Kuwait University **Physics Department**

Physics 121

Final Exam
Spring Semester (2024-2025)

May 22, 2025
Time: 08:00 – 10:00

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

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

Instructors: Drs. Abdulmohsen, Alfailakawi, Alotaibi, Burahmah, Hadipour, Kokkalis, Razee

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 **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	P8	P9	P10	Total
Pts	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**3**	**4**	**40**

GOOD LUCK

P1. A student walks 30^o south of east for 5 km ($\vec{A}$), and then straight north for 10 km ($\vec{B}$), as shown below. The entire motion takes 90 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)

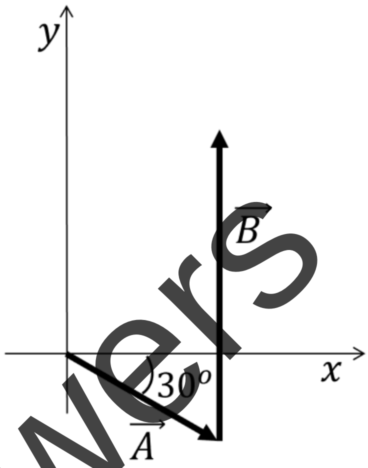
$D_x = 5\cos(30) + 0 = 4.3\ km$

$D_y = -5\sin(30) + 10 = 7.5\ km$

$D = \sqrt{D_x^2 + D_y^2} = 8.7\ km$

(b) $\bar{v} = \frac{D}{\Delta t} = \frac{8.7}{1.5} = 5.8\frac{km}{h}$

(c) $\bar{s} = \frac{Distance}{Time} = \frac{(5+10)}{1.5} = 10\frac{km}{h}$



P2. A model rocket starting form rest is uniformly accelerated vertically upwards with $2\ m/s^2$. At point A the rocket runs out of fuel but continues moving upward for a while until it reach a maximum height (point B). It then falls back to earth. **Ignore air resistance.**

a. Find the speed of the rocket the moment it run out of fuel (point A). **(1 point)**

b. Find the maximum altitude (from ground) the rocket had reached. **(1 point)**

b. Find the time it took for the rocket to fall from (B) to ground. **(2 points)**

Taking the origin to be at the ground and positive y direction upwards.

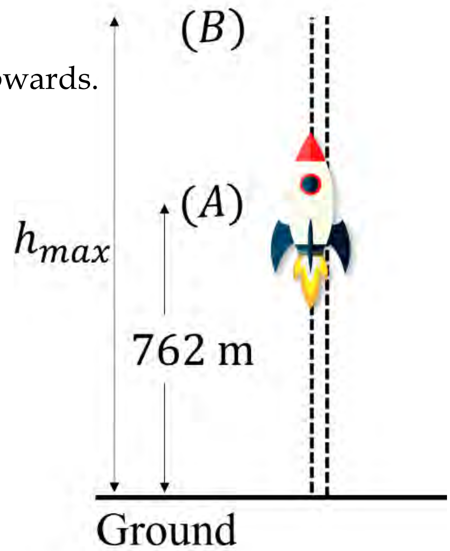
(a) Ground to (A): $v_A^2 = v_o^2 + 2a(y_A - y_o) \rightarrow v_A = 55.2\ m/s$

(b) (A) to (B): $v_B^2 = v_A^2 + 2a(y_B - y_A) \rightarrow$

$$y_B = \frac{v_B^2 - v_A^2}{2(-g)} + y_A = 917.5\ m$$

(c) (B) to ground: $y_o = y_B + v_B t + \frac{1}{2}(-g)t^2 \rightarrow$

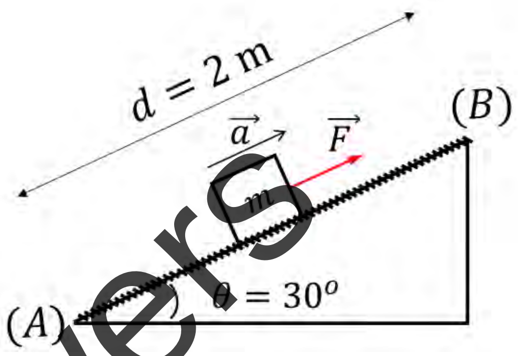
$$0 = 917.5 + \frac{1}{2}(-9.8)t^2 \rightarrow t = 13.7\ s$$



