5**	**4**	**4**	**4**	**5**	**4**	**30**

GOOD LUCK

P1. A vertical hoop of radius $R = 0.72$ m is fixed to the ground. A small block of mass $m = 0.2$ kg is sliding along the inside surface of the hoop **without friction**, as shown. At the **lowest point (point A)**, the block has a speed of 6 m/s.

a. Find the normal force exerted on the block at point A. **(2 points)**

b. Find the speed of the block at the top of the hoop (point B). **(2 points)**



(a) at point A

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

$$F_N = m\frac{v_A^2}{R} + mg = 12\ N$$

(b) $E_A = E_B$

$$\frac{1}{2}mv_A^2 = \frac{1}{2}mv_B^2 + mg(2R)$$

$$v_B = \sqrt{v_A^2 - 4gR} = 2.8\ m/s$$

P2. A 30 kg box **initially at rest** is pulled 5 m from point A to point B along a **rough** horizontal surface ($\mu_k = 0.2$), by a constant force of magnitude $F = 210$ N, as shown.

a. Find the net work done on the box. **(4 points)**

b. Find the speed of the box at point B. **(1 point)**

(a)

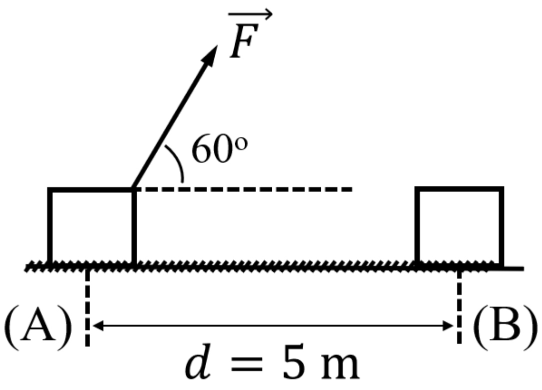
$$W_F = Fd\cos(60^o) = 525\ J$$

$$W_{F_{fr}} = F_{fr}d\cos(180^o) = -\mu_k F_N d$$

$$= -\mu_k\big(mg - F\sin(60^o)\big)d$$

$$= -112\ J$$

$$W_{net} = W_F + W_{F_{fr}} = 413\ J$$



(b)

$$W_{net} = \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mv_o^2 \to v = 5.25\ m/s$$

OR

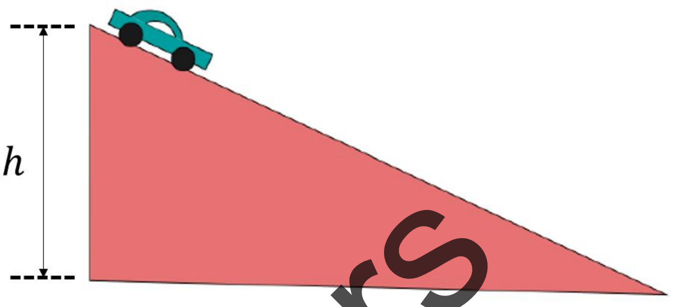
$$a = \frac{F\cos(60^o) - \mu_k\big(mg - F\sin(60^o)\big)}{m} = 2.75\ m/s^2$$

$$v^2 = v_o^2 + 2a(x - x_o) \to v = 5.25\ m/s$$

P3. A 1000 kg car starts with 10 m/s speed at the top of an incline of height h. The car reaches the bottom of the incline with 20 m/s in 8 s. The work done by the engine during this motion is 52000 J. Assume a **frictionless** descend of the car.

a. Find the height *h* of the incline. (3 points)

b. Find the average power of the engine. (1 point)



(a) $W_{mg} + W_{eng} = \Delta KE \rightarrow$

$$mgh = -W_{eng} + \frac{1}{2}m(v^2 - v_o^2) \rightarrow$$

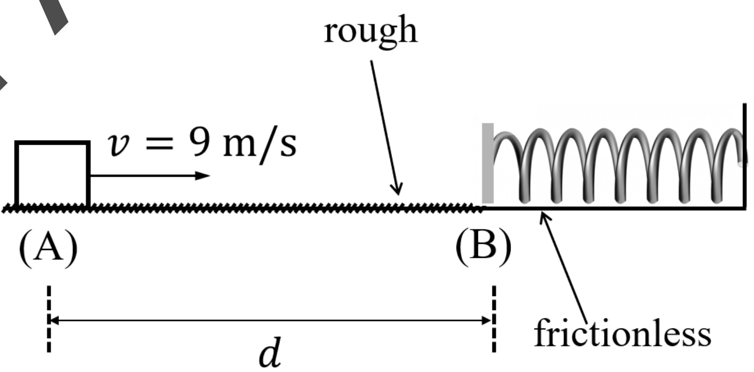
$$\rightarrow h = 10\ m$$

(b) $P_{eng} = \frac{W_{eng}}{t} = 6500\ W$

P4. A block ($m = 2$ kg) moves on a **rough** surface ($\mu_k = 0.30$) from point A with a speed of 9 m/s and arrives at B with 3 m/s. The block there collides with a relaxed spring ($k = 450$ N/m). The surface beyond point B is **frictionless**.

a. Find the distance *d* between points A and B. (2 points)

b. Find the maximum compression of the spring. (2 points)



