Kuwait University **Physics Department**

Physics 121

Final Exam
Fall Semester (2022-2023)

December 29, 2022
Time: 08:00 – 10:00

Student's Name: …………………………………………… Serial No: ……………………

Student's Number: ………………………………………… Section No: …………………

Instructors: Drs. Ali, Alotaibi, Alsmadi, Hadipour, Kokkalis, Razee

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<u>Important Instructions to the Students</u>:

1. Answer all questions and problems.
2. Full mark = 40 points as arranged in the table below.
3. No solution = no points.
4. **Use SI units.**
5. Take g = 9.8 m/s^2.
6. Mobiles and electronic devices are <u>**strictly prohibited**</u> during the exam.
7. Programmable calculators, which can store equations, are not allowed.
8. **Cheating incidents will be processed according to the university rules.**

For use by Instructors only

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

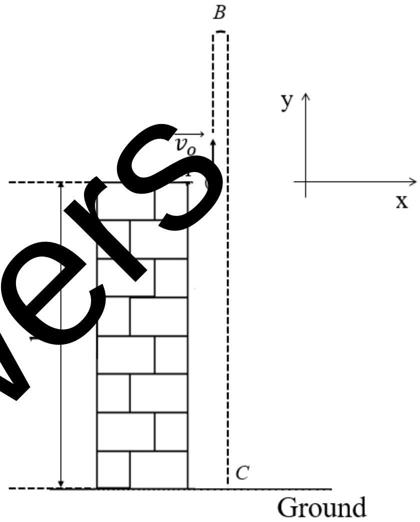
GOOD LUCK

P1. A ball is thrown vertically upwards from the top of a building (point A), with initial speed v_o. The ball reaches its maximum height (point B) in 0.5 s, and then comes to ground (point C), as shown. The average velocity for the entire motion is $-5.0\ \text{m/s}$. Ignore air resistance.

a. With what initial velocity the ball was thrown? **(1 point)**

b. Find the height (h) of the building. **(2 points)**

c. How much time did it take to reach point C? **(1 point)**



(a) $(A) \to (B): v = v_0 + at \to v_0 = v - at = 0 - (-9.8)0.5 \to v_0 = 4.9\ m/s$

(b) $\overline{v} = \frac{v_0 + v_C}{2} \to v_C = 2\overline{v} - v_0 = 2(-5) - 4.9 \to v_C = -14.9\frac{m}{s}$

$$(A) \to (C): v_C^2 = v_o^2 + 2a(y - y_0) \to y = \frac{v_C^2 - v_o^2}{2a} + y_0 = \frac{(-14.9)^2 - 4.9^2}{2(-9.8)} + 0$$

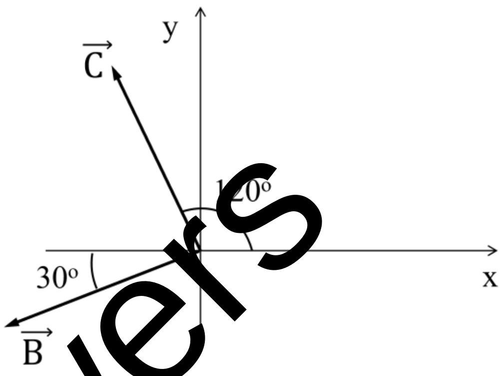
$\to y = -10.1\ m \to h = 10.1\ m$

(c) $\overline{v} = \frac{Displacement}{Time} = \frac{\Delta y}{\Delta t} \to \Delta t = \frac{y - y_o}{\overline{v}} = \frac{-10.1 - 0}{-5} = 2.0\ s$

P2. Two vectors with magnitudes $B = 20.0$ m, and $C = 20.0$ m are shown. Vector $\overrightarrow{D}$ is given by the equation $\overrightarrow{D} = \overrightarrow{B} + \overrightarrow{C}$.

