Kuwait University Physics Department

جامعة الكويت
KUWAIT UNIVERSITY

Physics 121

Final Exam
Spring Semester (2022-2023)

May 14, 2023
Time: 17:00 – 19:00

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

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

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

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Important Instructions to the Students:

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 **strictly prohibited** 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

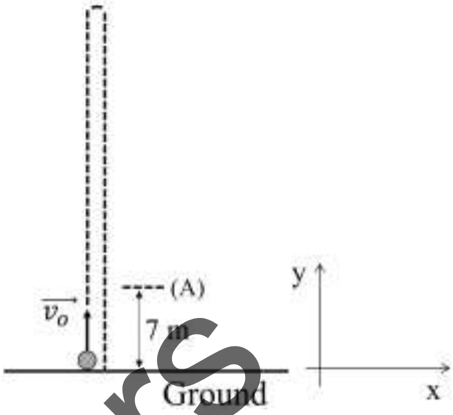
#	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Pts	4	4	4	4	4	4	4	4	4	4	40

GOOD LUCK

P1. A stone is thrown from the ground vertically upward, with initial speed $v_o = 20$ m/s. Ignore air resistance.

a. How much time did the stone take to reach the ground again? **(2 points)**

b. Find the speed of the stone at a height of 7 m above the ground (point A)? **(2 points)**



(a) $y = y_0 + v_0 t + \frac{1}{2}at^2 \rightarrow 0 = 0 + 20t + \frac{1}{2}(-9.8)t^2$

$\rightarrow t = 0\ s$ or $t = 4.08\ s \rightarrow\ t = 4.08\ s$

(b) $v_A^2 = v_o^2 + 2a(y_A - y_0) \rightarrow v_A^2 = (20)^2 + 2(-9.8)(7 - 0)$

$\rightarrow v_A = 16.2\ m/s$

Or

$$\frac{1}{2}mv_o^2 + mgh_1 = \frac{1}{2}mv_A^2 + mgh_2 \rightarrow \frac{1}{2}(20)^2 + 0 = \frac{1}{2}v_A^2 + 9.8 \times 7$$

$\rightarrow v_A = 16.2\ m/s$

P2. Two vectors with magnitudes $A = 10$ m, and $B = 15$ m are shown. Vector $\vec{C}$ is given by the equation $\vec{C} = 3\vec{A} - \vec{B}$.

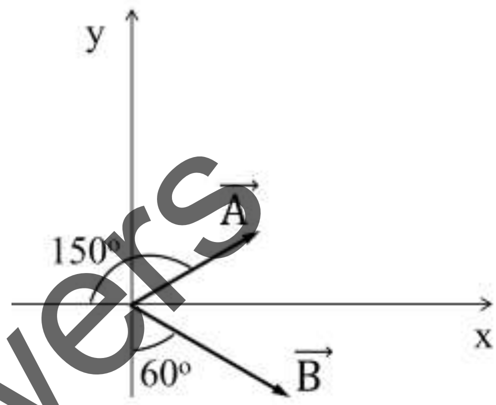
a. Find the magnitude of vector $\vec{C}$. **(3 points)**

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

(a)

$C_x = 3A_x - B_x = 3(A\cos 30°) - (B\sin 60°) = 13\ m$

$C_y = 3A_y - B_y = 3(A\sin 30°) - (-B\cos 60°) = 22.5\ m$



$C = \sqrt{C_x^2 + C_y^2} = 26\ m$

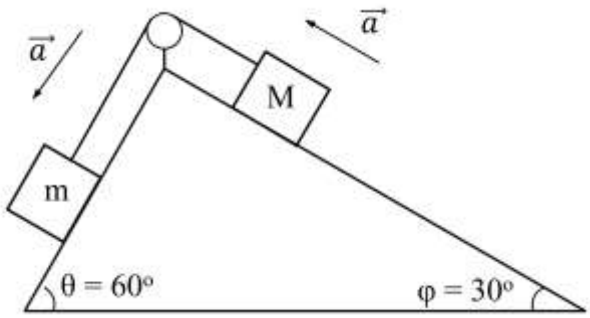
(b)

$\theta = \tan^{-1}\left|\frac{C_y}{C_x}\right| = 60°$

P3. Two blocks $m = 10$ kg and M are connected by a massless cord over a frictionless and massless pulley. Block m is moving down the incline with uniform acceleration of magnitude $a = 2\ \text{m/s}^2$, as shown in the figure. Ignore friction.

a. Find the force of tension in the cord. **(2 points)**

b. Find the mass of block M. **(2 points)**



a.

