NS-1001:Applied Physics

BS-CS, Cy-Sec

Saturday, 23rd September, 2023

Course Instructors

Dr. Mehwish Hassan, Dr.Tashfeen Zehra, Kashif Ali

Serial No:

Sessional Exam-I

Total Time: 1 Hour

Total Marks: 40

Signature of Invigilator

[redacted]

Student Name Roll No. Course Section Student Signature

DO NOT OPEN THE QUESTION BOOK OR START UNTIL INSTRUCTED.

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4. After asked to commence the exam, please verify that you have **seven (7)** different printed pages including this title page. There are total of **4** questions.
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Question 1 [7+3]

i. A student standing on the ground throws a ball straight up. The ball leaves the student's hand with a speed of 15 m/s when the hand is 2.0 m above the ground. How long is the ball in the air before it hits the ground? (The student moves her hand out of the way.)

$V_{iy} = 15\ m/s$, $\theta = 90°$, $h_1 = 2\ m$

- Time at a height of 2m

$t = \frac{2(V_i \sin\theta)}{g} = \frac{2(15 \sin 90)}{9.8} = 3.06\ s$

- Time for next 2m:

$V_f = V_i + gt = 15 + (9.8)(3.6) = 14.98\ (-\hat{j})$

$t_2 = \frac{h_1}{V_f} = (2)\left(\frac{1}{14.98}\right) = 0.13\ s$

$t = t_1 + t_2 = 3.06 + 0.13 = \underline{3.19\ s}$

ii. For the three vectors shown in the Fig.1, $\vec{A} + \vec{B} + \vec{C} = 1\hat{j}$
What is vector B?

a. Write $\vec{B}$ in component form.

b. Write $\vec{B}$ as a magnitude and a direction.

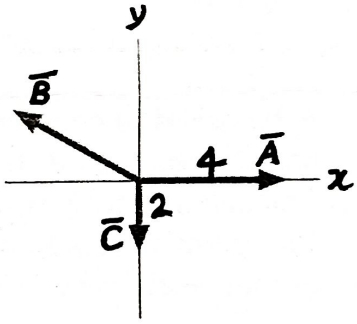

Fig. 1

$\vec{A} = 4\hat{i}$, $\vec{C} = -2\hat{j}$

As $\vec{A} + \vec{B} + \vec{C} = 1\hat{j}$

$4\hat{i} + \vec{B} - 2\hat{j} = 1\hat{j}$

$\underline{B = -4\hat{i} + 3\hat{j}}$

$|B| = \sqrt{(-4)^2 + (3)^2}$ $\quad (\because |B| = \sqrt{B_x^2 + B_y^2})$

$= \sqrt{25} = \underline{5}$

$\theta_B = -\tan^{-1}\left(\frac{B_y}{B_x}\right) + 180 = -\tan^{-1}\left(\frac{3}{4}\right) + 180$

$\underline{\theta_B = 143.13°}$

10

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Question 2 [5+3+2]

You are to throw a ball with a speed of 12.0 m/s at a target that is height h = 5.00 m above the level at which you release the ball (Fig.2). You want the ball's velocity to be horizontal at the instant it reaches the target.

(a) At what angle θ above the horizontal must you throw the ball?
(b) What is the horizontal distance from the release point to the target?
(c) What is the speed of the ball just as it reaches the target?

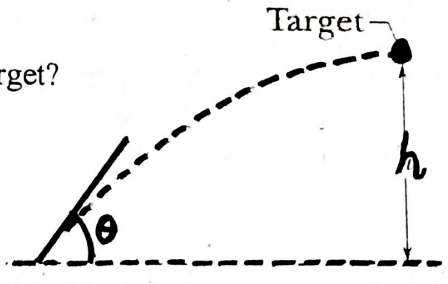

Fig.2

$V_i = 12\ m/s$, $h = 5\ m$

At h, $V_{fy} = 0\ ms^{-1}$

a) $H = \dfrac{V_i^2 \sin^2\theta}{2g}$

$\sin^2\theta = \dfrac{2gH}{V_i^2} \Rightarrow \sqrt{\sin^2\theta} = \sqrt{\dfrac{2gH}{V_i^2}} \Rightarrow \sin\theta = \dfrac{\sqrt{2gH}}{V_i}$

$\theta = \sin^{-1}\dfrac{\sqrt{2gH}}{V_i} = \sin^{-1}\left(\dfrac{\sqrt{2(9.8)(5)}}{12}\right)$

$\theta = 55.59°$

b) distance between release point and target is given by $\dfrac{\text{Range}}{2}$.

