S.No. 294987

SHIV NADAR

INSTITUTION OF EMINENCE DEEMED TO BE
UNIVERSITY
DELHI NCR

TEST ANSWER BOOK

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Course Code: PHY101 Course Title: PHYSICS -1

Date: 27/9/24 No. of Continuation Sheets Used: 1

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Q.No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	Sub Total	TOTAL
Marks	04	03	04	05	2.5	07	06							31.5 +2.5 =34
Q.No.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	Sub Total	
Marks														

Signature of the Examiner

Ans 1) $x(t) = A \sin(\omega t + \phi_0)$

At $t=0$, $x = 2cm$

$2 = 4\sin(\phi)$ as $\omega t = 0$ $\sin\phi = \frac{1}{2}$ $\therefore \phi = 30^\circ = \frac{\pi}{6}$

$T = \frac{2\pi}{\omega}$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi$

1

(a) $x = 4\sin\left(\pi t + \frac{\pi}{6}\right) = x(t)$

1

(b) $v = \frac{dx}{dt} = 4\pi \cos\left(\pi t + \frac{\pi}{6}\right) = \dot{x}(t)$

1

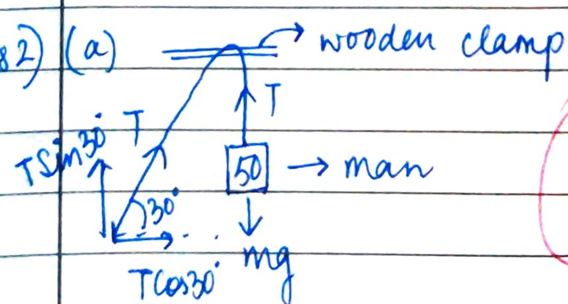
(c) $a = \ddot{x}(t) = \frac{dv}{dt} = -4\pi^2 \sin\left(\pi t + \frac{\pi}{6}\right)$

1

(d) As shown above, $\phi = 30^\circ$ or $\frac{\pi}{6}$

1

Ans 2) (a)



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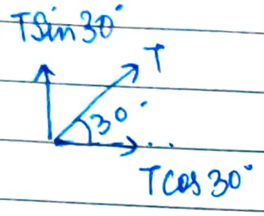
(b)



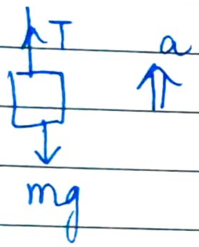
$$T \sin 30^\circ = 300$$

$$T\left(\frac{1}{2}\right) = 300$$

$$T = 600\,N$$

Max^m tension that will not detach the clamp is 600 N.

(c)



$$T - mg = ma$$

we know, $T = 600\,N$
$g = 10\,m/s^2$
$m = 50\,kg$

$$600 - 50(10) = 50(a)$$

$$\frac{100}{50} = a$$

$$a = 2\,m/s^2$$

$\therefore$ max^m acceleration with which man can climb safely is $2\,m/s^2$.

Ans 3)

$$U(x) = -axe^{-\left(\frac{x^2}{b^2}\right)}$$

$$\frac{dU}{dx} = -a\left(e^{-\left(\frac{x^2}{b^2}\right)} + xe^{-\left(\frac{x^2}{b^2}\right)}\left(\frac{-2x}{b^2}\right)\right) \quad \text{[By product rule]}$$

$$= -a\left(e^{-\left(\frac{x^2}{b^2}\right)}\left(1 - \frac{2x^2}{b^2}\right)\right)$$

$$= ae^{-\left(\frac{x^2}{b^2}\right)}\left(\frac{2x^2}{b^2} - 1\right) = 0$$

$$x = \pm \frac{b}{\sqrt{2}}$$

$$\frac{d^2U}{dx^2} = a\left(e^{-\left(\frac{x^2}{b^2}\right)}\left(\frac{4x}{b^2}\right) + \left(\frac{2x^2-1}{b^2}\right)e^{-\left(\frac{x^2}{b^2}\right)}\left(\frac{-2x}{b^2}\right)\right) \quad \text{[Product Rule]}$$

$$= ae^{-\left(\frac{x^2}{b^2}\right)}\left[\frac{4x}{b^2} + \left(\frac{2x^2}{b^2} - 1\right)\left(\frac{-2x}{b^2}\right)\right]$$

$$= ae^{-\left(\frac{x^2}{b^2}\right)}\left[\frac{4x}{b^2} + \frac{2x}{b^2} - \frac{4x^3}{b^4}\right] = ae^{-\left(\frac{x^2}{b^2}\right)}\left[\frac{6x}{b^2} - \frac{4x^3}{b^4}\right]$$

