Kuwait University **Physics Department**

Physics 121

Final Exam
Fall Semester (2024-2025)

December 31, 2024
Time: 08:00 – 10:00

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

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

Instructors: Drs. Abdulmuhsen, Alfailakawi, Alotaibi, Alrefai, 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	**3**	**4**	**5**	**4**	**4**	**5**	**4**	**3**	**4**	**4**	**40**

GOOD LUCK

P1. An object is **dropped** from a 2 m height above ground. **Ignore air resistance.**

a. Find the time it takes to reach the ground. (2 points)

b. Find the speed of the object just before it strikes the ground. (1 point)

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

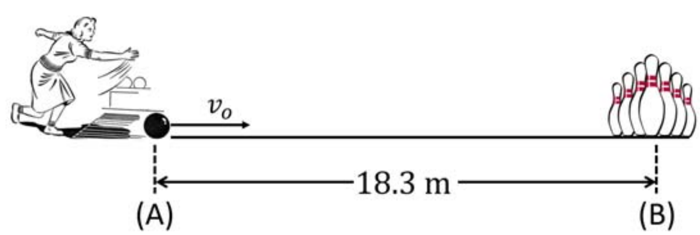
(a) $y = y_0 + v_0 t + \frac{1}{2}at^2 \rightarrow t = \sqrt{\frac{2\Delta y}{g}} = \sqrt{\frac{2(-2)}{(-9.8)}} = 0.64\ s$

(b) $v = v_o + at = 0 + (9.8)0.64 = 6.3\ m/s$

P2. A 6.4 kg bowling ball is released from the hand of a player with $v_o = 9.40\ \mathrm{m/s}$ and hits the pins at the end of a 18.3 m long bowling lane. The player hears the ball hitting the pins 2.80 s after the ball is released from her hands. Assume the speed of sound is 340 m/s.

a. Find the acceleration of the ball, assuming that is constant. (3 points)

b. Find the net force applied on the ball during this motion. (1 point)



$$t_{B\rightarrow A} = \frac{d}{v_{sound}} = \frac{18.3}{340} = 0.05\ s$$
$$t_{A\rightarrow B} = t_{total} - t_{B\rightarrow A} = 2.8 - 0.05 = 2.75\ s$$

$$x = x_o + v_o t_{A\rightarrow B} + \frac{1}{2}a t_{A\rightarrow B}^2 \rightarrow a = 2\frac{(x-x_o) - v_o t_{A\rightarrow B}}{t_{A\rightarrow B}^2} = -2.0\ m/s^2$$

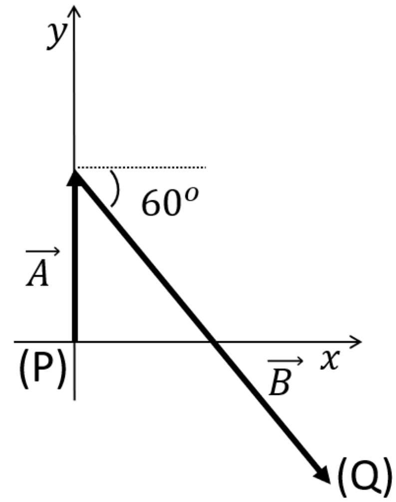
$$F_{net} = ma = 6.4 \times (-2.0) = -12.8\ N$$

P3. A student walks with **constant speed** from point P to point Q, by following the paths $A = 200$ m, and $B = 400$ m, as shown. The total time of the trip is 0.5 h.

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

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

c. Find the average speed of the student. **(1 point)**



(a) $D_x = A_x + B_x = A_x + Bcos(60^o)$

$= 0 + 400cos(60^o) = 200\ m$

$D_y = A_y + B_y = A_y + \left(-Bsin(60^o)\right)$

$= 200 - 400\sin(60^o) = -146.4\ m$

$D = \sqrt{D_x^2 + D_y^2} = \sqrt{200^2 + 146.4^2} = 247.9\ m$

(b) $\theta = \tan^{-1}\left(\frac{D_y}{D_x}\right) = 36.2^o$

$\rightarrow Direction = 360^0 - 36.2^o = 323.8^o$

(c) $average\ speed = \frac{Total\ Distance}{Time} = \frac{200+400}{0.5*3600} =$

0.33 m/s

P4. A 4 kg box is moving up a **smooth incline** with an initial speed of $v_A = 3$ m/s (point A). It reaches **to a maximum height** (point B), then returns to the initial position and continues it's motion along a **rough horizontal** surface **until it stops** (point C).

a. How far (d_1) does the box move along the incline? **(2 points)**

b. Find the coefficient of kinetic friction (μ_k) between the horizontal surface and the box. Take $d_2 = 1$ m. **(2 points)**