a. Find the magnitude of vector $\overrightarrow{D}$. **(3 points)**

b. Find the direction of $\overrightarrow{D}$, with respect to the positive *x-axis*. **(1 point)**



$$B_x = -B\cos 30° = -20\cos 30° = -17.3\ m$$
$$B_y = -B\sin 30° = -20\sin 30° = -10.0\ m$$

$$C_x = -C\sin 30° = -20\sin 30° = -10.0\ m$$
$$C_y = C\cos 30° = 20\cos 30° = 17.3\ m$$

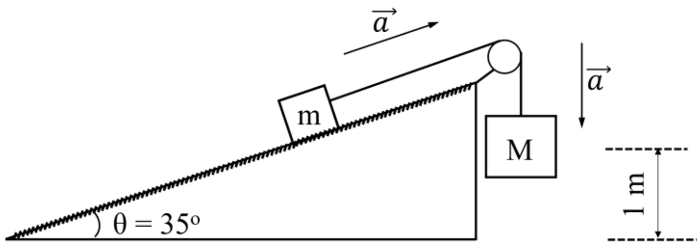
$$D_x = B_x + C_x = -17.3 - 10 = -27.3\ m$$
$$D_y = B_y + C_y = -10 + 17.3 = 7.30\ m$$

$$D = \sqrt{D_x^2 + D_y^2} = 28.3\ m$$
$\theta' = \tan^{-1}\left|\frac{D_y}{D_x}\right| = 15° \rightarrow \theta = 180^o - 15° = 165°$ with the positive *x*-axis.

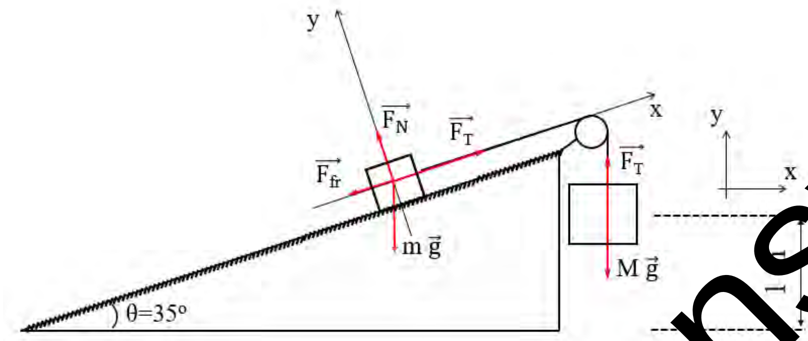
P3. Two blocks $m = 25$ kg and $M = 35$ kg, are connected by a massless cord over a frictionless and massless pulley, as shown below. The coefficient of kinetic friction between the inclined surface and block m is $\mu_k = 0.20$.

a. Find the acceleration of block m as it slides up the inclined plane. **(3 points)**

b. Block M starts from rest from 1 m above ground, as shown. Find the time taken by block M to hit the floor. **(1 point)**



Taking the *xy-coordinate* system shown below:



a.

Block m:

y-axis: $F_N - mg\cos\theta = 0 \rightarrow F_N = mg\cos\theta$

x-axis: $-mg\sin\theta - F_{fr} + F_T = -mg\sin\theta - \mu_k\, F_N + F_T = m\,a$ Eq. (1)

Block M:

y-axis: $F_T - Mg = M(-a)$ Eq. (2)

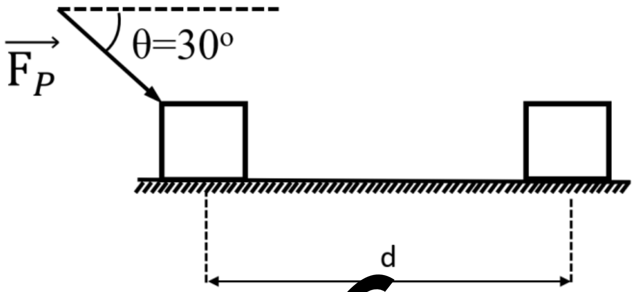
From Eqs. (1) and (2): $-mg\sin\theta - \mu_k\, F_N - Ma + Mg = m\,a$

$$a = \frac{-mg\sin\theta - \mu_k\, mg\cos\theta + Mg}{M + m} \rightarrow a = 2.7\frac{m}{s^2}$$

b. $y = y_o + v_o t + \frac{1}{2}at^2 \rightarrow -1 = 0 + 0 + \frac{1}{2}(-2.7)t^2 \rightarrow t = 0.7\ s$

