August 7, 2021

Department of Mathematics and Natural Sciences

PHY111 - Principles of Physics-I

Midterm Assessment, Summer 2021

Time: 2 Hours (5:00 pm to 7:00 pm)

Total Marks: 30

Answer all questions.

1. The motion of a particle which moves along the straight line is defined by the relation $x(t) = t^3 - 9t^2 + 24t - 8$ where x and t are expressed in meters and seconds respectively. Note that the coefficients of t have dimensions accordingly.

(a) (4 marks) Determine when the velocity of the particle is zero.

(b) (4 marks) Calculate the position vector and distance travelled by the particle when the acceleration is zero. Consider that at the starting point time t = 0 sec.

(c) (2 marks) Does the particle move at constant velocity or constant acceleration? Justify your answer.

2. Fig. 1 shows a three-body system where m_1 and m_2 are connected by a string and both are sliding on the different surfaces of block M. A force $\vec{F}$ is applied on block M and the whole system moves to the right. Magnitude of the force $\vec{F}$ is $250\ N$ and the masses, $M = 20\ kg$, $m_1 = 3\ kg$ and $m_2 = 4\ kg$. All surfaces are frictionless, the pulley is massless, and the string is massless and inextensible.

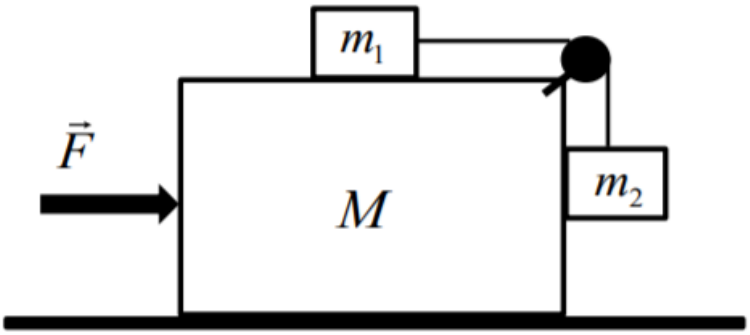

Fig. 1

(a) (2 marks) Draw the free body diagrams of m_1, m_2 and block M.

(b) (5 marks) Determine the acceleration vectors of all mobile bodies in the situation where they are always in contact as shown in Fig .1.

(c) (3 marks) Calculate the normal reaction forces on block M and m_1; tension in the string and contact force between block M and m_2.

3. In a Bangladesh-Australia cricket match, Sakib Al Hasan throws a ball towards the batsman. The ball starts to spin with 18.0 rev/s. The radius of the ball is 7.1cm.

(a) (2 marks) Find the tangential speed of the outer periphery of the ball as it spins.

(b) (2 marks) What is the centripetal acceleration of the cricket ball?

(c) (6 marks) Let's consider, due to air friction, the spin of the ball decays at the rate of 0.6 rev/s^2. Now find how long it will take for the ball to stop spinning and the total angle through which it will rotate during this time. (Consider the rate as constant).

PHY 111

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sec : 17

Ans to the qr no 1 (a)

Given,

$$x(t) = t^3 - 9t^2 + 24t - 8$$

velocity of the moving particle, $V = \frac{dx}{dt}$

Now, $\frac{d(xt)}{dt} = \frac{d(t^3 - 9t^2 + 24t - 8)}{dt}$

$\Rightarrow \frac{d(xt)}{dt} = 3t^2 - 2 \times 9t + 24 - 0$

$\Rightarrow \frac{d(xt)}{dt} = 3t^2 - 18t + 24$

$\therefore v = \frac{d(xt)}{dt} = 3t^2 - 18t + 24$

we have to determine the time (t) when valucity is zero. If is when,

$v = 3t^2 - 18t + 24 = 0$

$\Rightarrow 3(t^2 - 6t + 8) = 0$

$\Rightarrow t^2 - 4t - 2t + 8 = 0$

$\Rightarrow$

$\Rightarrow \quad t(t-4) - 2(t-4) = 0$

$\Rightarrow (t-2)(t-4) = 0$

$t = 2 \quad \text{or} \quad t = 4$

$\therefore$ velocity is zero at, $t = 2s, 4s.$

Ans to the NO 1 (b)

Acceleration of the particle, $a = \frac{dv}{dt}$

Now, $a = \frac{d}{dt}(3t^2 - 18t + 24)$

$a = 2.3t - 18$

$a = 6t - 18$

when, Acceleration is zero,

$6t - 18 = 0$

$t = 18/6 = 3\ s$

we know, $x(t) = t^3 - 9t^2 + 24t - 8$

for the value, $t = 3$,

$x(3) = (3)^3 - 9(3)^2 + 24 \times 3 - 8$

$\Rightarrow x(3) = 27 - 81 + 72 - 8$

$\Rightarrow x(3) = 10\ \hat{i}$

$$x(0) = (0)^3 - 9(0)^2 - 24(0) - 8$$

$$= -8$$

$$x(3) - x(0) = 10 - (-8)$$

$$= 18 \text{ m}$$

$\therefore$ distance 18 m

Answer to the or no 1 (c)

