Kuwait University — Physics Department

Physics 121

Final Exam
Fall Semester (2023-2024)

January 4, 2024
Time: 08:00 – 10:00

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

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

Instructors: Drs. Abdullah, Afrousheh, Alotaibi, Hadipour, Kokkalis, Razee, Zaman

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.**

Model Answers

For use by instructors

Grades:

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

GOOD LUCK

P1. An object moves in one direction in a straight line. At $t_1 = 0$ s its position is $x_1 = 10$ m and after 5 s the object is found at $x_2 = -40$ m. During this motion:

a. Find the total distance and the displacement of the object. (2 points)

b. Find the average speed of the object. (1 point)

c. Find the average velocity of the object. (1 point)

(a)

$Total\ distance = 10 + 40 = 50\ m$

$\Delta x = x_2 - x_1 = -40 - 10 = -50\ m$

(b) $average\ speed = \frac{Total\ distance}{Time} = \frac{50}{5} = 10\ m/s$

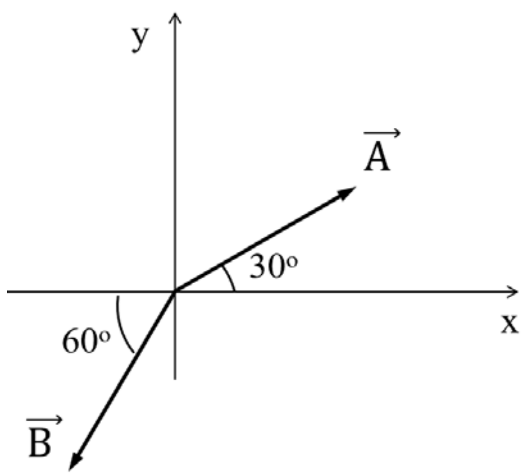
(c) $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{-50}{5} = -10\ m/s$

Model Answers

P2. Two vectors $\overrightarrow{A}$ and $\overrightarrow{B}$, with magnitudes of $A = B = 10$ units, are shown below. The resultant vector is $\overrightarrow{C} = \overrightarrow{A} + \overrightarrow{B}$:

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

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



(a)

$C_x = A_x + B_x = Acos(30) - Bcos(60)$

$= 8.66 - 5.00 = 3.66$ units

$C_y = A_y + B_y = Asin(30) - Bsin(60)$

$= 5.00 - 8.66 = -3.66$ units

$C = \sqrt{C_x^2 + C_y^2} = 5.20$ units

(b) $\theta = \tan^{-1}\left(\frac{C_y}{C_x}\right) = -45^o$

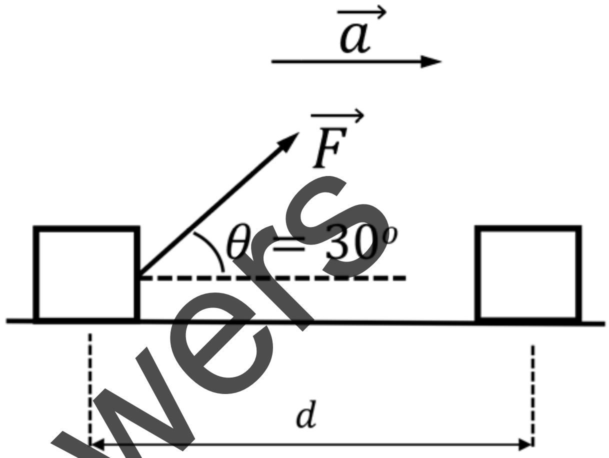
Model Answers

P3. A $10 - $kg box is on a horizontal frictionless surface. A pulling force $\vec{F}$ **uniformly accelerates** the box to the east, as shown. During this motion, the box **starts from rest** and covers a distance of $d = 15$ m in 5 s.

a. Find the acceleration of the box during this motion. **(1 point)**

b. Find the magnitude of the normal force. **(3 points)**

(a) $x = x_o + v_o t + \frac{1}{2}at^2 \rightarrow a = \frac{2d}{t^2} = 1.2\,\frac{m}{s^2}$



(b)

For box x-axis:

$$F_{net}^{x} = ma \rightarrow F\cos(30) = ma \rightarrow$$

$$F = \frac{ma}{\cos(30)} = 13.9\,N$$

For box y-axis:

$$F_{net}^{y} = 0 \rightarrow F\sin(30) + F_N - mg = 0$$

$$\rightarrow F_N = mg - F\sin(30) = 91.1\,N$$

P4. A block of mass $m = 5$ kg, **is released from rest** at the top of a rough inclined surface ($\theta = 30^o$), as shown. The block reaches the bottom of the incline at a speed of 2 m/s.