P4. A block of mass $M = 6.0$ kg is being pushed by a force F_P on a rough horizontal surface (see figure). The box starts from rest and achieves a speed of 3.0 m/s after moving a distance of $d = 5.0$ m to the east. If the average force of friction is 8.0 N, find the work done by the force F_P. **(3 points)**

$$W_{net} = \Delta KE \rightarrow W_{F_P} + W_{F_{fr}} = \frac{1}{2}Mv^2 - 0$$
$$\rightarrow W_{F_P} = \frac{1}{2}Mv^2 - W_{F_{fr}} = \frac{1}{2}Mv^2 + F_{fr}d$$
$$\rightarrow W_{F_P} = 67\ J$$



P5. A 0.15 kg ball at the end of a 0.75 m long cord is revolving in a vertical circle 2.0 m above ground, as shown. The tension in the cord can withstand up to four times the weight of the ball.

a. Find the *maximum* speed of the ball at the bottom of the loop such that the rope does not break. **(2 points)**

b. The cord finally brakes when the ball is at the bottom. Find the work done by the force of gravity on the ball when it reaches the ground. **(2 points)**

Bottom:

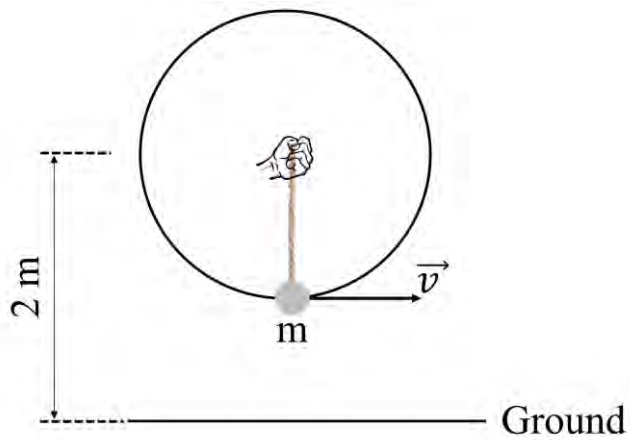
$F_T - mg = m\frac{v^2}{R}$ Eq. (1)

For $F_T = 4mg$

$v = v_{max}$ and Eq. (1)

$$\rightarrow 4mg - mg = m\frac{v_{max}^2}{R}$$

$$\rightarrow v_{max} = \sqrt{3gR} = 4.7\ m/s$$

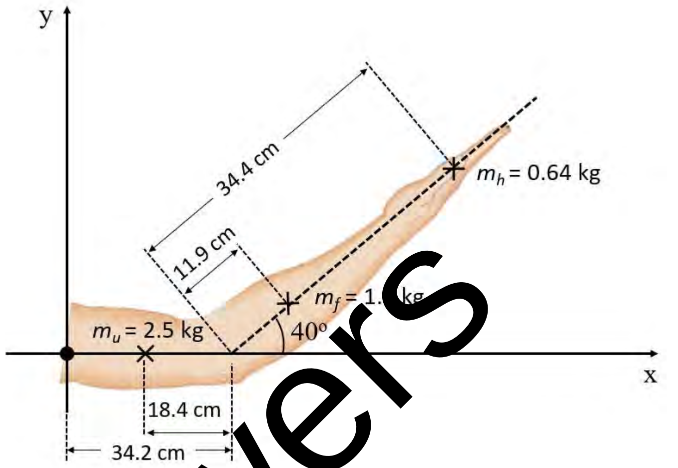


$$W_{F_G} = -\Delta PE = PE_i - PE_f$$
$$\rightarrow W_{F_G} = mg(2 - 0.75) - 0 = 1.8\ J$$

P6. The figure shows the arm of an athlete bent at 40^o. Each part of the arm has mass m_u, m_f, m_h. 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.