(a) $W_{f_k} = \Delta KE + \Delta PE \rightarrow \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 = -\mu_k mgd$

$$\rightarrow d = 12\ m$$

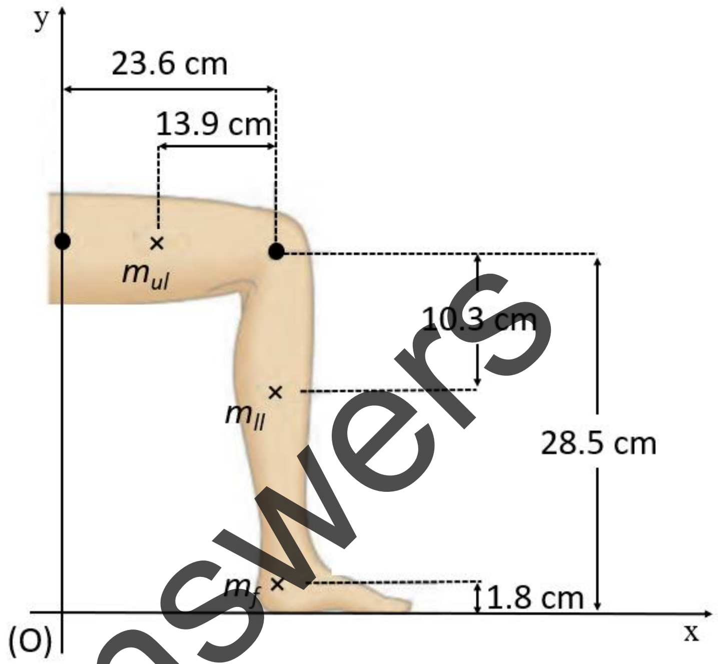
(b) $\frac{1}{2}mv_B^2 = \frac{1}{2}kx_{max}^2$

$$x_{max} = 0.2\ m$$

P5. The figure below shows the leg of a person bent at 90^o. The upper leg (ul), lower leg (ll), and feet (f) have masses $m_{ul} = 21.5\%$, $m_{ll} = 9.6\%$, and $m_f = 3.4\%$ of the total body's mass. The corresponding centers-of-mass are indicated by " $\times$ ". **Find the *x*-coordinate and *y*-coordinate of the center-of-mass of the entire leg, measured from the origin (point O).** **(4 points)**

$$X_{CM} = \frac{x_{ul}m_{ul} + x_{ll}m_{ll} + x_f m_f}{m_{ul} + m_{ll} + m_f}$$
$$= \frac{9.7 \times 21.5 + 23.6 \times 9.6 + 23.6 \times 3.4}{21.5 + 9.6 + 3.4}$$
$$\rightarrow X_{CM} = 15\ cm$$

$$Y_{CM} = \frac{y_{ul}m_{ul} + y_{ll}m_{ll} + y_f m_f}{m_{ul} + m_{ll} + m_f}$$
$$= \frac{28.5 \times 21.5 + 18.2 \times 9.6 + 1.8 \times 3.4}{21.5 + 9.6 + 3.4}$$
$$\rightarrow Y_{CM} = 23\ cm$$



	$x\ (cm)$	$y\ (cm)$
m_{ul}	$23.6 - 13.9 = 9.7$	28.5
m_{ll}	23.6	$28.5 - 10.3 = 18.2$
m_f	23.6	1.8

P6. A wheel is rotating with a constant angular acceleration of $0.08\ \text{rad/s}^2$. At $t = 0$, the angular velocity of the wheel is 0.1 rad/s. For a point which is 3 m from the rotation axis of the wheel, at $t = 2$ s:

a. Find the linear velocity. **(2 points)**

b. Find the magnitude of the total linear acceleration. **(3 points)**

(a) $\omega = \omega_o + \alpha t = 0.1 + 0.08 \times 2 = 0.26\ rad/s$

$v = r\omega = 3 \times 0.26 = 0.78\ m/s$

(b) $a_R = \frac{v^2}{R} = 0.20\ m/s^2$

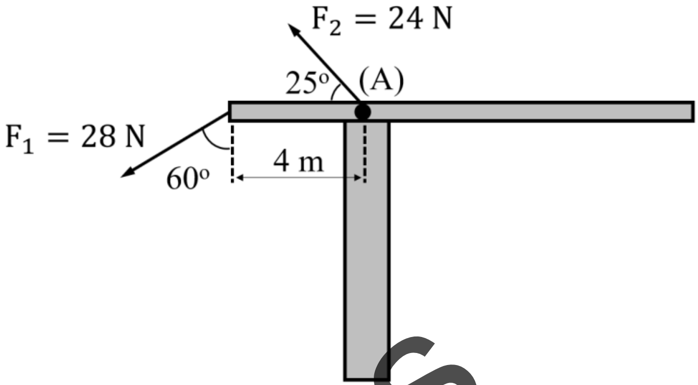
$a_{tan} = R\alpha = 0.24\ m/s^2$

$a = \sqrt{{a_R}^2 + {a_{tan}}^2} = \sqrt{0.20^2 + 0.24^2} = 0.31\ m/s^2$

P7. A uniform horizontal rod of mass $m = 2$ kg and length $l = 12$ m is pivoted at 4 m from the left end (point A) by a vertical beam. Two additional forces (F_1 and F_2) are acting on the horizontal rod as shown.

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

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



(a) $\tau_{F_1}^{(A)} = +4 \times 28 \times \cos(60^o) = 56\ N.m$

$\tau_{F_2}^{(A)} = 0\ N.m$

$\tau_{F_G}^{(A)} = -2 \times 9.8 \times (6 - 4) = -39.2\ N.m$

(b) $\tau_{net}^{(A)} = \tau_{F_1}^{(A)} + \tau_{F_2}^{(A)} + \tau_{F_G}^{(A)}$

$= 56 + 0 - 39.2 = 16.8\ N.m$