Kuwait University **Physics Department**

Physics 121

Final Exam
Spring Semester (2023-2024)

May 23, 2024
Time: 08:00 – 10:00

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

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

Instructors: Drs. Abdullah, Afrousheh, Alotaibi, Hadipour, Kokkalis, Razee, Zaman

Important:

1. Answer all questions and problems (No solution = no points).
2. Full mark = 40 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 **<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.**

For use by instructors

Grades:

#	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Pts	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**3**	**40**

GOOD LUCK

P1. A boat sails 20^o south of east for 20 km ($\vec{A}$), and 60^o north of east for 25 km ($\vec{B}$), as shown below. The whole trip takes 50 min.

a. Find the magnitude of the total displacement ($\vec{D} = \vec{A} + \vec{B}$). (3 points)

b. Find the magnitude of the average velocity. (1 point)

c. Find the average speed. (1 point)

(a)

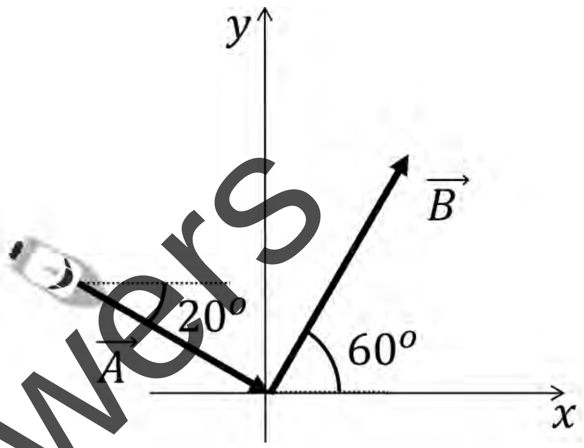
$D_x = 20\cos(20) + 25\cos(60) = 18.8 + 12.5 = 31.3\ km$

$D_y = -20\sin(20) + 25\sin(60) = -6.8 + 21.7 = 14.8\ km$

$D = \sqrt{D_x^2 + D_y^2} = 34.6\ km$

(b) $\bar{v} = \frac{D}{\Delta t} = \frac{34.6\times10^3}{50\times60} = 11.5\,\frac{m}{s}$

(c) $\bar{s} = \frac{Distance}{Time} = \frac{(20+25)\times10^3}{50\times60} = 15\,\frac{m}{s}$



P2. A $10-$kg box is on a rough horizontal surface. A pulling force $\vec{F}$ of 80 N magnitude, **uniformly accelerates** the box from 10 m/s to 15 m/s, within a distance d, as shown.

a. Find the acceleration of the box during this motion. (1 point)

b. Find the work done by the force of friction during this motion. (3 points)

(a) $v^2 = v_o^2 + 2a(x - x_o) \rightarrow a = \frac{v^2 - v_o^2}{2d} = 6.25\ m/s^2$

(b) $W_{net} = \Delta KE \rightarrow W_{fr} + Fcos(30)d = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2$

$\rightarrow W_{fr} = \left(\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2\right) - Fcos(30)d = -67.8\ J$

Or

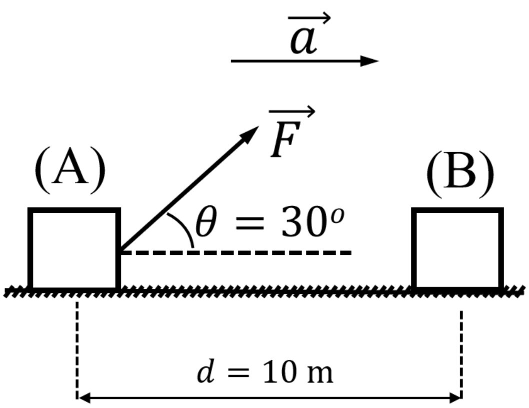
For box y-axis: $Fsin(30) + F_N - mg = 0$