(4 points)

	x (cm)	y (cm)
m_u	$34.2 - 18.4 = 15.8$	0
m_f	$34.2 + 11.9 \times \cos(40) = 43.3$	$11.9 \times \sin(40) = 7.65$
m_h	$34.2 + 34.4 \times \cos(40) = 60.6$	$34.4 \times \sin(40) = 22.1$



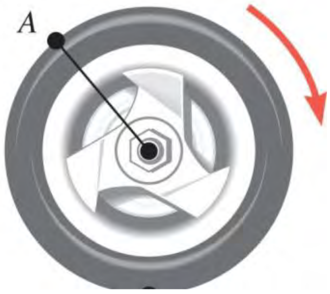
$$X_{CM} = \frac{x_u m_u + x_f m_f + x_h m_h}{m_u + m_f + m_h} = \frac{15.8 \times 2.5 + 43.3 \times 1.6 + 60.6 \times 0.64}{2.5 + 1.6 + 0.64} \rightarrow X_{CM} = 31.1\ cm$$

$$Y_{CM} = \frac{y_u m_u + y_f m_f + y_h m_h}{m_u + m_f + m_h} = \frac{0 \times 2.5 + 7.65 \times 1.6 + 22.1 \times 0.64}{2.5 + 1.6 + 0.64} \rightarrow Y_{CM} = 5.57\ cm$$

P7. A wheel starts from rest and rotates with constant angular acceleration about a fixed axis, passing through its center. It completes the first revolution in 0.20 s.

a. Find the angular acceleration of the wheel. **(2 points)**

b. Find the number of revolutions the wheel makes within the first 15 s. **(2 points)**



$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \rightarrow 2\pi = 0 + \frac{1}{2}\alpha 0.2^2$$

$$\rightarrow \alpha = 314.2\ rad/s^2$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \rightarrow \Delta\theta = 0 + \frac{1}{2}(314.2)15^2$$

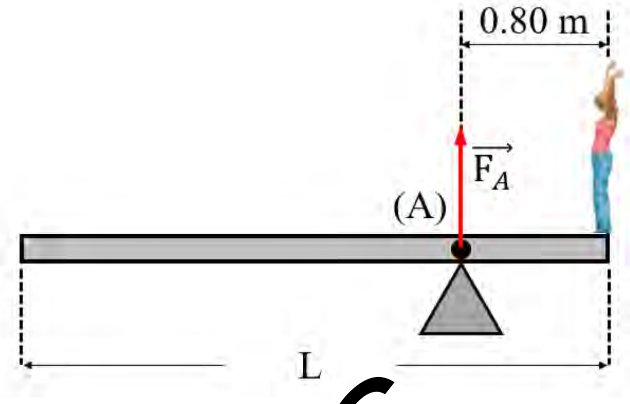
$$\rightarrow \Delta\theta = 35347.5\ rad$$

$$N = \frac{\Delta\theta}{2\pi} = 5626\ revolutions$$

P8. A girl weighting 441 N stands on the very end of a uniform board of length $L = 4.0$ m and mass M. The board is supported at point A, as shown. The entire system is in static equilibrium.

