September 18, 2021

Department of Mathematics and Natural Sciences

PHY111 - Principles of Physics-I

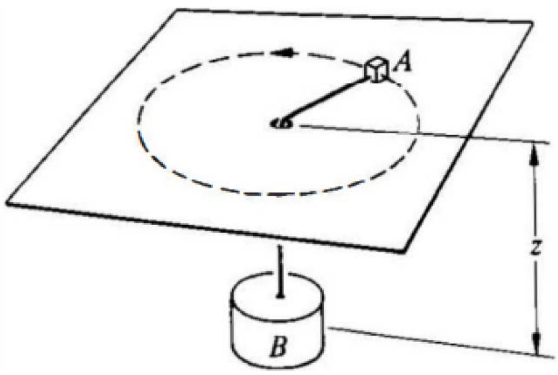
Final Assessment, Summer 2021

Time: 5:00 pm to 5:50 pm

Total Marks: 20

## Answer Q-1 and any one other question (in total two questions):

1. A horizontal frictionless table has a small hole in its center. Block A on the table is connected to block B hanging beneath by a string of negligible mass which passes through the hole. Initially, B is held stationary and A rotates at constant radius $r_0$ with steady angular velocity $\omega_0$.

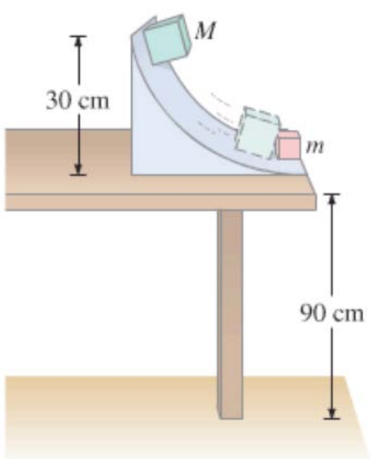



(a) (2 marks) Draw a free body diagram of all the mobile bodies.

(b) (3 marks) Find the radial and tangential component of the acceleration of block A.

(c) (5 marks) Find the acceleration of block B immediately after the release. Also find the tension in the string.

2. In a Physics lab, a cube $M = 4$ kg is slides down on a frictionless incline plane and elastically strikes with another mass $m = 2$ kg at the bottom of the incline as shown in the Figure. Just after the impact both the blocks move horizontally and strike the ground. Neglect the air friction for the following calculations.




(a) (4 marks) Calculate the velocities of each block just after the impact.

(b) (4 marks) Calculate the velocity of each of the blocks just before impact with the ground.

(c) (2 marks) Where does each of the blocks strikes the ground?

3. A block of mass $m$ = 2 kg is attached to a spring with spring constant k = 20 N/m. The block was pulled a distance $A$ = 5 cm from equilibrium along the positive $x$ axis. Now solve the following problems.

(a) (1 marks) Find the total energy of the system.

(b) (6 marks) Find the velocity, acceleration and the angular frequency of the block when $t$ = 2s. Also indicate their directions.

(c) (3 marks) Show that at any time $t$, the total energy of the system is conserved.

FINAL

# PHY 111

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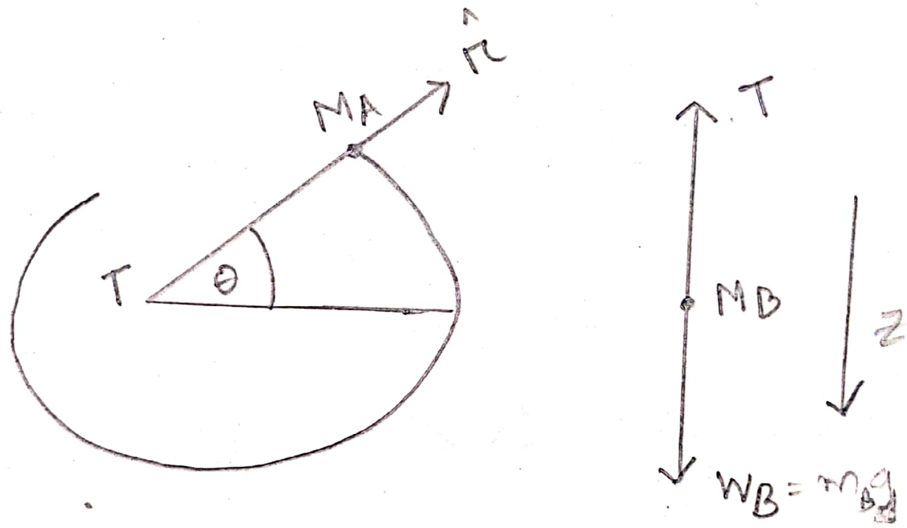
sec : 17

Ans to the qr no 1 (a)




free body diagram

Ans to the or no 1 (b)

constant radius of block A = $r_0$
steady angular velocity = $\omega_0$

∴ Radial acceleration of block A $= \frac{(-\omega_0 r_0)^2}{r_0}$

$= -\omega_0^2 r_0$

And, tangential acceleration = 0, since block moves with constant speed.

