Kuwait University **Physics Department**

جامعة الكويت
KUWAIT UNIVERSITY

Physics 121

Final Exam
Summer Semester (2022-2023)

July 24, 2023
Time: 11:00 – 13:00

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 = 38 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	**3**	**4**	**5**	**4**	**4**	**4**	**4**	**3**	**4**	**3**	**38**

GOOD LUCK

P1. A rock is thrown vertically upward from the roof of a 36.0 m tall building (point *A*), with an initial speed $v_o = 12.0\ \text{m/s}$. The rock reaches its maximum height (point B) and finally lands on the ground (point C). **Ignore air resistance**.

a. Find the speed of the rock just before it hits the ground (point C). (2 points)

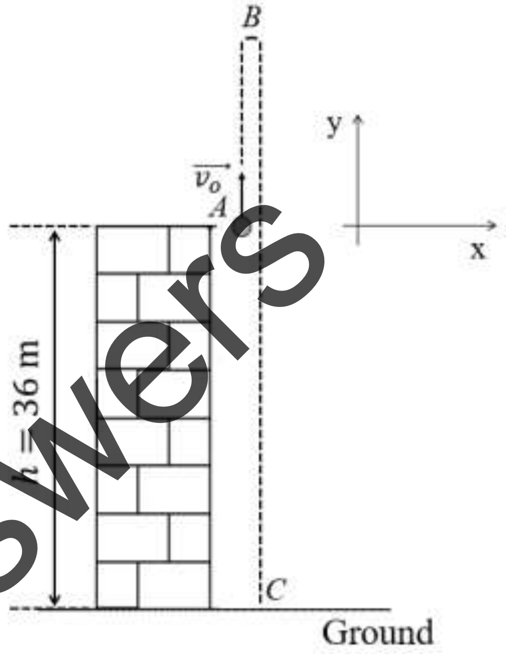
b. Find the time it took the rock to move from point B to point C. (1 point)

From $A \to C$

$$v^2 = v_o^2 + 2a(y - y_o)$$
$$= 12^2 + 2(-9.8)(-36)$$
$$\to v = 29.1\ m/s$$

From $B \to C$

$$v = v_o + at \to t = \frac{v - v_o}{a} = \frac{-29.1 + 0}{-9.8}$$
$$\to t = 3.0\ s$$



P2. Three vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ have the components shown in the table below. If vector $\vec{D} = \vec{A} + \vec{B} + \vec{C}$:

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

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

	x component	y component
A	-3	4
B	4	-2
C	5	1

(a)

$D_x = A_x + B_x + C_x = 6$

$D_y = A_y + B_y + C_y = 3$

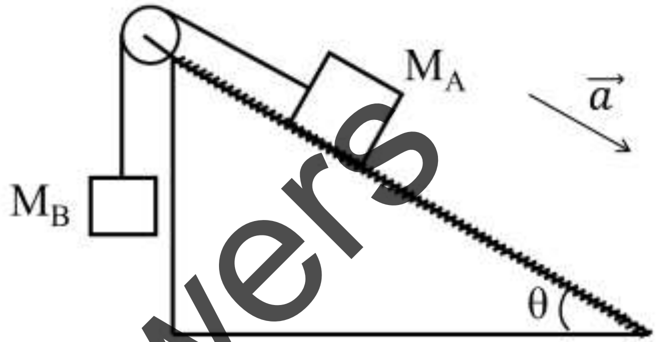
$$D = \sqrt{D_x^2 + D_y^2} = 6.7$$

(b) $\theta = \tan^{-1}\left(\frac{D_y}{D_x}\right) = 26.6^o$

P3. The box A ($M_A = 6$ kg) on an incline ($\theta = 30^o$) is connected to the box B by a massless rope over a massless and frictionless pulley as shown. When released the box A moves down the incline with acceleration $a = 0.5\ \text{m}/s^2$. **The coefficient of kinetic friction** between the box A and the surface is $\mu_k = 0.15$.

a. Find the tension on the rope. (3 points)

b. Find the mass of box B. (2 points)



(a)

For box A y-axis: $F_N = M_A g cos\theta$

For box A x-axis:

$$-F_T - \mu_k M_A g cos\theta + M_A g sin\theta = M_A a$$

$$\rightarrow F_T = -M_A a - \mu_k M_A g cos\theta + M_A g sin\theta = 18.8\ N$$

(b)

For box B y-axis: $F_T - M_B g = M_B a$

$$M_B = \frac{F_T}{g + a} = 1.8\ kg$$

P4. The figure shows a roller coaster car with mass $m = 100$ kg, leaving point A **from rest** and arriving at point B with 10 m/s. Point B is at the top of a semi-circular loop of radius $R = 20$ m.