$\dfrac{R}{2} = x = \left(\dfrac{V_i^2 \sin^2\theta}{g}\right)/2 = 5\ m$

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c) $2as = V_f^2 - V_i^2 \Rightarrow V_f^2 = 2as + V_i^2$

$V_f^2 = 2(9.8)(5) + (12)^2 = 242$

$V_f = \sqrt{242} = 15.55\ m/s$

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4.5/10

Question 3 [5+3+2]

Find the directional derivative of $\phi(x,y,z) = x^2yz + 4xz^2$ at (1,-2,1) in the direction of $2\hat{i} - \hat{j} - 2\hat{k}$.

$\phi(x,y,z) = x^2yz + 4xz^2$

$\nabla\phi = (2xyz + 4z^2)\hat{i} + (x^2z + 4xz^2)\hat{j} + (x^2y + 8xz)\hat{k}$

$(1,-2,1)$

$\nabla\phi = (2(1)(-2)(1) + 4(1)^2)\hat{i} + ((1)^2(1) + 4(1)(1)^2)\hat{j} + ((1)^2(-2) + 8(1)(1))\hat{k}$

$= (0)\hat{i} + 5\hat{j} + 6\hat{k}$

4.5/5

$\nabla\phi \cdot (2\hat{i} - \hat{j} - 2\hat{k}) = 0i - 5j - 12\hat{k}$

$\nabla\phi = 0\hat{i} + 5\hat{j} + 6\hat{k}$

$|\nabla\phi| = \sqrt{25 + 36} = \sqrt{61}$

$\vec{\nabla\phi} = \frac{0}{\sqrt{61}}\hat{i} + \frac{5}{\sqrt{61}}\hat{j} + \frac{6}{\sqrt{61}}\hat{k}$

$\nabla\phi \cdot (2\hat{i} - \hat{j} - 2\hat{k}) = 0\hat{i} - \frac{5}{\sqrt{61}}\hat{j} - \frac{12}{\sqrt{61}}\hat{k}$

Question 4 [10]

A rocket sled accelerates along a long, horizontal rail. Starting from rest, two rockets burn for 10 s, providing a constant acceleration. One rocket then burns out, halving the acceleration, but the other burns for an additional 5 s to boost the sled's speed to 625 m/s. How far has the sled traveled when the second rocket burns out?

$V_i = 0 ms^{-1}$ $V_f = 625 m/s$

$t_1 = 10s$ $a_1 = a$, $t_2 = 5s$, $a_2 = a/2$

$t_3 = 5s$

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distance travelled after second rocket burns:

$d_2 = V \times t = (625)(5) = 3125$.

distance travelled before the second rocket:

$d_1 = d - d_2 = d - 3125$

Formula Sheet

Equation of path of projectile motion	$y = (\tan \theta_0)x - gx^2/2(v_0{}^2\cos^2 \theta_0)$
Time of maximum height	$t_m = v_0 \sin\theta_0 /g$
Time of flight	$2t_m = 2(v_0 \sin\theta_0/g)$
Maximum height of projectile	$h_m = (v_0 \sin\theta_0)^2/2g$
Horizontal range of projectile	$R = v_0^2 \sin 2\theta_0/g$

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NS-1001: Applied Physics
BS-CS

Serial No:

Sessional II Exam

Total Time: 1 Hour

Total Marks: 40

Saturday, 4th November, 2023

Course Instructors

Dr. Mehwish Hassan, Kashif Ali, Dr. Tashfeen Zehra

Signature of Invigilator

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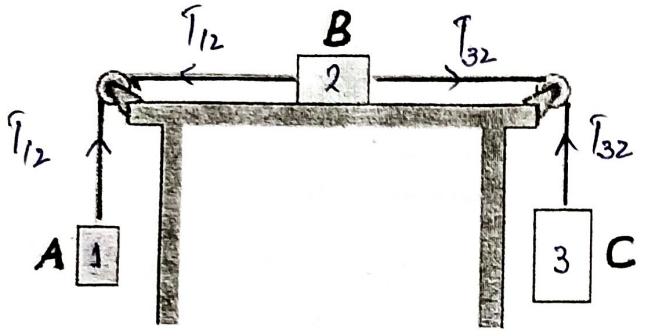
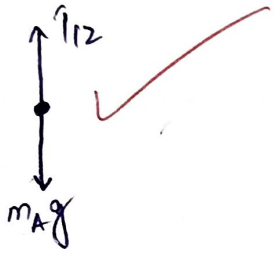
Figure shows three blocks attached by cords that loop over frictionless pulleys. Block B lies on a frictionless table; the masses are $m_A = 6.00$ kg, $m_B = 8.00$ kg, and $m_C = 10.0$ kg. When the blocks are released, what is the tension in the cord at the right ?(Free body Diagram is mandatory)



