NATIONAL UNIVERSITY OF SCIENES & TECHNOLOGY

APPLIED PHYSICS (PHY-102)

Assignment # 3

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Class: BEE-12-C

Semester: 1st

Dated: 10/12/2020

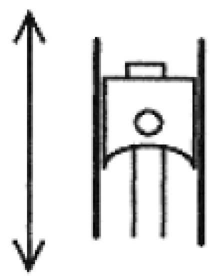
CMS ID: 345834

PHY-102 Applied Physics

Assignment #3

Date: 07-12-2020 Submission Date: 14-12-2020

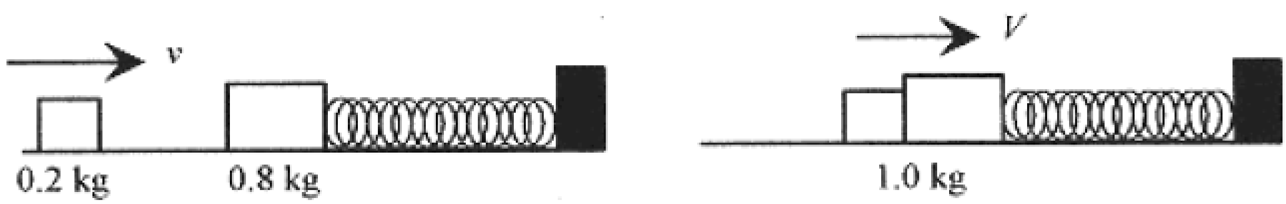
1) A piece of metal rests on top of a piston executing simple harmonic motion in the vertical plane with an amplitude of 0.20m. At what frequency will the piece of metal "float" at the top of the cycle?



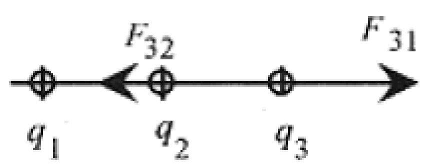
2) An oscillating mass-spring system has displacement 10cm, velocity -12m/s, and acceleration $-20 m/s^2$. What is the period of the system?

3) Find the maximum velocity of a mass-spring system with mass 2.0kg, spring constant 0.80 N/m, and amplitude of oscillation 0.36m.

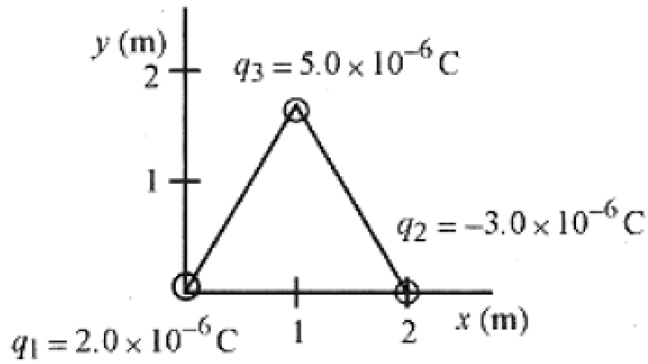
4) A 0.20kg block traveling at 20 m/s slides into and sticks to an 0.80kg block resting on a frictionless surface and connected to a spring with force constant 80N/m. What is the angular frequency, frequency, and displacement as a function of time? Also, what fraction of the original energy in the moving block appears in the system?



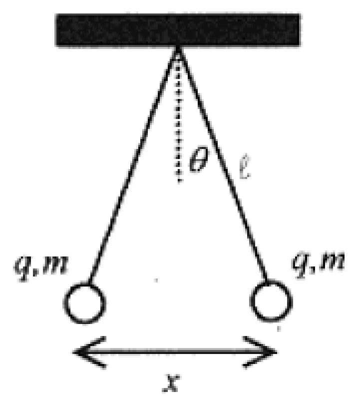
5) Consider a line of charges, q_1 = 8.0μC at the origin, q_2 = -12μC at 2.0 cm, and q_3 = 10μC at 4.0cm, as shown in Figure. What is the force on q_3 due to the other two charges?