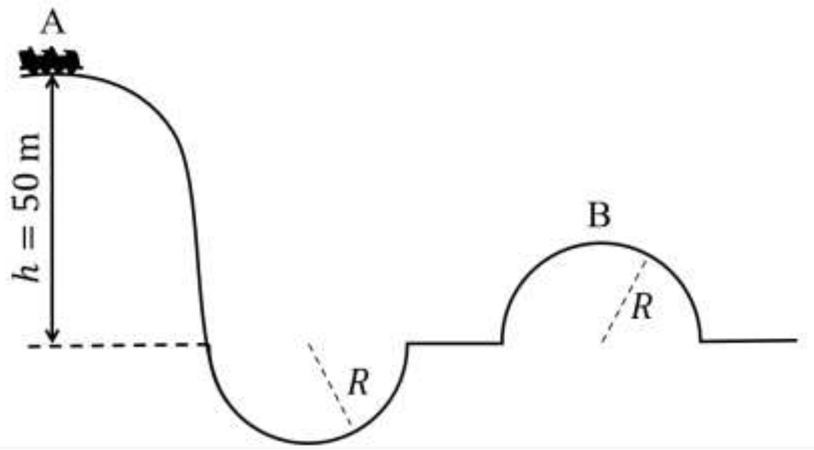
a. Find the work done by the force of friction during the motion from A to B. (2 points)

b. Find the apparent weight of the roller coaster at point B. (2 points)

(a) $W_{NC} = \Delta KE + \Delta PE =$

$(\frac{1}{2} m v_B^2 - 0) + (mgR - mgh)$

$\rightarrow W_{NC} = -24400\ J$



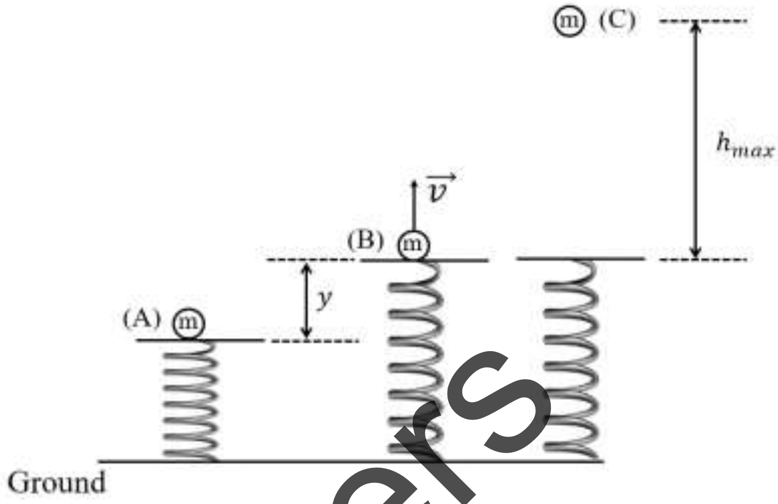
(b) $\sum F_R = m\frac{v_B^2}{R}$

$$\rightarrow F_N = mg - m\frac{v_B^2}{R} = 480\ N$$

P5. A vertical spring with stiffness constant 875 N/m is attached to ground as shown. At the free and of the spring a 0.38 kg ball is placed. The spring is compressed down by $y = 0.16$ m and **released from rest**. **Ignore any resistance force.**

a. **Find the speed of the ball (v) when it is just released from the spring at the equilibrium position. (2 points)**

b. **Find the maximum height (h_{max}) the ball can reach above the equilibrium position. (2 points)**



(a) $E_A = E_B$

$$\frac{1}{2}mv_A^2 + mg(-y) + \frac{1}{2}ky^2 = \frac{1}{2}mv_B^2 \rightarrow v_B = \sqrt{\frac{ky^2 + 2mg(-y)}{m}} = 7.47\ m/s$$