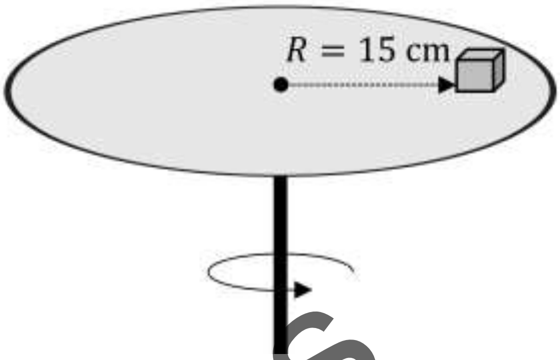
Block m:

x-axis: $mg\sin\theta - F_T = ma \rightarrow F_T = mg\sin\theta - ma = 64.9\ N$

Block M:

x-axis: $F_T - Mg\sin\varphi = Ma \rightarrow M = \frac{F_T}{g\sin\varphi + a} = 9.4\ kg$

P4. A box with mass m is placed on a horizontal round table 15 cm from the center. The table rotates with constant frequency of 45 rpm and the box just remains at its position. If the rotation frequency is slightly increased the box slides off outward. Find the coefficient of static friction (μ_s) between the box and the table. **(4 points)**



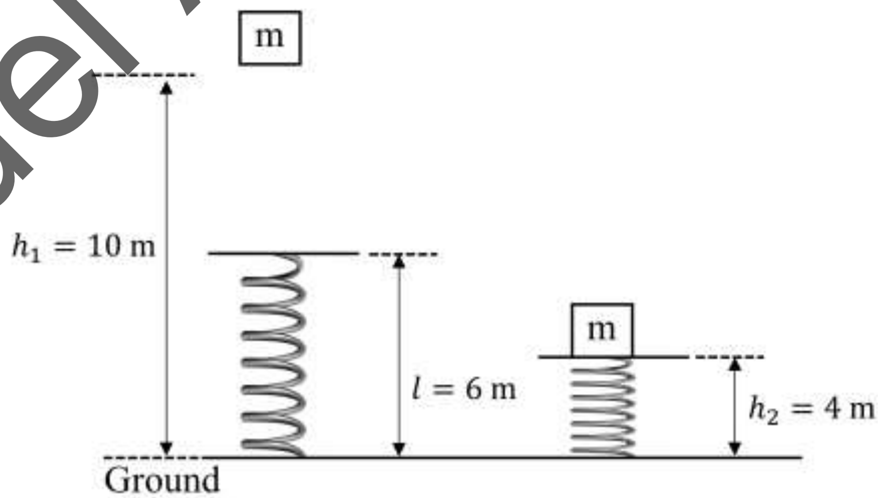
$$f = \frac{45}{60} = 0.75\ Hz \rightarrow T = \frac{1}{f} = 1.33\ s$$

$$v = \frac{2\pi R}{T} = \frac{2 \times 3.14 \times 0.15}{1.33} = 0.71\ m/s$$

$$F_c = F_{fr} \rightarrow \frac{mv^2}{R} = \mu_s mg$$

$$\rightarrow \mu_s = \frac{v^2}{Rg} = \frac{0.71^2}{0.15 \times 9.8} = 0.34$$

P5. A spring with stiffness constant $k = 109$ N/m and natural length $l = 6$ m is fixed vertically on the ground. A box with mass $m = 5$ kg is released from rest from a height $h_1 = 10$ m as shown below. Find the speed of the box when it is $h_2 = 4$ m above ground. Ignore air resistance. **(4 points)**



$$E_1 = E_2 \rightarrow \frac{1}{2}mv_1^2 + mgh_1 = \frac{1}{2}mv_2^2 + mgh_2 + \frac{1}{2}kx_2^2$$