$\rightarrow F_N = mg - Fsin(30) = 58\ N$

For box x-axis: $Fcos(30) - F_{fr} = ma$

$\rightarrow F_{fr} = Fcos(30) - ma = 6.78\ N$

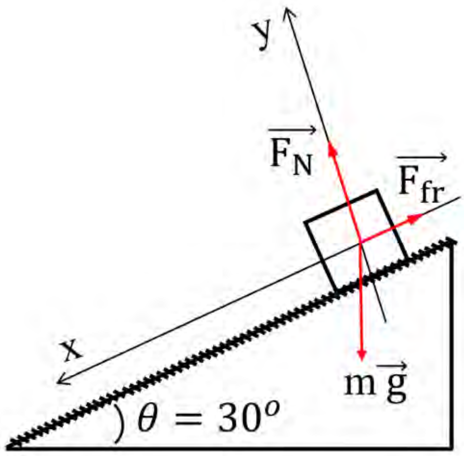
$W_{fr} = F_{fr}dcos(180) = -67.8\ J$



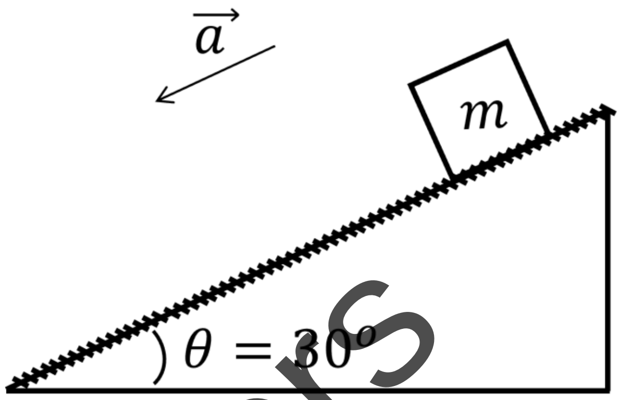
P3. A block of mass m slides down a rough inclined surface as shown. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.4$.

a. Draw the free body diagram for the mass m. **(1 point)**

b. Find the acceleration of the mass. **(3 points)**



(a)



(b)

m: y − axis: $F_N - mgcos\theta = 0 \rightarrow F_N = mgcos\theta$ (Eq. 1)

m: x − axis: $-F_{fr}^k + mgsin\theta = ma \rightarrow -\mu_k F_N + mgsin\theta = ma$ (Eq. 2)

From Eqs. (1) & (2)

$-\mu_k mgcos\theta + mgsin\theta = ma \rightarrow a = gsin\theta - \mu_k gcos\theta = 1.5\, m/s^2$

P4. A mass $m = 20$ kg is connected to a massless spring with stiffness constant $k = 380$ N/m, through a massless and frictionless pulley, as shown. The mass is released from rest when the spring is in its natural length. **When the mass has dropped by $y = 0.4$ m find:**

a. The speed of the mass. **(3 points)**

b. The acceleration of the mass. **(1 point)**

(a) $KE_i + PE_i = KE_f + PE_f \rightarrow$

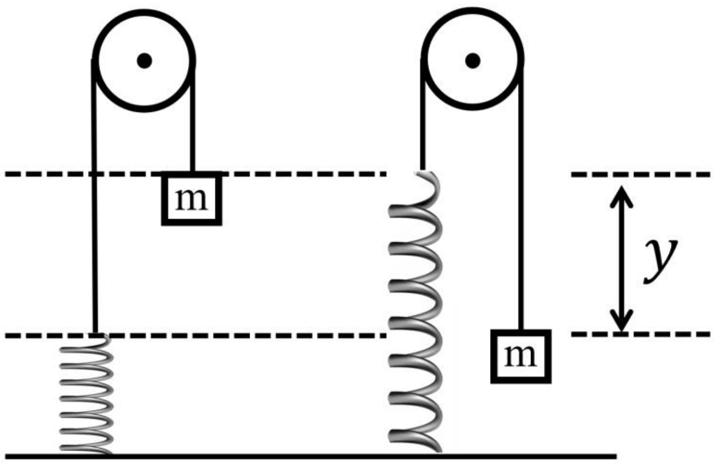
$$0 + 0 = \frac{1}{2}mv^2 + \frac{1}{2}ky^2 - mgy$$

$$\rightarrow v = \sqrt{\frac{2mgy - ky^2}{m}} = 2.2\, m/s$$

(b)