A)



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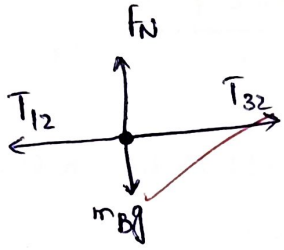

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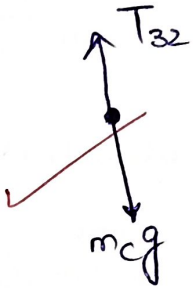

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For A:

$$T_{12} - m_A g = m_A a \quad \text{—(i)}$$

for B:

$$T_{32} - T_{12} = m_B a \quad \text{—(ii)}$$

for C:

$$m_C g - T_{32} = m_C a \quad \text{—(iii)}$$

Adding (i), (ii) and (iii) we get,

$$m_C g - m_A g = m_A a + m_B a + m_C a$$

$$a = \frac{(m_C - m_A)g}{m_A + m_B + m_C} = \frac{(10-6)9.8}{6+8+10} = 1.63\ ms^{-1}$$

Now

$$T_{12} = m_A(g+a) = 6(9.8 + 1.63) = 68.58\ N$$

put a, T_{12}, m_B in (ii)

$$T_{32} - 68.58 = 8(1.63)$$

$$\boxed{T_{32} = 81.62\ N}$$

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So the tension in the cord at the right is 81.62 N

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Question 2 [5+5 Marks]

(a) A 1.0 kg block oscillates on a spring with spring constant 20 N/m. At $t = 0$ s the block is 20 cm to the right of the equilibrium position and moving to the left at a speed of 100 cm/s. Determine (a) the period and (b) the amplitude.

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Given:

mass = m = 1.0kg , k = 20N/m

At t=0 , $x = 20\ cm = 0.2m$, $v = 100\ cm/s = 1m/s$

as $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{20}{1}} = \sqrt{20} = 4.47\ rad/s$

a) $\omega = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi}{4.47} = 1.4s$

02

b) Amplitude:-

$v = \omega\sqrt{A^2 - x^2}$

$v^2 = \omega^2(A^2 - x^2) \rightarrow \frac{v^2}{\omega^2} = A^2 - x^2$

$A^2 = \frac{v^2}{\omega^2} + x^2 \Rightarrow A = \sqrt{\frac{v^2}{\omega^2} + x^2}$

03

$A = \sqrt{\frac{1}{(4.47)^2} + (0.2)^2} = \cancel{\ }$

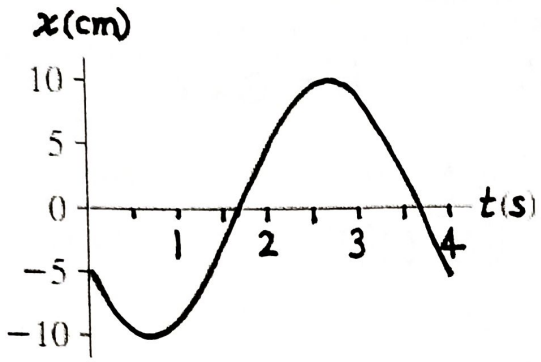
$A = 0.3\ m$

(b) Figure shows the position-versus-time graph of a particle in simple harmonic motion.

a. What is the phase constant?

b. What is the velocity at $t = 0$ s?

c. What is v_{max}?



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Here we can see that $A = 10cm$.

a) Phase constant $= \phi = ?$

02

As $x(t) = A\cos(\omega t + \phi)$

at $t = 0$, $x = -5$, $A = 10$

$-5 = 10\cos(0 + \phi)$

$\cos(\phi) = \frac{-1}{2} \Rightarrow \theta = \cos^{-1}(-1/2) = \frac{2\pi}{3}$ rad.

b) $v(t) = -\omega A \sin(\omega t + \phi)$

Here $T = 4s$, so $\omega = \frac{2\pi}{T} = \frac{\pi}{2}$

$v(0) = -\left(\frac{\pi}{2}\right)(10)\sin\left(0 + \frac{2\pi}{3}\right)$ 02

$= -5\pi \sin\left(\frac{2\pi}{3}\right) =$

$= -13.6$ cm/s

c) $V_{max} = -\omega A = -\left(\frac{\pi}{2}\right)(10) = -5\pi = -15.7$ cm/s

01

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Question 3 [10 Marks]

A 10.6-kg object oscillates at the end of a vertical spring that has a spring constant of 2.05×10^4 N/m. The effect of air resistance is represented by the damping coefficient $b = 3.00$ N.s/m. (a) Calculate the frequency of the damped oscillation (b) By what percentage does the amplitude of the oscillation decrease in each cycle? (c) How many oscillations will have been completed when the energy of the system drops to 5.00% of its initial value.