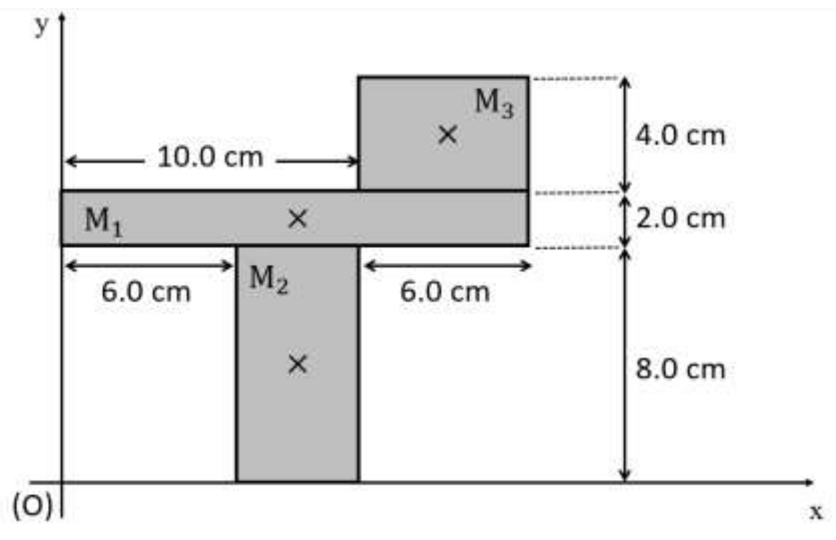
(b) $E_A = E_C$

$$\frac{1}{2}mv_A^2 + mg(-y) + \frac{1}{2}ky^2 = 0 + mgh_{max} \rightarrow h_{max} = 2.85\ m$$

P6. The structure shown below is made up of three uniform rectangular pieces. The three pieces have mass $M_1 = 2.0$ kg, $M_2 = 1.5$ kg, and $M_3 = 3.0$ kg. **Find the *x*-coordinate and *y*-coordinate of the center-of-mass of the entire structure, measured from the origin (point O). (4 points)**

$$X_{CM} = \frac{x_1M_1 + x_2M_2 + x_3M_3}{M_1 + M_2 + M_3}$$
$$= \frac{8 \times 2 + 8 \times 1.5 + 13 \times 3}{2 + 1.5 + 3}$$
$$\rightarrow X_{CM} = 10.3\ cm$$

$$Y_{CM} = \frac{y_1M_1 + y_2M_2 + y_3M_3}{M_1 + M_2 + M_3}$$
$$= \frac{9 \times 2 + 4 \times 1.5 + 12 \times 3}{2 + 1.5 + 3}$$
$$\rightarrow Y_{CM} = 9.2\ cm$$



	$x\ (cm)$	$y\ (cm)$
M_1	$\frac{10+6}{2}=8$	$8+\frac{2}{2}=9$
M_2	$6+\frac{10-6}{2}=8$	$\frac{8}{2}=4$
M_3	$10+\frac{6}{2}=13$	$8+2+\frac{4}{2}=12$

P7. A point P on the rim of a rotating wheel of radius $R = 48$ cm slows down uniformly from linear speed $v_o = 8$ m/s, and the wheel makes 40 revolutions **until stopping**.

a. Find the distance covered by the wheel before stopping. **(1 point)**

b. Find the angular acceleration of the wheel. **(3 points)**

(a) $N = \frac{d}{2\pi R} \rightarrow d = 120\, m$

(b) $v_o = r\omega_o \rightarrow \omega_o = \frac{v_o}{r} = \frac{8}{0.48} = 16.7\frac{rad}{s}$

$$N = \frac{\Delta\theta}{2\pi} \rightarrow \Delta\theta = 251.2\, rad$$

$$\omega^2 = \omega_o^2 + 2\alpha\Delta\theta \rightarrow \alpha = \frac{\omega^2 - \omega_o^2}{2\Delta\theta} = -0.56\, rad/s^2$$

P8. A 2.0 m long beam of mass M = 80.0 kg is held horizontal by a hinge at a vertical pole and a massless cable attaching to it as shown. The structure is in static equilibrium.

a. Find the tension in the cable. **(2 points)**

b. Find the horizontal component of the force exerted by the hinge on the beam. **(1 point)**