We find value of $\frac{d^2U}{dx^2}$ at $x = \pm\frac{b}{\sqrt{2}}$

At $x = +\frac{b}{\sqrt{2}}$, $\frac{d^2U}{dx^2} = ae^{-1/2}\left[\frac{2\sqrt{2}}{b} + \cancel{\frac{\sqrt{2}}{b}} - \cancel{\frac{\sqrt{2}}{b}}\right] = \frac{a\,2\sqrt{2}}{b\sqrt{e}}$

$$= \frac{2a}{b}\sqrt{\frac{2}{e}} > 0$$

i.e. Stable equilibrium

At $x = \frac{-b}{\sqrt{2}}$, $\frac{d^2u}{dx^2} = ae^{-1/2}\left[\frac{-3\sqrt{2}}{b} + \frac{4\sqrt{2}}{b^4}\left(\frac{b^3}{2\sqrt{2}}\right)\right]$

$= ae^{-1/2}\left[\frac{-2\sqrt{2}}{b}\right] = -\frac{2a}{b}\sqrt{\frac{2}{e}} < 0$

i.e. unstable equilibrium.

Stable equilibrium at $x = \frac{b}{\sqrt{2}}$.

Unstable equilibrium at $x = \frac{-b}{\sqrt{2}}$.

if $\frac{d^2u}{dx^2} > 0$ it indicates minima where stable equilibrium is obtained.

if $\frac{d^2u}{dx^2} < 0$ it indicates maxima where unstable equilibrium is obtained.

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Ans 4) General equation is given by:-

$m\ddot{x} + r\dot{x} + kx = 0$ where m is the mass of oscillator
$2\ddot{x} + 12\dot{x} + 50x = 0$ and r is the damping constant

(a) $r = 12$ Damping constant is the coefficient of $\dot{x}$.

$w_0 = \sqrt{\frac{K}{m}} = \sqrt{\frac{50}{2}} = 5s^{-1}$ Natural frequency (w_0) is given by $w_0 = \sqrt{\frac{K}{m}}$

1

(b) To find ~~dam~~ type of damping, we calculate β^2 & w_0^2.

where $\beta = \frac{r}{2m}$. and $w_0 = \sqrt{\frac{K}{m}}$.

We already calculated $w_0 = 5s^{-1}$ $\therefore$ $w_0^2 = 25$

$\beta = \frac{r}{2m} = \frac{12}{4} = 3$ $\therefore \beta^2 = 9$

$\because 25 > 9$

~~$w_0^2 > 9$~~ $\therefore w_0^2 > \beta^2$ i.e. it is

UNDERDAMPED.

The stiffness term dominates the damping resistance.
$\therefore$ oscillation occurs and motion is oscillatory and periodic.

Oscillation period is given by $T = \frac{2\pi}{w'}$ where w' is given by

~~$T =$~~ ~~$T = \frac{2\pi}{}$~~ $w' = \sqrt{w_0^2 - \beta^2}$

$$w' = \sqrt{w_0^2 - \beta^2} = \sqrt{25-9}$$
$$= \sqrt{16}$$
$$= 4s^{-1}$$

$$T = \frac{2\pi}{w'} = \frac{2\pi}{4} = \frac{\pi}{2}$$

2

$\therefore$ Time period is $\frac{\pi}{2}$.

(c) For system to return to equilibrium as quickly as possible, condition of critical damping is applied.

i.e. $\beta^2 = w_0^2$

$$\frac{r^2}{(2m)^2} = \frac{k}{m}$$

2

$$\frac{r^2}{(2\times2)^2} = 25$$

$$r^2 = 25 \times 16$$

$$r = 5\times4 = 20$$

$\therefore$ new value of damping constant will be 20.