P3. A $6-$kg box is pulled upward along a **rough incline** by a force $\vec{F}$, as shown. The acceleration of the box is $2\ \mathrm{m/s^2}$, and the coefficient of kinetic friction between the box and the surface is 0.4.

a. Find the magnitude of the pulling force. (2 points)

b. Find the work done by the force of gravity on the box, during its motion from point A to point B. (2 points)



(a)

$y-$axis: $F_N - mgcos\theta = 0 \rightarrow F_N = mgcos\theta$

$x-$axis: $F - mgsin\theta - \mu_k mgcos\theta = ma \rightarrow F = 61.8\ N$

(b)

$W_{F_G} = -\Delta PE = -m \cdot g \cdot h = -m \cdot g \cdot d \cdot \sin(30) = -58.8\ J$

P4. A mass $m = 20$ kg is connected to a massless spring with stiffness constant $380\ \mathrm{N/m}$, through a massless and frictionless pulley, as shown. The mass is released from rest when the spring is in equilibrium. Ignore any frictional force. **When the mass has dropped by 0.4 m, find:**

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

b. The net work done on the mass. (1 point)

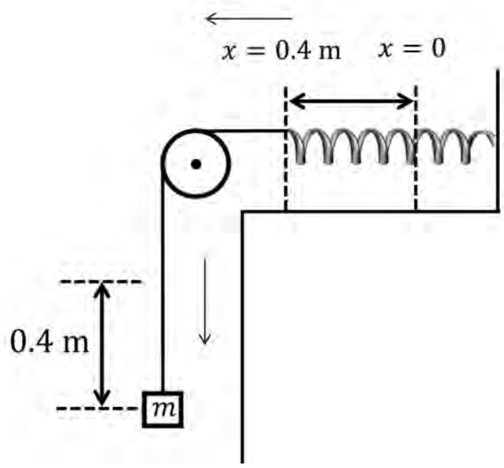
(a) $KE_i + PE_i = KE_f + PE_f \rightarrow$

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

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

(b)

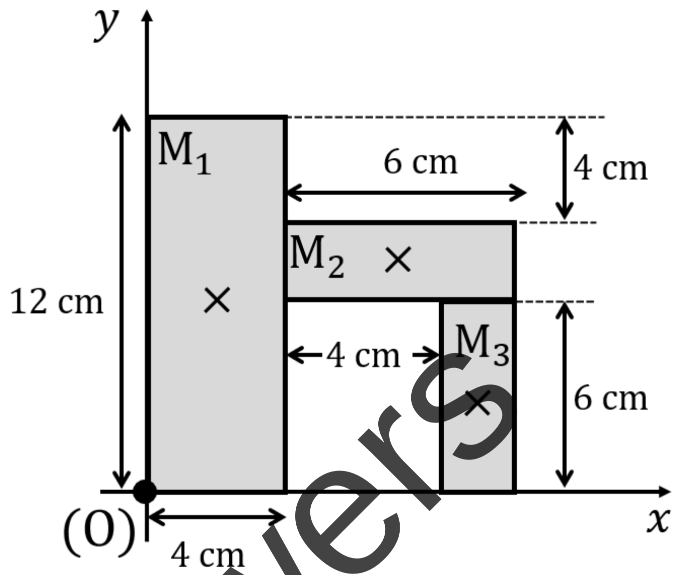
$W_{net} = \Delta KE = \frac{1}{2}mv^2 - 0 = 48\ J$