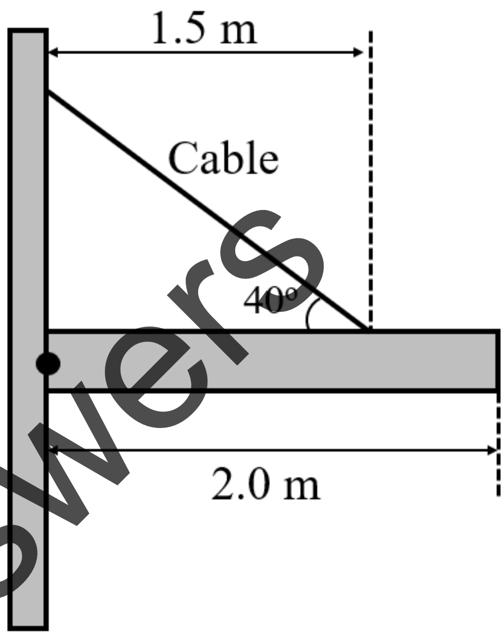
The second condition of equilibrium ($\tau_{net} = 0$) about hinge:

$$-Mg \times \left(\frac{2}{2}\right) + F_T \times 1.5 \times \sin 40^o = 0$$

$$\rightarrow F_T = \frac{Mg(1)}{1.5sin\,(40^0)} = 813\ N$$

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

$$F_{Hx} - F_T cos40^0 = 0 \rightarrow F_{Hx} = 623\ N$$



P9. A uniform board of length $L = 4.6$ m and mass $m = 52$ kg, is supported at two points A and B, as shown in the figure. A diver of mass $M = 68$ kg stands at the end of the board. The entire structure is in balance.

a. Find the magnitude of the force F_A acting on the board from the support. **(2 points)**

b. Find the magnitude of the force F_B acting on the board from the support. **(2 points)**

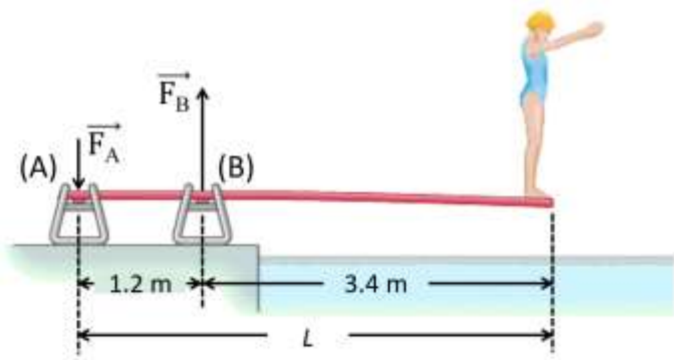
The second condition of equilibrium about point B

$$\tau_{net}^B = 0 \rightarrow F_A \times 1.2 - 52 \times 9.8 \times (2.3 - 1.2) - 68 \times 9.8 \times 3.4 = 0 \rightarrow F_A = 2355\ N$$

$$\tau_{net}^A = 0 \rightarrow F_B \times 1.2 - 52 \times 9.8 \times 2.3 - 68 \times 9.8 \times 4.6 = 0 \rightarrow F_B = 3531\ N$$

Or from the first condition of equilibrium ($F_{Net} = 0$)

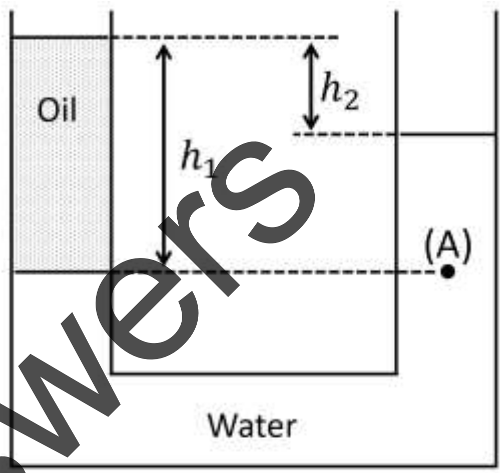
$$F_B = F_A + mg + Mg = 3531\ N$$



P10. Water and oil are poured into a U-shaped tube open at both ends. They come to equilibrium as shown, where $h_1 = 10$ cm and $h_2 = 4$ cm. Take the density of water to be $\rho_w = 10^3$ kg/m^3 and the density of oil ρ_o.

a. Find the gauge pressure at point A inside the water. (2 points)

b. Find the density of oil ρ_o. (1 point)



$$P = \rho_W g h = \rho_W g(h_1 - h_2) = 588\ Pa$$
$$P = \rho_o g h_1 \rightarrow \rho_o = 600\ kg/m^3$$