The equation of motion then will be given by:-

$$2\ddot{x} + 20\dot{x} + 50x = 0$$

Ans 5) a) Two points - $A(0, \sqrt{2})$ and $B(-1,-1)$

~~For $A(0,\sqrt{2})$~~

For any point (x, y), polar coordinates are given by (r, θ) where $r = \sqrt{x^2+y^2}$ and $\theta = \tan^{-1}\left(\frac{y}{x}\right)$

For $A(0, \sqrt{2})$

$r = \sqrt{0^2+(\sqrt{2})^2} = \sqrt{2}$

$\theta = \tan^{-1}\left(\frac{\sqrt{2}}{0}\right) = N.D. \Rightarrow \theta = 90^\circ$

$\therefore$ polar coordinates of A are $(\sqrt{2}, 90^\circ)$

2

For $B(-1,-1)$

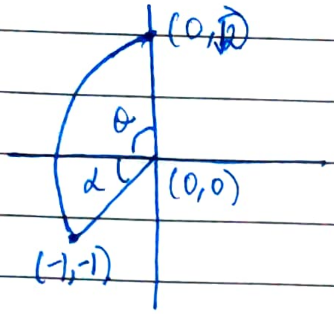
$r = \sqrt{(-1)^2+(-1)^2} = \sqrt{2}$

$\theta = \tan^{-1}\left(\frac{-1}{-1}\right) = 1 \Rightarrow \theta = 45^\circ$ But since, $(-1,-1)$ lies in 3^{rd} quadrant, we add 180°.

$\theta = 180^\circ + 45^\circ = 225^\circ$

$\therefore$ polar coordinates of B are $(\sqrt{2}, 225^\circ)$

(b)



$\tan\alpha = \left(\frac{-1}{-1}\right) = 1$

$\alpha = 45^\circ$

$\theta = 90^\circ$

0.5 + 2.5

Total angle subtended by circular sector $= \theta + \alpha$
$= 90^\circ + 45^\circ$
$= 135^\circ = \frac{3\pi}{4}$

Here, $r = \sqrt{2}$

$~~360^\circ \rightarrow 2\pi~~$
$~~1^\circ \rightarrow \frac{2\pi}{360^\circ}~~$
$~~135^\circ \rightarrow \frac{2\pi}{360^\circ}(135^\circ)~~$

Angle — Area
$360^\circ \rightarrow \pi r^2 \quad (r = \sqrt{2})$

$2\pi \rightarrow 2\pi$

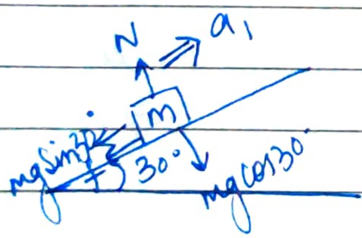
$1 \rightarrow \cancel{2\pi}/\cancel{2\pi}\ 1$

$\frac{3\pi}{4} \rightarrow \frac{3\pi}{4} \times \frac{1}{\cancel{2}} = \frac{3\pi}{4\cancel{8}}$

did not use correct definition

$\therefore$ Area of sector $= \frac{3\pi}{\cancel{8}4}$ sq. units

Ans 6) (a)



$f = \mu N \qquad N = mg\cos 30^\circ = \frac{\sqrt{3}}{2} mg$

$ma_1 = mg\sin 30^\circ + f$ → Force equation

$\cancel{m}a_1 = \frac{\cancel{m}g}{2} + \mu\frac{\sqrt{3}}{2}\cancel{m}g$

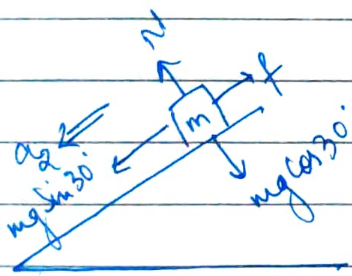
$a_1 = g\left(\frac{1}{2} + \frac{\sqrt{3}}{2}\mu\right)$

$$S = \frac{1}{2} a_1 t_1^2$$

$$s = \frac{1}{2} t_1^2 \left(\frac{g}{2} + \frac{\sqrt{3}}{2} \mu g \right)$$

$$t_1^2 = \frac{2s}{g\left(\frac{1}{2} + \frac{\sqrt{3}}{2}\mu \cancel{g}\right)} = \frac{4s}{g(1+\sqrt{3}\mu)}$$

$$t_1 = 2\sqrt{\frac{s}{g(1+\sqrt{3}\mu)}}$$

(b) 