a. Find the mass of the board (M), in kg. **(2 points)**

b. Find the magnitude of the supporting force F_A. **(2 points)**



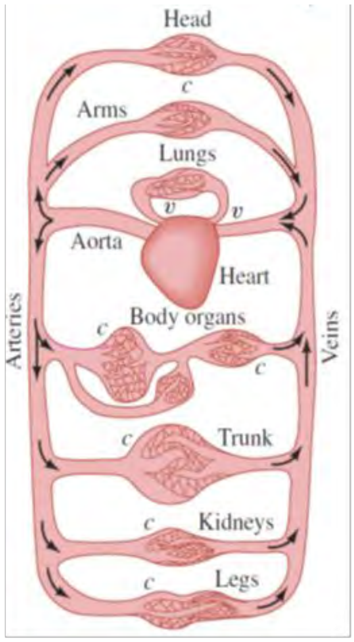
Net torque around point (A): $\sum \vec{\tau} = -0.80 \times 441 + \left(\frac{L}{2} - 0.80\right) \times Mg = 0 \rightarrow M = 30\ kg$

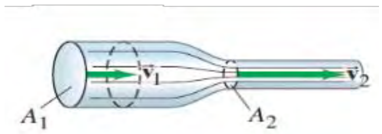
$$\sum \vec{F} = F_A - 441 - Mg = 0 \rightarrow F_A = 735\ N$$

P9. Blood flows from the human heart into the aorta and then passes into the major artery, as shown. The cross-sectional area of the aorta is $A_1 = 4.5 \times 10^{-4}$ m^2 and the speed of the blood passing through it is $v_1 = 0.4$ m/s. The cross-sectional area of the artery is $A_2 = 2.0 \times 10^{-4}$ m^2. The blood density is $\rho = 1.05 \times 10^3$ kg/m^3.

a. Calculate the speed of the blood flow in the artery (v_2). **(2 points)**

b. Calculate the pressure difference between the aorta and artery measured at the same level. **(2 points)**





$$A_1 v_1 = A_2 v_2 \rightarrow 4.5 \times 10^{-4} \times 0.4 = 2.0 \times 10^{-4} \times v_2$$
$$\rightarrow v_2 = 0.9 \frac{m}{s}$$

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2 \rightarrow P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$
$$\rightarrow P_1 - P_2 = \frac{1}{2}(1.05 \times 10^3)(0.9^2 - 0.4^2)$$
$$\rightarrow P_1 - P_2 = 341.25\ N/m^2$$

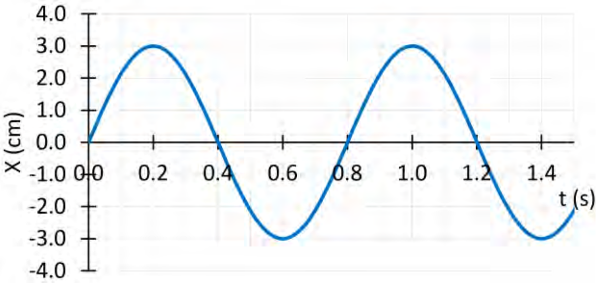
P10. A 1.4 kg ball is attached to a spring and undergoes simple harmonic oscillation. The graph below shows the ball's position x (in cm) as a function of time t (in s). Find:

a. the period of the oscillation. **(1 point)**

b. the spring stiffness constant k. **(1 point)**

c. the total energy of the oscillation. **(1 point)**

d. the ball's speed at $t = 0.4$ s. **(2 points)**



$T = 0.8\ s$

$$T = 2\pi\sqrt{\frac{m}{k}} \rightarrow k = m\left(\frac{2\pi}{T}\right)^2 = 86.3\ N/m$$

$$E = \frac{1}{2}kA^2 = \frac{1}{2} \times 86.3 \times (0.03)^2 = 0.04 J$$

At $t = 0.4\ s$ the mass is at the equilibrium point ($x = 0\ cm$) (see the graph). At that position KE is max. and $PE = 0\ J$. Applying conservation of mechanical energy between the two positions of the oscillation:

$$E = \frac{1}{2}kA^2 = 0.04\ J = \frac{1}{2}mv_0^2 \rightarrow v_0 = v_{max} = 0.24\ m/s$$