(a) $(A) \rightarrow (B): E_A = E_B$

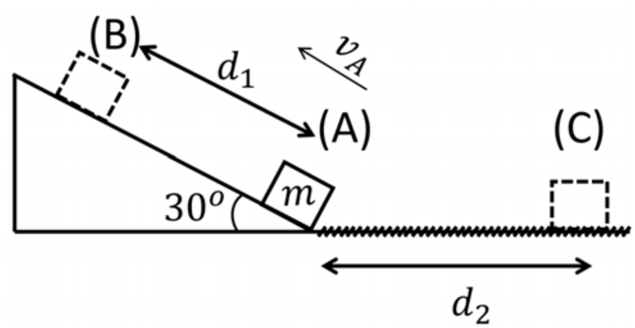
$\rightarrow \frac{1}{2}mv_A^2 + 0 = 0 + mgh_1 \rightarrow h_1 = \frac{v_A^2}{2g} = 0.46\ m$

$sin30^o = \frac{h_1}{d_1} \rightarrow d_1 = \frac{h_1}{sin30^o} = 0.92\ m$

(b) $(A) \rightarrow (C): W_{NC} = \Delta KE + \Delta PE$

$\rightarrow -\mu_k mgd_2 = \left(0 - \frac{1}{2}mv_A^2\right) + 0$

$\rightarrow \mu_k = \frac{v_A^2}{2gd_2} = 0.46$



OR$(B) \rightarrow (C): W_{NC} = \Delta KE + \Delta PE \rightarrow$

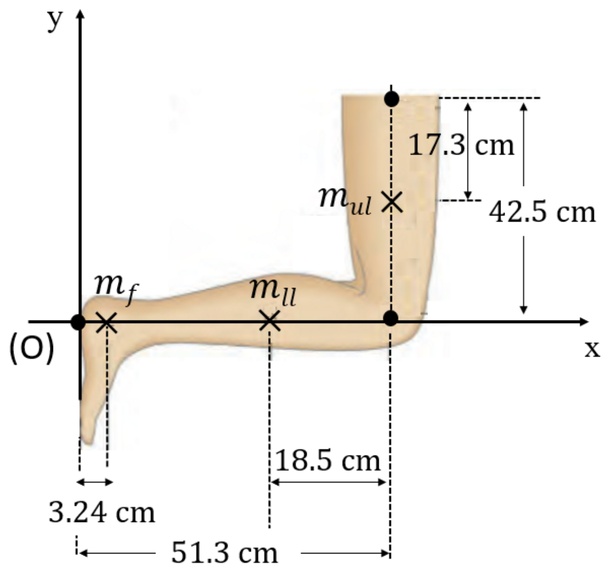
$-\mu_k mgd_2 = (0-0) + (0 - mgh_1)$

$\rightarrow \mu_k = \frac{h_1}{d_2} = 0.46$

P5. The leg of an athlete during a stretching position is bent at 90^o, as shown below. The upper leg (ul), lower leg (ll), and feet (f) have masses $m_{ul} = 15.1$ kg, $m_{ll} = 6.72$ kg, and $m_f = 2.38$ kg, respectively. The corresponding centers-of-mass are indicated by " **x** ". **Find the** ***x*****-coordinate and** ***y*****-coordinate of the center-of-mass of the leg, measured from the origin (point O).** **(4 points)**

$$X_{CM} = \frac{x_{ul}m_{ul} + x_{ll}m_{ll} + x_f m_f}{m_{ul} + m_{ll} + m_f}$$
$$= \frac{51.3 \times 15.1 + (51.3 - 18.5) \times 6.72 + 3.24 \times 2.38}{15.1 + 6.72 + 2.38}$$
$$\rightarrow X_{CM} = 41.4\ cm$$

$$Y_{CM} = \frac{y_{ul}m_{ul} + y_{ll}m_{ll} + y_f m_f}{m_{ul} + m_{ll} + m_f}$$
$$= \frac{(42.5 - 17.3) \times 15.1 + 0 \times 6.72 + 0 \times 2.38}{15.1 + 6.72 + 2.38}$$
$$\rightarrow Y_{CM} = 15.7\ cm$$



P6. A rotating wheel **accelerates uniformly** from 10 rpm to 40 rpm in 4 s.

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

b. Find the magnitude of the total acceleration at 10 rpm for a point 15 cm from the center. **(3 points)**

(a) $\omega_o = 2\pi f_o = 2\pi \frac{10}{60}\ rad/s;\ \omega = 2\pi f = 2\pi \frac{40}{60}\ rad/s;$

$$\omega = \omega_o + \alpha t \rightarrow \alpha = \frac{\omega - \omega_o}{t} = \frac{2\pi \frac{30}{60}}{4} = 0.8\ rad/s^2$$

(b) $a_{tan} = r\alpha = 0.15 \times 0.8 = 0.12\ m/s^2$

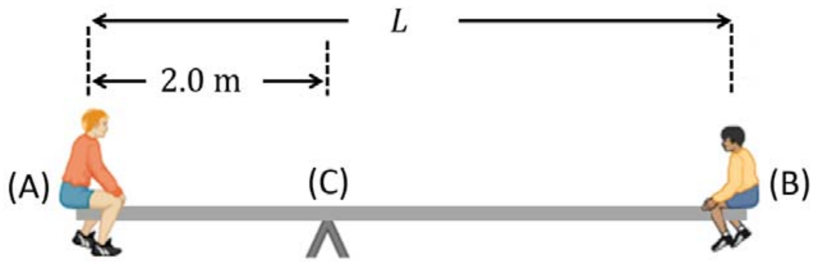
$$a_{rad} = \omega_o^2 r = \left(2\pi \frac{10}{60}\right)^2 0.15 = 0.16\ m/s^2$$

$$a = \sqrt{a_{tan}^2 + a_{rad}^2} = \sqrt{0.16^2 + 0.12^2} = 0.2\ m/s^2$$

P7. A uniform horizontal beam of mass M and length $L = 5.0$ m is used as a seesaw. Two persons with masses $m_A = 80$ kg and $m_B = 40$ kg **are balanced** at the two ends of the seesaw, as shown.