P5. A structure made up of three uniform rectangular pieces is shown below. The three pieces have mass $M_1 = 3$ kg, $M_2 = 1$ kg, and $M_3 = 2$ kg. **Find the *x*-coordinate and *y*-coordinate of the center-of-mass of the structure, measured from the origin (point O). (4 points)**

$$X_{CM} = \frac{x_1 M_1 + x_2 M_2 + x_3 M_3}{M_1 + M_2 + M_3}$$
$$= \frac{2 \times 3 + 7 \times 1 + 9 \times 2}{3 + 1 + 2}$$
$$\rightarrow X_{CM} = 5.17 cm$$

$$Y_{CM} = \frac{y_1 M_1 + y_2 M_2 + y_3 M_3}{M_1 + M_2 + M_3}$$
$$= \frac{6 \times 3 + 7 \times 1 + 3 \times 2}{3 + 1 + 2}$$
$$\rightarrow Y_{CM} = 5.17\ cm$$



	$x\ (cm)$	$y\ (cm)$
M_1	$\frac{4}{2} = 2$	$\frac{12}{2} = 6$
M_2	$4 + \frac{6}{2} = 7$	$6 + \left(\frac{12 - 10}{2}\right) = 7$
M_3	$4 + 4 + \left(\frac{6 - 4}{2}\right) = 9$	$\frac{6}{2} = 3$

P6. During a dental procedure, a rotating disk-shaped drill with radius of 2 mm, **accelerates uniformly** about its center from rest to 180,000 rpm in 1.2 s.

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

b. At $t = 1.2$ s, find the radial acceleration of a point at the edge of the disk. (1 point)

c. At $t = 1.2$ s, a small particle ($m = 10^{-5}$ kg) sticks briefly at the edge of the disk. Find the magnitude of the radial force on it. (1 point)

(a) $\omega_o = 0 \frac{rad}{s}$; $\omega = 2\pi f = 2 \cdot 3.14 \cdot \frac{180000}{60} = 18{,}850\ rad/s$

$$\omega = \omega_o + \alpha t \rightarrow \alpha = \frac{\omega - \omega_o}{t} = \frac{18{,}850}{1.2} = 15{,}708\ rad/s^2$$

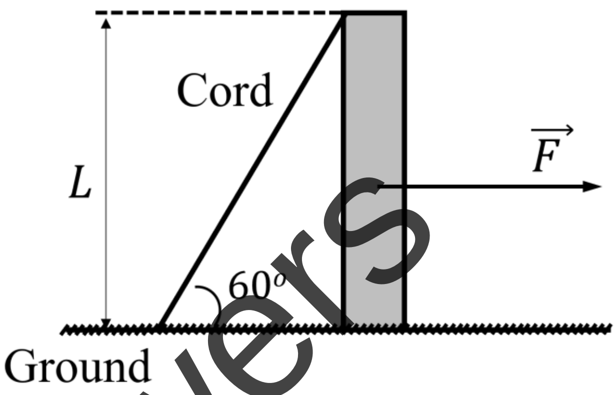
(b) $a_R = \frac{v^2}{r} = \omega^2 r = 18{,}850^2 \cdot 0.002 = 7.11 \times 10^5\ m/s^2$

(c) $F_R = m a_R = 10^{-5} \cdot 7.11 \times 10^5 = 7.11\ N$

P7. A uniform beam of mass $m = 10$ kg and length $L = 1$ m is kept vertical by a massless cord attached to the ground from the edge. The structure **is balanced** when a force $F = 10$ N is applied on the beams mid-point as shown.

a. Find the magnitude of the force of tension at the top-end of the beam. (2 points)

b. Find x-component of the contact force at the bottom-end of the beam. (2 points)



(a)

The second condition of equilibrium the contact point

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

$$F_T \cos(60)\, L - F\frac{L}{2} = 0 \rightarrow$$

$$F_T = \frac{F\frac{L}{2}}{\cos(60)\, L} = 10\ N$$

(b)

