Final Assignment
Summer 2024

Course Title: Physics I
Course Code: PHY 1101 (Summer 2024)

Submitted by:

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Ques. 1

a. Elastic Collision:- An elastic collision is a particular type of collision in which both momentum and kinetic energy are conserved. This kind of collision is called an Elastic collision and objects participating in these collisions have a total kinetic energy equaling each other before, and after the event. These deform slightly during the crash, but immediately return to their original shape after the collision and energy is conserved with no permanent loss of energy.

Momentum: Conserved

Kinetic Energy: Conserved

Inelastic Collision — Momentum is conserved, but kinetic energy is not. However, much of that kinetic energy is converted into other forms like heat, the two colliding objects become stuck together after the impact.
Momentum: Conserved

Kinetic Energy: Not conserved

b.

According to the principle of conservation of momentum, a closed isolated system keeps constant at any given time if no external forces are applied to it. This states that the sum off all the momenta before a collision or interaction is equal to the sum of all momentum after a collision or interaction, i.e.

For two objects this is (mathematically):

Where:

$$m_1.v_1 + m_2.v_2 = m_1.v_1' + m_2 + v_2'$$

m_1 and m_2 are the masses of the two objects

v_1 and v_2 are their initial velocities

v_1' and v_2' are their velocities after the interaction

c.

1. Definition of Moment of Inertia: The moment of inertia for a body is the integral of (distance from axis square. Measuring some distance from a reference, consider an infinitesimally small segment of the rod having mass at this distance from the axis of rotation.

2. Mass per unit length: The linear mass density.

$\lambda = \frac{M}{L}$

3. Element of mass: A tiny element of mass.

$dm = \lambda dx = \frac{M}{L} dx$

4. Moment of inertia about the axis at distance.

The distance from the element at x to the axis is $(x-a)$.

The moment of inertia for the element is

$$dI = (x-a)^2 dm$$

Integrating over the length of the rod:

$$I = \int_o^L (x-a)^2 \frac{M}{L} dx$$

$$I = \frac{M}{L}\int_0^L (x^2 - 2ax + a^2)dx$$

$$I = \frac{M}{L}\left[\frac{x^3}{3} - a + a^2 x\right]_0^L$$

$$I = \frac{M}{L}\left[\frac{L^3}{3} - aL^2 + a^2 L\right]$$

$$I = M\,(\frac{L^3}{3} - aL + a^2)$$

d.

$$x(t) = Acos(\omega t + \varphi)$$

A = amplitude

t = time

$\omega = angular\ frequency$

$\varphi = phase\ constant$

$$x_1 = Acos(\omega t_1 + \varphi)$$

$$x_2 = Acos(\omega t_2 + \varphi)$$

$$v_1 = A\omega sin\,(\omega t_1 + \varphi)$$

$$v_2 = A\omega sin\,(\omega t_2 + \varphi)$$

Total mechanical Energy E

$$E = \frac{1}{2}mv^2 + \frac{1}{2}\,kx^2$$

$$\frac{1}{2}mv^2 + \frac{1}{2}\,kx^2 = \frac{1}{2}\,mv_2^2 + \frac{1}{2}\,kx^2$$

Substitute

$$k = m\omega^2$$

$$v_1^2 + \omega^2 x_1^2 = v_2^2 + \omega^2 x_2^2$$

Angular Frequency ω^2

$$\omega^2 = \frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}$$

Time period,

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

Finally ω^2 substitute ω^2 into the equation for T,

$$T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}}$$

2 Question:

a.

The initial speed of the jar $v_1 = 1.4\ m/s$

Distance from the bottom of the incline, $d_1 = 45\ cm = 0.45\ m$

Kinetic Energy $\mu_k = 0.15$

g = 9.8 m/s

i)

Initial Kinetic energy,

$$KE_i = \frac{1}{2}mv_i^2 = \frac{1}{2}m(1.4)^2 = 0.98\ mJ$$

Fractional Force f_1 given,

$$f^1 = \mu_k mgcos\theta$$

$$= 0.15. m. 9.8. cos40° = 1.13m$$

Fractional For a distance d is

$$w_f = f_f. d = 1.13m. d$$

Potential energy, gained by moving a distance d is

$$PE = mgdsing\theta = m. 98. d. sin40° = 6.63m. d$$

- $KE_i = PE + w_f$

$\rightarrow 0.98 = (6.3m. d) + (1.13. d)$

$\rightarrow 0.98 = 7.43d$

$$d = \frac{0.98}{7.43} = 0.132\ m$$

Thus the jar moves 0.132 m farther up to the incline before stopping.

ii)

The jar moves a total distance of $d_i\ + d = 0.45 + 0.132 = 0.582\ m$

The Potential energy lost is

$$PE = mgh = m.9.8.(0.582.sin40°) = m.366\ J$$

The work done by friction over a distance of 0.582m

$$w_f = \ f_f.d = \ 1.13m.0.582 = 0.658\ mJ$$

Final Kinetic energy,

$$KE_f\ = PE - w_f$$

$$= 3.66m - 0.658$$

$$= 3.002mJ$$

$$KE_f\ = \frac{1}{2}mv_f^2$$

$$v_f^2\ = 6.004$$

$$v_f\ = \sqrt{6.004} = 2.45\ m/s$$

Thus, the jar will be moving at a speed of approximately 2.45 m/s when it reaches the bottom of the incline.