6) Arrange three charges in the form of an equilateral triangle as shown in Figure and find the force on q_3 due to the other two.

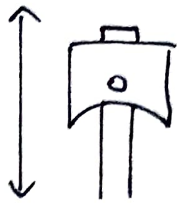


7) Consider two conducting balls both of mass m and equal charge q suspended by nonconducting cords of equal length, l as shown in Figure. How does the separation of the balls depend on charge, mass, and length?



1)

The metal floats when piston is moving downward and hence, has acceleration greater than g.



As $a = \omega^2 A$

$a = \omega^2 (0.2)$

Now,

$a = g$

$0.2\,\omega^2 = 9.8$

$\omega^2 = 49$

$\omega = 7$ rad/s

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

$\frac{1}{f} = \frac{2\pi}{\omega}$

$\omega = 2\pi f \Rightarrow f = \frac{\omega}{2\pi}$

$f = 1.11\ s^{-1}$

2)

$x(t) = x_0 \cos(\omega t + \phi)$

$v(t) = -x_0 \omega \sin(\omega t + \phi)$

$a(t) = -x_0 \omega^2 \cos(\quad + \phi)$

Given x, v and a at $t = 0$

1 • $\underline{0.1\,m = x_0 \cos(\phi)}$

2 • $+12\,m/s = +x_0 \omega \sin(\omega(0) + \phi) \Rightarrow \underline{12 = x_0 \omega \sin(\phi)}$

3 • $+20\,m/s^2 = +x_0 \omega^2 \cos(\phi) \Rightarrow \underline{20 = x_0 \omega^2 \cos(\phi)}$

Dividing 3 by 1

$\frac{20}{0.1} = \frac{\cancel{x_0}\, \omega^2 \cancel{\cos(\phi)}}{\cancel{x_0} \cancel{\cos(\phi)}}$

$\omega^2 = 200$

$\boxed{\omega = 14.14\ rad/s}$

As,

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

$$T = \frac{2\pi}{14.14}$$

$$\boxed{T = 0.44s}$$

3)

$V_{max} = ?$

$x_o = 0.36m$

$m = 2kg$

$k = 0.80 N/m$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{2}{0.8}} = 9.93s$$

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

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{9.93} = 0.632 \text{ rad/s}$$

$$V_{max} = \omega x_o$$

$$V_{max} = (0.632)(0.36)$$

$$V_{max} = 0.227 \text{ m/s}$$

4)

$m_1 = 0.2kg$ $m_2 = 0.8kg$

$V_1 = 20m/s$

$m_T = 1kg$

$$m_1V_1 + m_2V_2 = M_T V$$

$$(0.2)(20) + (0.8)(0) = (1)V$$

$$\boxed{V = 4 m/s}$$

$$T = 2\pi\sqrt{\frac{m_T}{k}} = 2\pi\sqrt{\frac{1}{80}}$$

$$T = 0.702\,s$$

$$f = \frac{1}{T} = 1.42\,s^{-1}$$

$$\omega = 2\pi f$$

$$\omega = 2\pi(1.42)$$

$$\omega = 8.944\,rad/s$$

As $V_{max} = \omega A$

$$4 = (8.944)A$$

$$A = x_0 = 0.447\,m$$

$$x(t) = x_0 \cos(\omega t + \phi)$$

$$x(t) = 0.447 \cos(8.94t + \phi)$$

Initial Energy of $m_1 = \frac{1}{2}m_1 V_1^2$

$$= \frac{1}{2}(0.2)(20)^2$$

$$= 40\,J$$

Total Energy of System $(m_T) = \frac{1}{2}kA^2$

$$= \frac{1}{2}(80)(0.447)^2$$

$$= 8\,J$$

Fraction of $m_1 = \frac{8}{40} \times 100$

$$= 20\% \text{ or } \frac{1}{5}$$

5)