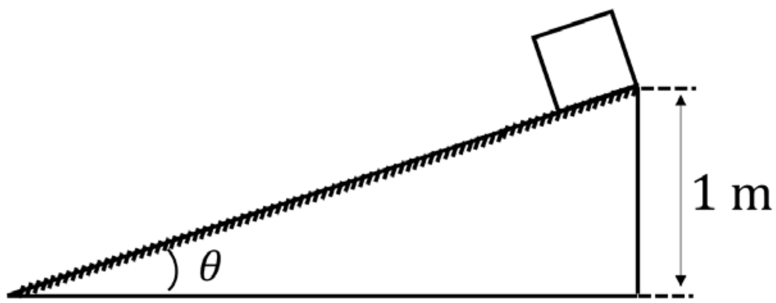
a. Find the work done by the force of friction. **(2 points)**

b. Find the coefficient of kinetic friction (μ_k), between the incline and the box. **(3 points)**

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

$$= \left(\frac{1}{2}mv_B^2 - 0\right) + (0 - mgh)$$

$$\rightarrow W_{NC} = -39\,J$$



(b) $d = \frac{h}{\sin(\theta)} = 2\,m$

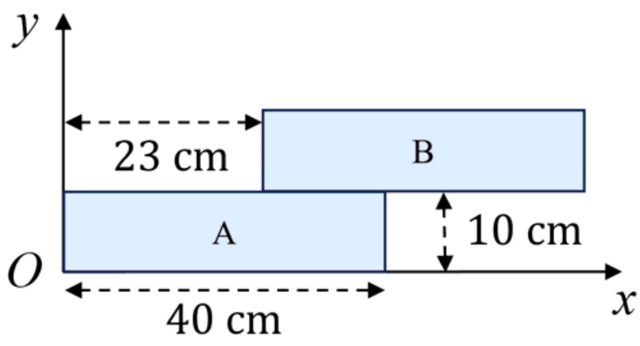
$$F_N = mg\cos(30) = 42.4\,N$$

$$W_{NC} = -d\,\mu_k F_N \rightarrow \mu_k = 0.46$$

P5. A structure made up of two uniform rectangular pieces of the same size is shown below. The two pieces have the same mass $M_1 = M_2 = M$. **Find the x-coordinate and y-coordinate of the center-of-mass of the structure, measured from the origin (point O). (4 points)**

$$X_{CM} = \frac{x_1 M_1 + x_2 M_2}{M_1 + M_2}$$
$$= \frac{20 \times M + 43 \times M}{2M}$$
$$\rightarrow X_{CM} = 31.5cm$$

$$Y_{CM} = \frac{y_1 M_1 + y_2 M_2}{M_1 + M_2}$$
$$= \frac{5 \times M + 15 \times M}{2M}$$
$$\rightarrow Y_{CM} = 10\ cm$$



	$x\ (cm)$	$y\ (cm)$
M_1	$\frac{40}{2} = 20$	$\frac{10}{2} = 5$
M_2	$23 + \frac{40}{2} = 43$	$10 + \frac{10}{2} = 15$

P6. A coin of 0.1 kg mass, is placed $r = 0.40$ m from the axis of a horizontal rotating turntable of variable speed.

a. When the frequency of the turntable is 20 rpm (at $t = 0$ s), find the radial (centripetal) force on the coin. (3 points)

b. At this moment ($t = 0$ s) the turntable slows down uniformly and makes 3 revolutions before stopping. Find the angular acceleration of the turntable. (2 points)