$m = 10.6\,kg$, $k = 2.05 \times 10^4$ N/m , $b = 3.00$

$$\omega = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}} = \sqrt{\frac{2.05\times10^4}{10.6} - \frac{(3)^2}{4(10.6)^2}}$$

$$\omega = 43.97\ s^{-1}$$

b) $x(t) = Ae^{-bt/2m}\cos(\omega t + \phi)$

$=$

$$E(t) = E_0 e^{-t/\tau}$$

$$= E_0 e^{-bt/m} = E_0 e^{-3t/10.6}$$

$$= \frac{1}{2}k(A\cos(\omega t+\phi))^2 \cdot e^{-3t/10.6}$$

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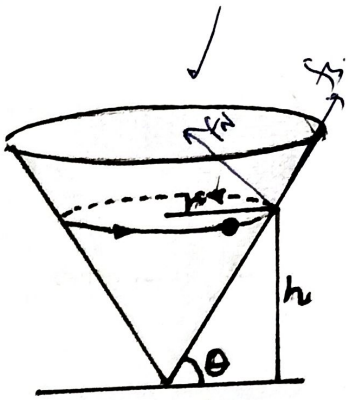
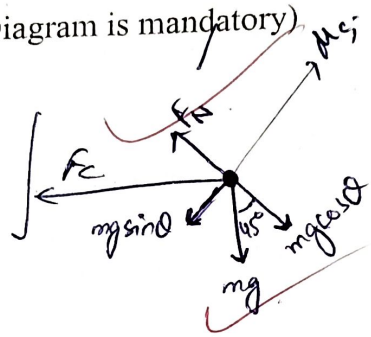
Question 4 [10 Marks]

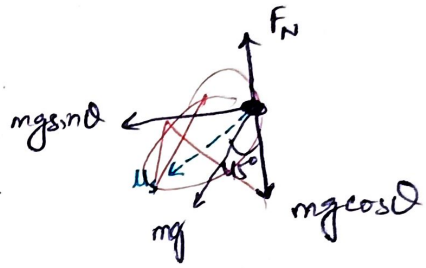


A small ball of mass m =20g rolls in a horizontal circle around the inside of the inverted cone shown in Figure. The walls of the cone make an angle θ =45° with a horizontal plane. The coefficient of static friction between the ball and the cone is $\mu_s = 0.2$, rolling friction is negligible.

What minimum speed v_{min} must the ball maintain at radius r=10cm to remain at a constant height h? (Free Body Diagram is mandatory)

Hint: Use rtz coordinate system





$m = 20g = 0.02kg$

$\theta = 45°$

$\mu_s = 0.2$

$r = 10cm = 0.1m$

$F_{net\,x} = \frac{mv^2}{r} \Rightarrow mg\sin\theta = \frac{mv^2}{r}$

$v^2 = rg\sin\theta \Rightarrow v = \sqrt{rg\sin\theta} = \sqrt{(0.1)(9.8)\sin(45)}$

$v = 0.832\ ms^{-1}$

$-mg\sin\theta - \frac{mv^2}{r} - f_s$

$(0.02)(9.8)\sin 45 = \frac{(0.02)v^2}{0.1} - (0.2)(0.02)(9.8)\cos(45°)$

$v = \frac{0.136 \times 0.1}{0.02}$

$= 0.6824\ ms^{-1}$

10%

2.5

Formula Sheet

SHM	$x(t) = A\cos(\omega t + \phi_0)$ $\omega = \sqrt{\frac{k}{m}}$
Mechanical Energy	$E = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$
Damped Oscillations	$x(t) = Ae^{-bt/2m}\cos(\omega t + \phi_0)$ $\omega = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$ $E(t) = E_0 e^{-t/\tau}$ $\tau = m/b$

$\omega = 2\pi f$, $\omega = \frac{2\pi}{T}$, $\omega = \sqrt{\frac{k}{m}}$, $\omega = \sqrt{\frac{g}{x}}$