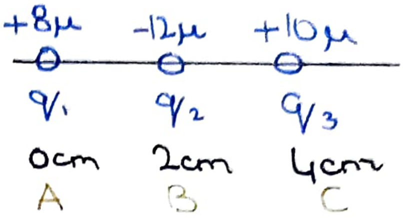
$$F_{q_3} = F_{CA} + (-F_{CB})$$

$$= \frac{k|q_3||q_1|}{d^2} - \frac{k|q_3||q_2|}{d^2}$$

$$= \frac{k|10\times10^{-6}||8\times10^{-6}|}{(0.04)^2} - \frac{k|10\times10^{-6}||-12\times10^{-6}|}{(0.02)^2}$$

$$= 450 - 675$$

$$= -225\,N \quad \text{or} \quad \boxed{225\,N \text{ towards -ive } x\text{-axis}}$$



6)

Let $q_1 = A$, $q_2 = B$, $q_3 = C$

★ $F_x = F_{CAx} + F_{CBx}$

$$= F_{CA}\cos(60) + F_{CB}\cos(60)$$

$$= (0.0225 + 0.03375)(\cos 60)$$

$$F_x = 0.028\,N$$

★ $F_y = F_{CAy} - F_{CBx}$

$$= (0.0225 - 0.03375)\sin(60)$$

$$F_y = -0.00974\,N$$

$$F_{net} = \sqrt{F_x^2 + F_y^2}$$

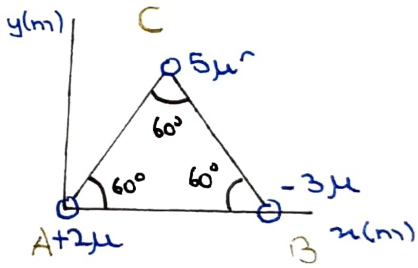
$$= \sqrt{(0.028)^2 + (-0.00974)^2}$$

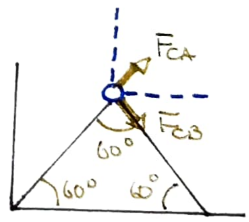
$$= 0.0296\,N$$

$$\theta' = \tan^{-1}(F_y/F_x) = 19.18°$$

$$\boxed{\theta_F = 2\pi - \theta' = 340.8°}$$

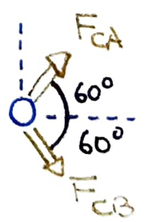
$F_{net} = 0.0296\,N$ at $340.8°$





$$F_{CA} = \frac{kq_3q_1}{d^2}$$

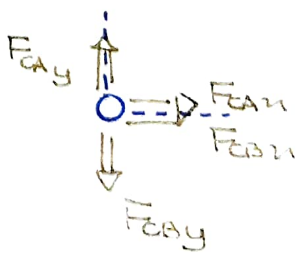
$$F_{CA} = 0.0225$$



$$F_{CB} = \frac{kq_3q_2}{d^2}$$

$$F_{CB} = 0.03375$$

★



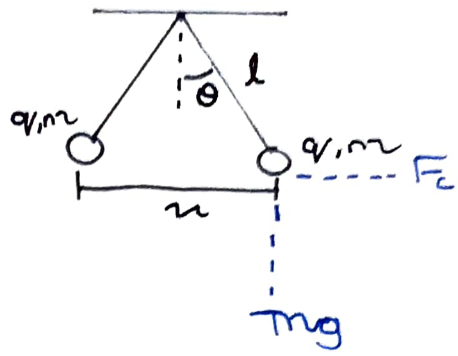
7)

$$T\sin\theta = F_c$$

$$T\cos\theta = mg$$

$$\tan\theta = \frac{F_c}{mg}$$

$$\tan\theta = \frac{kq^2}{x^2 mg}$$



For small θ, $\tan\theta \simeq \sin\theta$

$$x^2 = \frac{kq^2}{mg\sin\theta}$$

From figure, $\sin\theta = \frac{x/2}{l} = \frac{x}{2l}$

$$x^2 = \frac{kq^2 2l}{mgx}$$

$$x^3 = \frac{kq^2 2l}{mg}$$

$$\boxed{x = \left(\frac{2lkq^2}{mg}\right)^{1/3}}$$