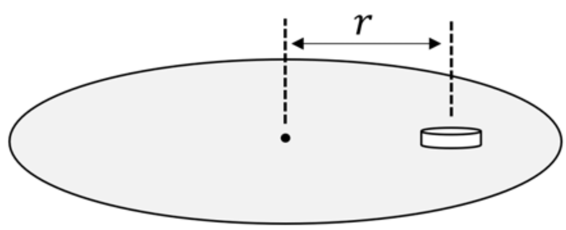
Model Answers

(a) $\omega_o = 2\pi f = 2 \cdot 3.14 \cdot \frac{20}{60} = 2.1\ rad/s$

$v = r\,\omega_o = 0.4 \cdot 2.1 = 0.84\ m/s$

$F_c = m\frac{v^2}{r} = 0.1\frac{0.84^2}{0.4} = 0.18\ N$

(b) $N = \frac{\Delta\theta}{2\pi} \rightarrow \Delta\theta = 18.8\ rad$

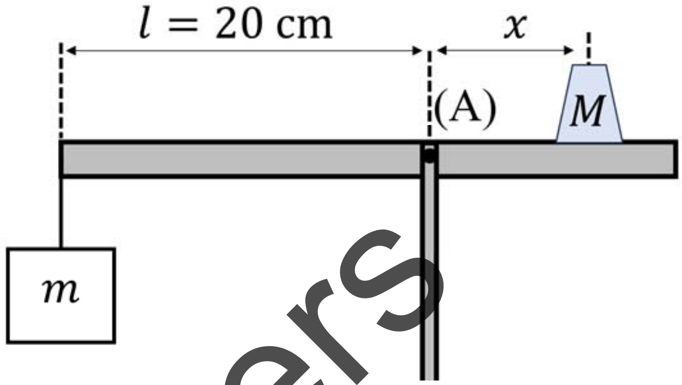


$$\omega^2 = \omega_o^2 + 2\alpha\Delta\theta \rightarrow \alpha = \frac{\omega^2 - \omega_o^2}{2\Delta\theta} = -0.12\ rad/s^2$$

P7. A horizontal beam is supported by a vertical pole at the pivot point A. A mass $m = 0.6$ kg is hanging from the left end of the beam, balanced by a counter-weight of mass $M = 1.5$ kg, as shown. The system is in static equilibrium. **Ignore the mass of the horizontal beam.**

a. Find the distance x of the mass M from the pivot. **(2 points)**

b. Find the normal force on the beam from the support. **(2 points)**



The second condition of equilibrium about point A $\tau_{net}^{A} = 0 \rightarrow$

$$-xMg + lmg = 0 \rightarrow x = \frac{lm}{M}$$
$$= \frac{(0.2)(0.6)}{1.5} = 0.08\, m$$

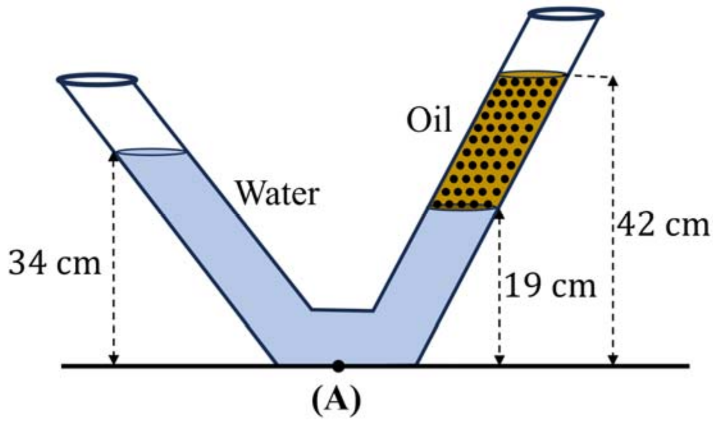
The first condition of equilibrium

$$\sum F_y = 0 \rightarrow F_N - mg - Mg = 0$$
$$\rightarrow F_N = (m + M)g = (1.5 + 0.6)(9.8)$$
$$= 20.6\, N$$

P8. A V-shaped tube contains water ($\rho_w = 10^3$ kg/m^3) and oil (ρ_o), as shown.