a. Find the mass M of the seesaw. **(2 points)**

b. Find the normal force exerted by the fulcrum (at point C) on the beam. **(2 points)**



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

$$-Mg \times \left(\frac{5}{2} - 2\right) + m_A g \times 2 - m_B g \times (5 - 2) = 0$$

$$\rightarrow M = \frac{2m_A - 3m_B}{0.5} = 80\ kg$$

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

$$F_N - Mg - m_A g - m_B g = 0$$
$$\rightarrow F_N = Mg + m_A g + m_B g = 1960\ N$$

P8. Crude oil ($\eta = 0.8$ Pa. s) flows from an oil field to a tanker terminal, through a horizontal pipe of radius 0.5 m and length 15 km. The flow is laminar, and the oil is delivered at the terminal at a rate of 0.5 m^3/s.

a. Find the pressure difference necessary to keep oil flowing at that rate. **(2 points)**

b. The time it takes to fill a container of 40, 000 m^3 volume. **(1 point)**

(a) $Q = \frac{\pi R^4}{8\eta}\frac{\Delta P}{L} \rightarrow \Delta P = \frac{8\eta}{\pi R^4} Q\ L = 2.4 \times 10^5 Pa$

(b) $Q = \frac{\Delta V}{\Delta t} \rightarrow \Delta t = \frac{\Delta V}{Q} = 80{,}000\ s$

P9. A pair of vertical, open-ended glass tubes inserted into a horizontal pipe are often used together to measure flow velocity in the pipe. Such an instrumentation is shown below, with water ($\rho = 10^3$ kg/m^3) carried from point 1 ($v_1 = 0.5$ m/s) to point 2 ($v_2 = 1.5$ m/s), and the fluid rises to heights h_1 and h_2, in the two open-ended tubes.

a. Find the pressure difference ($\Delta P = P_1 - P_2$) between points 1 and 2. (2 points)

b. Find the height difference ($\Delta h = h_1 - h_2$) of the fluid levels, in the two open tubes. (2 points)

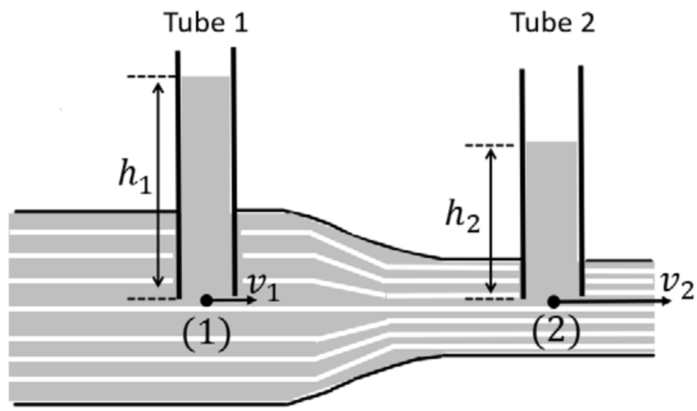
(a) $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

$\rightarrow P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$

$\rightarrow \Delta P = 10^3 Pa$

(b) $\Delta P = \rho g(h_1 - h_2)$

$\rightarrow \Delta h = \frac{\Delta P}{\rho g} = 0.1\, m$



P10. A particle of mass 0.5 kg is attached to a spring with stiffness constant $k = 200$ N/m, executing **simple harmonic motion.** The mechanical energy of the mass-spring system is 9 J.

a. Find the amplitude of the motion. (1 point)

b. Find at which position the speed of the particle becomes 5 m/s. (1 point)

c. Find the magnitude of the maximum acceleration of the particle. (1 point)

d. At $t = 0$ s the particle is at the equilibrium position with initial speed v_o. Write the equation for the position of the particle as a function of time. (1 point)

(a) $E = \frac{1}{2}kA^2 \rightarrow A = \sqrt{\frac{2E}{k}} = 0.3\, m$

(b) $E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2 \rightarrow x = \sqrt{\frac{2E - mv^2}{k}} = 0.16\, m$

(c) $a_{max} = \frac{F_s^{max}}{m} = \frac{kA}{m} = 120\, m/s^2$

(d) $x = Asin(\omega t) = Asin(2\pi f t) = Asin\left(2\pi\left(\frac{1}{2\pi}\sqrt{\frac{k}{m}}\right)t\right) = Asin\left(\sqrt{\frac{k}{m}}t\right) =$

$0.3sin(20t)$