$F_s - mg = m(-a) \rightarrow$

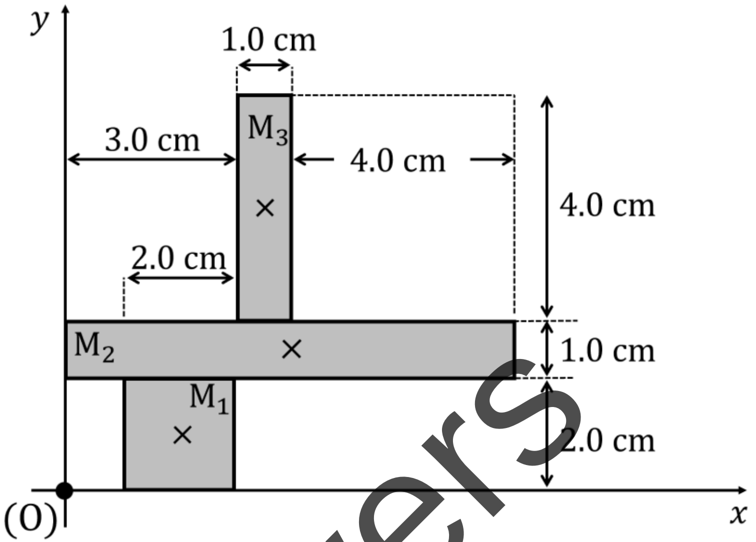
$$a = \frac{mg - ky}{m} = 2.2\, m/s^2$$



P5. A structure made up of three uniform rectangular pieces is shown below. The three pieces have mass $M_1 = 2$ kg, $M_2 = 5$ kg, and $M_3 = 4$ kg. **Find the *x*-coordinate and *y*-coordinate of the center-of-mass of the structure, measured from the origin (point O). (4 points)**

$$X_{CM} = \frac{x_1 M_1 + x_2 M_2 + x_3 M_3}{M_1 + M_2 + M_3}$$
$$= \frac{2 \times 2 + 4 \times 5 + 3.5 \times 4}{2 + 5 + 4}$$
$$\rightarrow X_{CM} = 3.45cm$$

$$Y_{CM} = \frac{y_1 M_1 + y_2 M_2 + y_3 M_3}{M_1 + M_2 + M_3}$$
$$= \frac{1 \times 2 + 2.5 \times 5 + 5 \times 4}{2 + 5 + 4}$$
$$\rightarrow Y_{CM} = 3.14\ cm$$



	$x\ (cm)$	$y\ (cm)$
M_1	$(3-2) + \left(\frac{2}{2}\right) = 2$	$\frac{2}{2} = 1$
M_2	4	$2 + \frac{1}{2} = 2.5$
M_3	$3 + \frac{1}{2} = 3.5$	$2 + 1 + \frac{4}{2} = 5$

P6. A centrifuge rotor **accelerates uniformly** about its center from rest to 1,000 rpm in 30 s.

a. Find the angular acceleration of the rotor. (2 points)

b. At $t = 30$ s, find the radial acceleration of a point 8 cm from the center. (1 point)

c. At $t = 30$ s, find the radial force on a particle of mass $m = 3 \times 10^{-16}$ kg, found at that point. (1 point)

(a) $\omega_o = 0\frac{rad}{s};\ \omega = 2\pi f = 2 \cdot 3.14 \cdot \frac{1000}{60} = 104.7\ rad/s$

$$\omega = \omega_o + \alpha t \rightarrow \alpha = \frac{\omega - \omega_o}{t} = \frac{104.7}{30} = 3.49\ rad/s^2$$

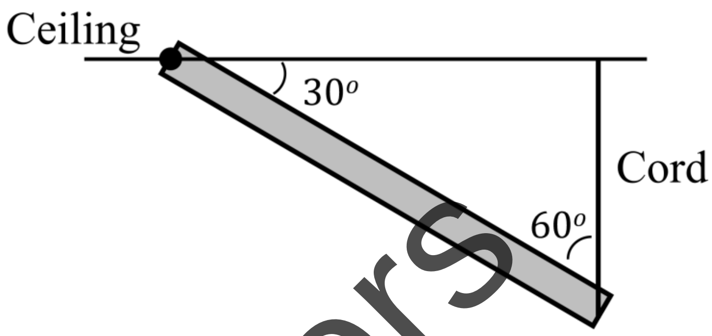
(b) $a_R = \frac{v^2}{r} = \omega^2 r = 104.7^2 \cdot 0.08 = 877\ m/s^2$

(c) $F_R = m a_R = 3 \times 10^{-16} \cdot 877 = 2.63 \times 10^{-13}\ N$

P7. A uniform beam of mass $m = 10$ kg and length $L = 1$ m is hinged on the ceiling from one end. The other end of the beam is tied by a cord as shown. **The structure is in equilibrium.**

a. Find the tension in the cord connected to the ceiling. (2 points)

b. Find the force on the hinge. (2 points)



(a)