The first condition of equilibrium

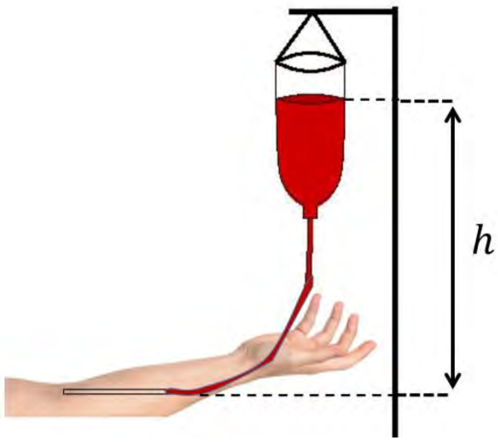
$$\sum F_x = 0 \rightarrow -F_T \cos(60) + F - F_{cx} = 0$$

$$\rightarrow F_{cx} = -F_T \cos(60) + F = 5\ N$$

P8. A patient is given 450×10^{-6} m^3 blood transfusion ($\eta = 0.004$ Pa.s, $\rho = 1060$ kg/m^3) at a rate of 3.3×10^{-8} m^3/s. The needle has 25 mm length, and inner radius 0.4 mm. The blood pressure of the patient is 10374 Pa.

a. Find at what height (h) the bottle should be placed above the needle. (3 points)

b. Find the time it will take for the transfusion to finish. (1 point)



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

$$P_1 - P_2 = \frac{8\eta l Q}{\pi R^4} = 328.3\ Pa \rightarrow$$

$$P_1 = 328.3\ Pa + P_2 = 10702.3\ Pa$$

$$P_1 = \rho g h \rightarrow h = \frac{P_1}{\rho g} = 1.03\ m$$

$$\Delta t = \frac{\Delta V}{Q} \rightarrow \Delta t = \frac{450 \times 10^{-6}}{3.3 \times 10^{-8}}$$

$$= 13{,}636.4\ s = 3.8\ h$$

P9. Blood ($\rho = 1060\ \text{kg/m}^3$) flows in the main artery of a human body, through a segment where the artery narrows from a cross-sectional area $4 \times 10^{-4}\ \text{m}^2$ to $2 \times 10^{-4}\ \text{m}^2$. The bloods speed at the wider section is $v_1 = 0.4\ \text{m/s}$. The height difference between the two points is $h = 4$ mm, with the narrower point being higher.

a. Find the speed of blood flowing though the narrower section. **(1 point)**

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

(a)

$$A_1 v_1 = A_2 v_2 \rightarrow$$

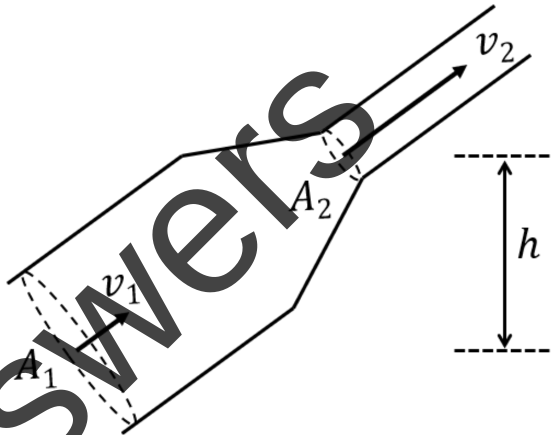
$$v_2 = \frac{A_1}{A_2} v_1 = \frac{4 \times 10^{-4}}{2 \times 10^{-4}} (0.4) = 0.8\ m/s$$

(b)

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

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

$$P_1 - P_2 = 295.95\ Pa$$



P10. A mass is attached to a spring and set on a horizontal frictionless surface, performing a **simple harmonic oscillation**. The position of the mass every moment is given by the equation $x = 0.3 \cdot cos(8 \cdot t)$, where x is in meters and t is in seconds.

a. Find the maximum speed of the mass. **(2 points)**

b. Find the magnitude of the maximum acceleration of the mass. **(2 points)**

$$2\pi f = 8\ rad/s \rightarrow f = \frac{4}{\pi}\ Hz;\ T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \rightarrow \sqrt{\frac{k}{m}} = 2\pi f$$

(a) $\frac{1}{2}kA^2 = \frac{1}{2}mv_{max}^2 \rightarrow v_{max} = A\sqrt{\frac{k}{m}} = 0.30 \times 8 = 2.4\ m/s$

(b) $a_{max} = \frac{F_s^{max}}{m} = \frac{kA}{m} = (2\pi f)^2 A = 19.2\ m/s^2$