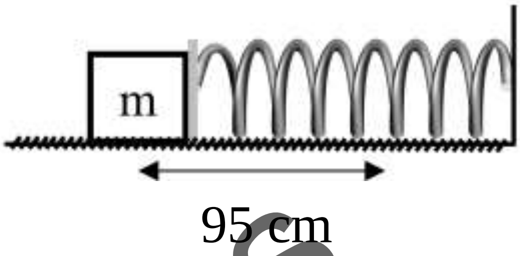
$$\rightarrow 0 + 5 \times 9.8 \times 10 = \frac{1}{2} \times 5 \times v_2^2 + 5 \times 9.8 \times 4 + \frac{1}{2} \times 109 \times (6-4)^2$$

$$\rightarrow v_2 = 5.5\ m/s$$

P6. A $10-$kg box is moving on a rough horizontal surface and collides with a spring with initial speed 5 m/s. The box comes to rest after the spring is compressed by $x = 95$ cm. The spring stiffness constant is $k = 100$ N/m.

a. Calculate the work done by the force of friction. **(2 points)**

b. Find the coefficient of kinetic friction (μ_k). **(2 points)**



$$W_{NC} = \Delta KE + \Delta PE \rightarrow W_{F_{fr}} = \frac{1}{2}kx^2 - \frac{1}{2}mv^2$$

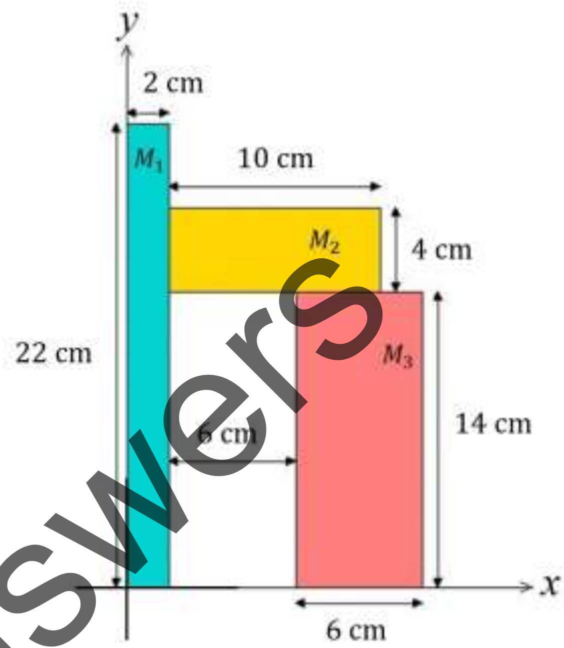
$$\rightarrow W_{F_{fr}} = \frac{1}{2} \times 100 \times 0.95^2 - \frac{1}{2} \times 10 \times 5^2 = -79.9\,J$$

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

$$\rightarrow \mu_k = \frac{-W_{F_{fr}}}{mgx} = 0.86$$

P7. The h-shaped structure is made up of three uniform rectangular pieces as shown in the figure. The three pieces have mass $M_1 = 2.0$ kg, $M_2 = 1.5$ kg, and $M_3 = 3.0$ kg. The *x-axis* and *y-axis* are drawn for you. Find the coordinates of the center-of-mass of the h-shaped structure. **(4 points)**

	x (cm)	y (cm)
M_1	$\frac{2}{2} = 1$	$\frac{22}{2} = 11$
M_2	$2 + \frac{10}{2} = 7$	$14 + \frac{4}{2} = 16$
M_3	$2 + 6 + \frac{6}{2} = 11$	$\frac{14}{2} = 7$



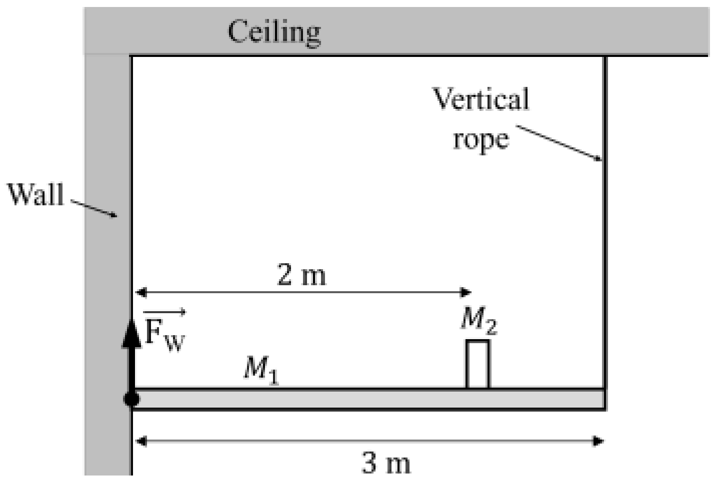
$$X_{CM} = \frac{x_1 M_1 + x_2 M_2 + x_3 M_3}{M_1 + M_2 + M_3} = 7.0\ cm$$