a. Find the gauge pressure at the bottom of the tube (point A). **(1 point)**

b. Find the density of oil (ρ_o). **(2 points)**



(a)

$$P_A = \rho_W g h = 10^3 \cdot 9.8 \cdot 0.34$$
$$= 3332\, Pa$$

(b)

$$\rho_o g h_{oil} = \rho_w g h_w$$
$$\rightarrow \rho_o = \rho_w \frac{h_w}{h_{oil}} = 10^3 \frac{34 - 19}{42 - 19}$$
$$= 652 \frac{kg}{m^3}$$

or

$$P_A = \rho_w g 0.19 + \rho_o g(0.42 - 0.19)$$
$$\rightarrow \rho_o = 652\ \frac{kg}{m^3}$$

Model Answers

P9. Water flows from an open tank as shown. The elevation of point 1 is 10 m, and the elevation of points 2 and 3 is 2 m. The cross-sectional area at point 2 is $A_2 = 0.048\ \text{m}^2$ and at point 3 $A_3 = 0.016\ \text{m}^2$.

a. Find the speed of fluid at point 3. (Hint: $v_1 = 0$ m/s and $P_1 = P_3 = P_O$). (2 points)

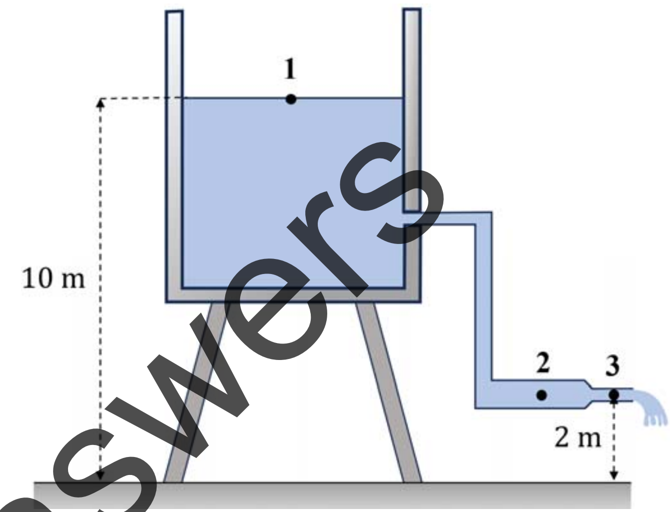
b. Find the speed of fluid at point 2. (2 points)

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_3 + \frac{1}{2}\rho v_3^2 + \rho g y_3$$

$$P_0 + \rho g y_1 = P_0 + \frac{1}{2}\rho v_3^2 + \rho g y_3$$

$$\rho g(y_1 - y_3) = \frac{1}{2}\rho v_3^2$$

$$\rightarrow v_3 = \sqrt{2g(y_1 - y_3)} = \sqrt{2(9.8)(10-2)} = 12.5\ m/s$$



$$A_3 v_3 = A_2 v_2 \Rightarrow v_2 = \frac{A_3}{A_2} v_3 = \frac{0.016}{0.048}(12.5) = 4.2\ m/s$$

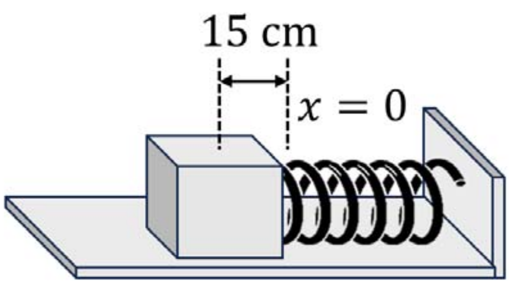
P10. A 0.1 kg mass is attached to a spring and set on a horizontal frictionless table. The mass is pulled a distance 15 cm from the equilibrium and then released, performing **a simple harmonic oscillation** with a frequency of 2.3 Hz.

a. Find the spring constant k. (1 point)

b. Find the maximum speed of the mass. (2 points)

(a) $T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \rightarrow$

$$k = (2\pi)^2 m f^2 = 21\ N/m$$



(b) $A = 0.15\ m$

$$\frac{1}{2} m v_{max}^2 = \frac{1}{2} k A^2$$

$$\rightarrow v_{max} = A\sqrt{\frac{k}{m}} = 0.15\sqrt{\frac{21}{0.1}} = 2.2\ m/s$$

Model Answers