The second condition of equilibrium about hinge

$$\tau_{net}^{H} = 0 \rightarrow$$

$$-mg\frac{L}{2}\sin(60) + F_T \sin(60)\, L = 0 \rightarrow$$

$$F_T = 0.5mg = 49\ N$$

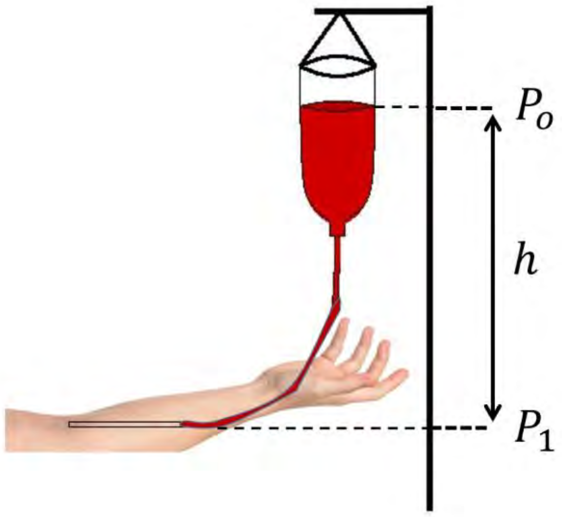
(b)

The first condition of equilibrium

$$\sum F_y = 0 \rightarrow F_T - mg + F_H = 0$$

$$\rightarrow F_H = mg - F_T = 0.5mg = 49\ N$$

P8. A patient is given blood transfusion ($\eta = 0.004$ Pa.s, $\rho = 1050\ \text{kg/m}^3$) at a rate of $3.3 \times 10^{-8}\ \text{m}^3/\text{s}$. The needle has 25 mm length, and inner radius 0.4 mm. The blood pressure of the patient is 10374 Pa. **Find at what height (h) the bottle should be placed above the needle. (4 points)**



$$Q = \frac{\pi R^4 (P_1 - P_2)}{8\eta l} \rightarrow$$

$$P_1 - P_2 = \frac{8\eta l Q}{\pi R^4} = 328.4\ Pa \rightarrow$$

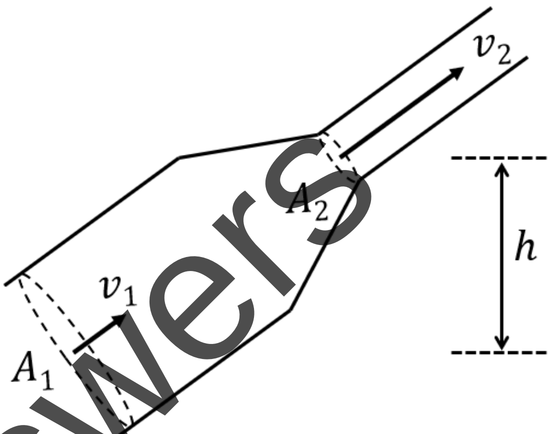
$$P_1 = 328.4\ Pa + P_2 = 10702.4\ Pa$$

$$P_1 = \rho g h \rightarrow h = \frac{P_1}{\rho g} = 1.04\ m$$

P9. Water ($\rho = 10^3 \text{kg/m}^3$) flows in a pipeline as shown. The pipe's cross-sectional area at point 1 is 0.08 m^2 and the water speed there is 5.9 m/s. Point 2 is $h = 5.2$ m above point 1, and the cross-sectional area at point 2 is 0.02 m^2.

a. Find the speed of fluid at point 2. **(2 points)**

b. Find the pressure difference ($P_1 - P_2$) between points 1 and 2. **(2 points)**



(a)

$A_1 v_1 = A_2 v_2 \rightarrow$

$$v_2 = \frac{A_1}{A_2} v_1 = \frac{0.08}{0.02}(5.9) = 23.6\ m/s$$

(b)

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 + \rho g y_2 - \frac{1}{2}\rho v_1^2 - \rho g y_1$$

$$P_1 - P_2 = 312035\ Pa$$

P10. A 0.1 kg mass is attached to a spring and set on a horizontal frictionless surface. The mass is pulled a distance of 12 cm from the equilibrium and at $t = 0$ s is released, performing **a simple harmonic oscillation** with a frequency of 0.4 Hz.

a. Find the spring constant *k*. **(1 point)**

b. Find the maximum speed of the mass. **(1 point)**

c. Find the mechanical energy of the system. **(1 point)**

(a) $T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \rightarrow k = (2\pi)^2 m f^2 = 0.63\frac{N}{m}$

(b) $\frac{1}{2}kA^2 = \frac{1}{2}mv_{max}^2 \rightarrow v_{max} = A\sqrt{\frac{k}{m}} = 0.30\ m/s$

(c) $E = \frac{1}{2}kA^2 = 4.5 \times 10^{-3} J$