The motion of the particle,

$$x(t) = t^3 - 9t^2 + 24t - 8$$

from (a) we get,

$$v = \frac{d(xt)}{dt} = 3t^2 - 18t + 24$$

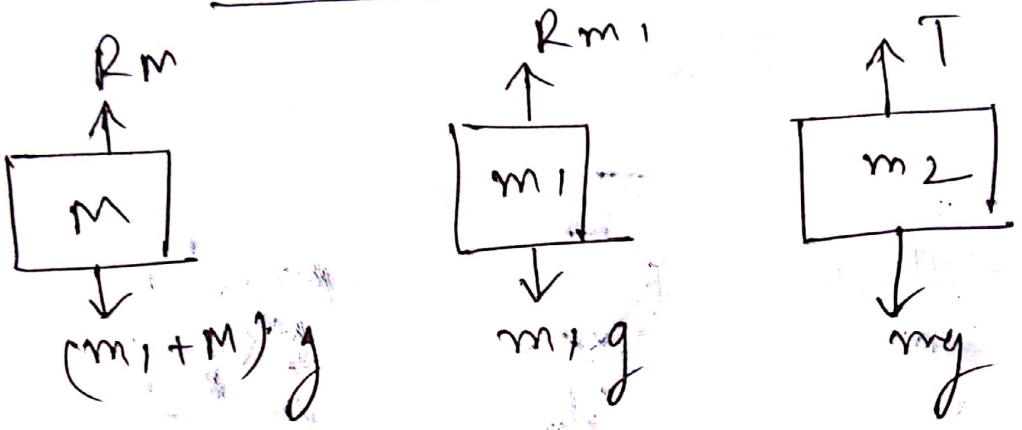
From (b) we get,

$$a = \frac{d(vt)}{dt} = 6t - 18$$

We can see from these equations that both ~~of~~ velocity and acceleration is depended on time (t).

∴ The particle does not move at constant velocity or acceleration.

Ans to the qr no 2 (a)



Ans to the qr no 2 (b)

Acceleration of pully,

$$T - m_2 g = m_2 a \quad \cdots (1)$$

$$T = m_1 a \quad \cdots (11)$$

from (1), (11),

$$m_1 a - m_2 g = -m_2 a$$

$$\Rightarrow a = \frac{m_2 g}{m_1 + m_2}$$

$$= \frac{4 \times 9.8}{4+3} = 5.6$$

$a = 5.6 \text{ m/s}^2$

since all the masses are connected the acceleration will be same for the whole system because it is a frictionless surface

$$\therefore a = 5.6 \text{ m/s}^2$$

Now, The total mass = (20+3+4) = 27 kg

Again, force magnatude, F = 250 N

we know, $F = ma$

$$a = \frac{f}{m} = \frac{250}{27} = 9.26 \text{ m/s}^2$$

on M, $a_M = 9.26\,\hat{i} - 9.8\,\hat{j}$ (Ans)

on m_1, $a_{m_1} = (9.26 + 5.6)\,\hat{i}$ (Ans)

$= 14.86\,\hat{i}$

m_2, $a_{m_2} = (9.81 + 5.6)\,\hat{j} + 9.26\,\hat{j}$ (Ans)

Ans to the qr no 2 (c)

we get from b, $a = 5.6\ m/s^{-2}$

$$T = m_1 a$$

$$= 3 \times 5.6 = 16.8$$

$$\therefore T = 16.8\ N$$

For M, reaction $F = -200\,\hat{i}$

For m_1, reaction $F = -(200 + 16.8)\,\hat{i}$

$$= -216.8\,\hat{i}$$

For m_2, reaction $F = -200\,\hat{i} + 414.2\,\hat{j}$

$$= -200\,\hat{i} + 16.84\,\hat{j}$$

Ans to the or no 3 (a)

Given,

The ball starts to spin with 18 rev/s

radius of the ball, $r = 7.1\ cm$

$= 0.071\ cm$

Angular velocity, $\omega = (2\pi 18)\ rad/s$

$= 113.097\ rad/s$

$\therefore$ Tangential speed, $v = \omega r$

$= 113.097 \times 0.071$

$= 8.029$

$\therefore$ Tangential speed, $v = 8.029\ m/s$

Ans to the or no 3(b)

we found,

tangential speed, $v = 8.029$ m/s

radius $= 0.071$ cm

The centripetal acceleration of the ball

$$a = \frac{v^2}{r}$$

$$= \frac{(8.029)^2}{0.071}$$

$$= 907.96 \text{ m/s}^2$$

∴ The centripetal acceleration 907.96 m/s²

Ans to the qr no 3 (c)

From a,

Angular velocity, $\omega_0 = 113.097$ rad/s

rate of decay, $\alpha = -0.6$ rev/s^2

$= -3.769$ rad/s^2

When the ball stops spinning ω would be equal to zero,

Now, $\omega = \omega_0 + \alpha t$

$\Rightarrow 0 = 113.097 - (3.769) \times t$

$\Rightarrow t = \frac{113.097}{3.77}$

$\Rightarrow t = 29.9999,$

$\Rightarrow t = 29.99$ s

$\therefore t = 30$ s

The total angle through which it will rotate is,

$$\theta = \left(\frac{\omega + \omega_0}{2}\right) t$$

$$= \left(\frac{0 + 113.097}{2}\right) \times 30$$

$$= 56.5485 \times 30$$

$$= 1696.45 \text{ rad}$$

$$= 269.9^\circ$$

$\therefore$ $\theta = 269.9^\circ$

$t = 30\,s$