∴ Reqwired radial acceleration = $-\omega_0^2 r_0$

Tangential acceleration = 0

Ans to the qr no 1 (c)

Here,
Mass of block A = $m_A$
Mass of block B = $m_B$

For block B,
Tension, T = $m_B g$ ... (i)

For block A,
$$\frac{m_A v^2}{r_0} - F_c = m_A a \quad \ldots (ii)$$

Here, Centripetal acceleration of A = $\frac{m_A v^2}{r_0}$
Centripital force = $F_c$
acceleration = a

Again, $F_c = T$
$\Rightarrow F_c = m_B g$

From eq (II),

$$\frac{m_A v^2}{} - m_B g = m_A a$$

$$\Rightarrow m_A a = \frac{m_A v^2 - m_B g r_0}{R}$$

$$\Rightarrow a = \frac{m_A v^2 - m_B g r_0}{m_A r_0}$$

$\therefore$ Acceleration of block B $= \dfrac{m_A v^2 - m_B g r_0}{m_A r_0}$

$\therefore$ Tension in string, $T = m_B g$

Ans to the Q no 3(a)

Given,

Mass of block, $m = 2\ kg$

constant, $k = 20\ Nm^{-1}$

Distance pulled, $x = 5\ cm = 0.05\ m$

$\therefore$ Total energy of system $= \frac{1}{2} k x^2$

$= \frac{1}{2} \times 20 \times (0.05)^2$

$= 250\ J$

$\therefore$ Total energy $250\ J$

## Ans to the qr no 3 (b)

As the motion is periodic with amplitude at $t=0$ as 5 cm

at $t=0$,

$x(t) = A\cos(\omega t)$

$v(t) = -A\omega \sin(\omega t)$

$a(t) = -A\omega^2 \cos(\omega t)$

Here,

$\omega = \sqrt{K/m} = \sqrt{10}$

~~A = 0.05 m~~

At $t = 2$ sec,

$v(2) = -(0.05 \times \sqrt{10}) \sin(2\sqrt{10})$

$= -0.017 \ ms^{-1}$

acceleration, $a(2) = -(0.05 \times \sqrt{10}^2) \cos(2\sqrt{10})$

$= -0.497 \ ms^{-2}$

Here negative signs indicate direction along negative x axis.

$\therefore$ Angular frequency $\sqrt{10}$ rads$^{-1}$

velocity $0.017$ ms$^{-1}$ (along x axis)

acceleration $= 0.497$ ms$^{-2}$ x axis

Ans to the Q. no 3(c)

Total energy of spring $= \frac{1}{2}kx^2 + \frac{1}{2}mv^2$

$E = K + U$

$= \frac{1}{2}KA^2\cos(\omega t + \delta) + \frac{1}{2}KA^2\sin^2(\omega t + \delta)$

$= \frac{1}{2}KA^2$

At, $t = 0$,

$U = \frac{1}{2}KA^2 \sin^2 0 = 0$

$K = \frac{1}{2}KA^2 \cos^2(\omega^2 \times 0) = \frac{1}{2}KA^2$

At, $t = \frac{T}{4}$,

$U = \frac{1}{2}KA^2 \sin(\omega \times \frac{T}{4}) = \frac{1}{2}KA^2 \sin^2\frac{\pi}{2}$

$= \frac{1}{2}KA^2$

$K = \frac{1}{2}KA^2 \cos^2(\omega \times \frac{T}{4}) = \frac{1}{2}KA^2 \cos^2\frac{\pi}{2} = 0$

similarly $t = T$,

$U = \frac{1}{2} KA^2 \sin^2 \left(\frac{2\pi}{T} \times T\right) = 0$

$K = \frac{1}{2} KA^2 \cos^2 (\omega \times T) = \frac{1}{2} KA^2$

$\therefore$ At all time the total energy is $\frac{1}{2} KA^2$ and $A$ is amplitude

$\therefore$ energy is conserved.