b)

M=0.56kg (mass of the stick),

L=1m (length of the stick),

The axis is located at the 20 cm mark, so a = 0.20 m

Formula

$$I = \frac{L^2}{3} - aL + a^2$$

$$I = \frac{1^2}{3} - 0.20.1 + 0.20^2$$

$$I = \ 0.56(0.3333 - 0.20 + 0.04)$$

$$I = 0.56(0.1733)$$

$$I = 0.097 kg \cdot m2$$

The rotational inertia III of the meter stick about an axis located at the 20 cm mark is approximately,

$$0.097 kg \cdot m2$$

3 Question:

a)

Given,

$m_1 = 2.0$ kg

$m_2 = 5.0$ kg

$v_1 = 10$ m/s

$v_2 = 3.0$ m/s

k = 1120 N/m

Linear Momentum

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_f$$

$$= (2.0)(10) + (5.0)(3.0) = (2.0 + 5.0) v_f$$

$$\rightarrow 20 + 15 = 7 v_f$$

$$\rightarrow v_f = \frac{35}{7} = 5\ m/s$$

Total initial kinetic Energy

$$KE_{initial} = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

$$= \frac{1}{2}(2.0)(10)^2 + \frac{1}{2}(5.0)(3.0)^2$$

$$KE = 122.5\ J$$

$$v_f = 5\ m/s$$

The Final Kinetic Energy

$$KE_{final} = \frac{1}{2}(m_1 + m_2) v_f^2$$

$$= \frac{1}{2}(7.0)(5.0)^2$$

$$= 87.5\ J$$

$$PE_{spring} = KE_{initial} - KE_{final}$$

$$= 122.5 - 87.5\ J$$

$= 35.0\,J$

Maximum Compresion is

$PE_{spring} = \frac{1}{2}kx_{spring}^2$

$\rightarrow 35.0\,J = \frac{1}{2}(1120)x_{max}^2$

$\rightarrow x_{max}^2 = \frac{35.0\,J}{560}$

$\rightarrow x_{max}^2 = 0.0625\,m^2$

$x_{max} = \sqrt{0.0625}$

= 0.25 m

The Maximum compression of the spring is 0.25 m.

b)

Given,

A = 2.0 m

$v_{max} = 1.5\,m/s$

The maximum speed is related to the angular frequency and the amplitude as ,

$v_{max} = A\omega$

$\rightarrow \omega = \frac{v_{max}}{A}$

$\rightarrow \omega = \frac{1.5\,m/s}{2.0\,m}$

= 0.75 rad/s

The Angular frequency of the oscillations is 0.75 rad/s

4 Question:

a)

Given,

$$u_x = 25m/s$$

$$v_{y1} = 25m/s$$

$$h = 3m$$

i)

Before the explosion, the horizontal momentum of the bomb is:

$$Pinitial = mbomb \cdot vinitial = m \cdot 25$$

After the explosion, the other fragment would be moving in velocity. v_2 Since the fragment with vertical motion doesn't have any horizontal momentum (it's moving straight up), we can write:

$$m.25 = \frac{m}{2}.v_2$$

$$v^2 = 50m/s$$

Thus, the velocity of the other fragment after the explosion is 50 m/s horizontally.

ii)

To find how long the second piece will be in the air, we substitute this to the formula for free fall.

$$h = \frac{1}{2}gt^2$$

h = 3m (the height)

g = 9.8m/s (acceleration due to gravity)

Rearranging for t:

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2.3}{9.8}} = \sqrt{0.612} = 0.78\,second$$

Horizontal Distance $= v_{2x} \times t = 50 \times 0.78 = 39.1\ m$

So, the fragment travels 39.1 meters horizontally before hitting the ground

4 Question:

b)

The gravitational force mg

The Normal Force N

Radial component : $mg\ cos\theta$

Tangential component : $mg\ sin\theta$

In The radial direction, the centripetal force is provided by the normal and the radial component of gravity

$$N + mg\ cos\theta = \frac{mv^2}{R}$$

The Block loses contact when the Normal Force $N = 0$

$$mg\ cos\theta = \frac{mv^2}{R}$$

$$v^2 = gRcos\theta$$

The Total Mechanical energy,

$$\theta = 0°$$

$$mgh = \frac{1}{2}mv^2$$

$$mgR = mgRcos\theta + \frac{1}{2}v^2$$

$$gR = gRcos\theta + \frac{1}{2}gRcos\theta$$

$$gR = (gRcos\theta)\left(1 + \frac{1}{2}\right)$$

$$gR = \frac{3}{2}gRcos\theta$$

$$cos\theta = \frac{2}{3}$$

The vertical distance x is given by,

$$x = R(1 - cos\theta)$$

$$x = R\left(1 - \frac{2}{3}\right)$$

$$x = \frac{R}{3}$$

The block loses contact with the spare at the distance of $\frac{R}{3}$ below the top of the sphere