$$N = mg\cos 30° = \frac{\sqrt{3}}{2} mg$$

$$f = \mu N$$

$$mg\sin 30° - f = ma_2 \quad \rightarrow \text{force equation}$$

$$\frac{\cancel{m}g}{2} - \frac{\mu\sqrt{3}}{2}\cancel{m}g = \cancel{m}a_2$$

$$a_2 = \frac{g}{2}(1-\sqrt{3}\mu)$$

$$S = \frac{1}{2} a_2 t_2^2$$

$$S = \frac{1}{2} t_2^2 \left(\frac{g}{2}(1-\sqrt{3}\mu) \right)$$

$$t_2 = 2\sqrt{\frac{s}{g(1-\sqrt{3}\mu)}}$$

(c) $\cancel{t_2 = 2t_1}$ $\mu = ?$

$t_1 = 2t_2$

We know, $t_1 = 2\sqrt{\dfrac{s}{g(1+\sqrt{3}\mu)}}$

$t_2 = 2\sqrt{\dfrac{s}{g(1-\sqrt{3}\mu)}}$

$\dfrac{t_1}{t_2}\ \cancel{\dfrac{t_2}{t_1}} = 2$

$$\frac{t_1}{t_2} = \frac{\dfrac{1}{\sqrt{1+\sqrt{3}\mu}}}{\dfrac{1}{\sqrt{1-\sqrt{3}\mu}}}$$

$$2\ \cancel{\frac{1}{2}} = \sqrt{\frac{1-\sqrt{3}\mu}{1+\sqrt{3}\mu}}$$

3

$$4 = \frac{1-\sqrt{3}\mu}{1+\sqrt{3}\mu}$$ (Squaring both sides)

$$4+4\sqrt{3}\mu = 1-\sqrt{3}\mu$$

$\cancel{\sqrt{3} = 5\sqrt{3}\mu}$

$\cancel{\mu = \frac{\sqrt{3}}{5}}$

$5\sqrt{3}\mu = -\sqrt{3}$

$\mu = -\dfrac{\sqrt{3}}{5}$ Coeff. of friction.

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Main Answer Booklet No. 294987

CONTINUATION TEST ANSWER BOOK

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Course Code: PHY101 Course Title: Introduction to Physics - I

Date: 27/9/24 Signature of Invigilator:

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Ans7) $\vec{F} = F_0 (e^{xy}\hat{i} + y^3\hat{j})$

$W = \int \vec{F} \cdot ds$

~~$W = \int \vec{F} \cdot (dx\hat{i} + dy\hat{j})$~~

~~$= e^{xy}\hat{i} + y^3\hat{j}$~~

(a) $W_{AA'B} = \int_{AA'} \vec{F} \cdot ds + \int_{A'B} \vec{F} \cdot ds$

$$= \int_{y=0,\,x=0}^{y=0,\,x=1} e^{xy}\hat{i} + \cancel{y^3\hat{j}}\, dx + \int_{x=1,\,y=0}^{x=1,\,y=1} e^{xy}\hat{i} + y^3\hat{j}\, dy$$

$$= \int_{x=0}^{x=1} 1\, dx + \int_{y=0}^{y=1} e^{y}\hat{i} + y^3\hat{j}\, dy$$

$$= [x]_0^1 + \left[e^{y} + \frac{y^4}{4}\right]_0^1$$

$$= \cancel{1} + e + \frac{1}{4} - \cancel{e^0}$$

$$W_{AA'B} = \frac{e+1}{4}$$

(b) For the line AB, $y=x$

$$W_{AB} = \int \vec{F} \cdot ds$$

$$= \int \vec{F} \cdot (dx\,\hat{i} + dy\,\hat{j})$$

$$= \int (e^{xy}\,\hat{i} + y^3\,\hat{j}) \cdot (dx\,\hat{i} + dy\,\hat{j})$$

$$= \int_{x=0,\,y=0}^{x=1,\,y=1} e^{xy}\,dx\,\hat{i} + y^3\,dy\,\hat{j}$$ (for AB, $y=x$)

$$= \int_0^1 (e^{x^2} + x^3)\,dx$$

$$= \left[xe^{x^2} + \frac{x^4}{4}\right]_0^1$$

$$= \frac{e+1}{4} - 0 - 0$$

$$W_{AB} = \frac{e+1}{4}$$

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(c) $\because W_{AB} = W_{AA'B}$, $\therefore$ the force is conservative.