$$Y_{CM} = \frac{y_1 M_1 + y_2 M_2 + y_3 M_3}{M_1 + M_2 + M_3} = 10.3\ cm$$

P8. A $3 - \mathrm{m}$ long uniform beam of mass $M_1 = 30$ kg is fixed at the wall, and it is kept horizontal by a vertical massless rope attached to the ceiling from the edge of the beam. A box of mass $M_2 = 80$ kg is placed on the beam, as shown in the figure.

a. Find the force of tension in the vertical rope. **(2 points)**

b. Find the magnitude of the force on the beam due to the wall (F_W). **(2 points)**



The second condition of equilibrium ($\tau_{net} = 0$) about the hinge on the wall:

$$-M_1 g \times 1.5 - M_2 g \times 2 + F_T \times 3 = 0 \rightarrow F_T = \frac{M_1 g \times 1.5 + M_2 g \times 2}{3} = 670\ N$$

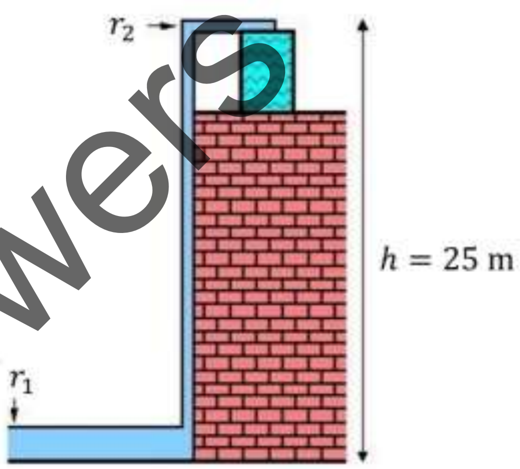
The first condition of equilibrium ($F_{net} = 0$):

$$F_W + F_T - M_1 g - M_2 g = 0 \rightarrow F_W = M_1 g + M_2 g - F_T = 408\ N$$

P9. A water supply pipe has a radius $r_1 = 3$ cm at the ground level and it narrows down to r_2 at the top of the 25-m high building. The volume flow rate of water in the pipe is $Q = 8 \times 10^{-3}\ \text{m}^3/\text{s}$. At the top, assume that the pressure is equal to the atmospheric pressure ($P_2 = 1$ atm), and the water speed is $v_2 = 25.5\ \text{m/s}$. The density of water is $10^3\ \text{kg/m}^3$.

a. Calculate the water speed at the ground level end of the pipe (v_1). **(2 points)**

b. Find the pressure at the ground level. **(2 points)**



(a) Equation of continuity

$$Q = A_1 v_1 = A_2 v_2 \rightarrow Q = \pi r_1^2 v_1 \rightarrow v_1 = \frac{Q}{\pi r_1^2}$$

$$\rightarrow v_1 = \frac{8 \times 10^{-3}}{\pi (3 \times 10^{-2})^2} = 2.83\ m/s$$

(b) Bernoulli's equation

$$P_1 + \frac{1}{2}\rho v_1^2 = P_o + \frac{1}{2}\rho v_2^2 + \rho g h$$

$$\rightarrow P_1 = P_o + \frac{1}{2}\rho v_2^2 + \rho g h - \frac{1}{2}\rho v_1^2$$

$$\rightarrow P_1 = 6.66 \times 10^5 Pa$$

P10. A 0.15-kg ball is attached to a horizontal spring on a frictionless table and oscillates according to the equation: $x = 0.2\cos(22\,t)$, where x is in meters and t in seconds.

a. Find the spring stiffness constant k. **(2 points)**

b. Find the ball's speed when it is 0.1 m from the equilibrium position. **(2 points)**

$2\pi f = 22\,rad/s$ and $A = 0.2\,m$

$$\frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \rightarrow k = m(2\pi f)^2 = 72.6\,N/m$$

$$E = \frac{1}{2}kA^2 = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

$$\rightarrow \frac{1}{2} \times 72.6 \times 0.2^2 = \frac{1}{2} \times 72.6 \times 0.1^2 + \frac{1}{2} \times 0.15 \times v^2 \rightarrow v = 3.8\,m/s$$