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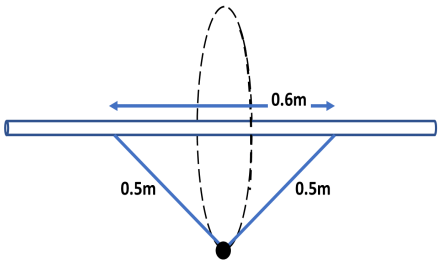
Contents

1 Uniform Circular Motion

1. **(PSPM 08/09)**

   (a) What is meant by centripetal force?

   (b) Calculate the centripetal acceleration of an object at the equator due to rotation of earth. The radius of earth is $6.4 \times 10^6 m$. [**Ans:** $a_c = 3.39 \times 10^{-2} ms^{-2}$]



   (c) The figure above shows a $0.3kg$ object attached to a horizontal rod by two strings, each of length $0.5m$. The object is whirled with speed $8.0ms^{-1}$ around the rod axis. Calculate the tension in the string when the object is at the

      i. lowest point [**Ans:** $T = 31.9N$]

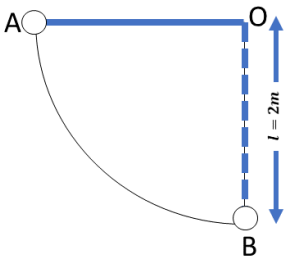
      ii. highest point [**Ans:** $T = 28.2N$]

2. **(PSPM 10/11)**
   A $0.2kg$ ball, attached to the end of a string, is rotated in a horizontal circle of radius $1.5m$ on a frictionless table surface. The string will snap when the tension exceeds $50N$.

   (a) What is the maximum speed of the ball? [**Ans:** $v_m ac = 19.4ms^{-1}$]

   (b) If there were friction on the table, what will happen to the maximum speed of the ball? Explain your answer.

3. **(PSPM 10/11)**



   A small bob of mass $10g$ is attached to the end of a massless string of length 2 m. The other end of the string is fixed at point O as shown in the figure above. Initially the bob is held at point A which is at the same level as point O, keeping the string taut and then released. Determine

   (a) the linear velocity of the bob at point B directly beneath point O.[**Ans:** $v_B = 6.26ms^{-1}$]

   (b) the angular velocity of the bob at point B. [**Ans:** $\omega_B = 3.13rad\ s^{-1}$]

   (c) the tension of the string when the bob is at point B. [**Ans:** $T_B = 0.294N upwards$]

   (d) the linear velocity of the bob at a point midway through arc AB. [**Ans:** $v_c 5.26ms^{-1}$]

   (e) whether the linear velocity of the bob at point B be lower, higher or similar if the experiment is performed on the surface of the moon. Explain your answer briefly.

4. **(PSPM 11/12)**

   (a) A cyclist negotiates a curve at constant speed. Is the cyclist accelerating? Explain your answer.

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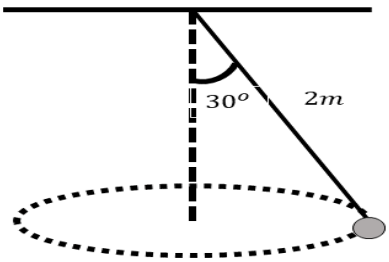


(b) shows a $0.6kg$ ball revolving in a horizontal circle. It is hung using a cord of length $2m$ which makes an angle of 30^o with the vertical.

i. Sketch and label all forces on the ball.

ii. In what direction is the acceleration of the ball?

iii. Calculate the speed of the ball. [**Ans:** $v = 2.38ms^{-1}$]

(c) A car is rounding a flat unbanked curve with radius $250m$. The coefficient of friction between the tyres and road is 0.92.

i. Sketch and label all forces on the car.

ii. Calculate the maximum speed at which the driver can take the curve without sliding. [**Ans:** $v = 47.5ms^{-1}$]

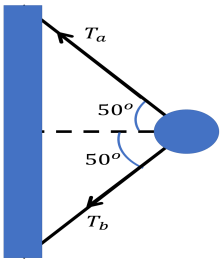
5. **(PSPM 12/13)**

(a) Name the centripetal force that is responsible for the following motions:

i. A car moves around a curve without skidding.

ii. The moon orbiting the earth.

(b) The diagram below shows a bob revolves in a horizontal circle of radius r. The string has a length of $0.5m$ and makes 30^o with the vertical.



i. Sketch the free body diagram for the bob.

ii. Calculate the speed of the bob. [**Ans:** $v = 1.19ms^{-1}$]

iii. Calculate the period of revolution. [**Ans:** $T = 1.32s$]

6. **(PSPM 13/14)**
A $60cm$ conical pendulum bob revolves freely. The pendulum string makes an angle of 37^o with the vertical.

(a) Sketch and label a free body diagram of the pendulum bob

(b) Calculate the speed of the pendulum bob

(c) Calculate the angular velocity of the pendulum bob

(d) If the angle remains unchanged but a longer string is used, will the angular velocity decrease, same, or increase? Justify your answer.

7. **(PSPM 14/15)**

(a) A body is performing a uniform circular motion.

i. Explain why the body experiences a force despite it is moving with constant speed.

ii. Write an equation of the force **and** state its direction.

(b) Two ice skaters, each of mass $60kg$ hold hands and spin in a circle with a period of $4.3s$. The distance between then is $1.44m$.

i. Calculate the angular velocity.

ii. Calculate the centripetal acceleration.

iii. Calculate the pulling force that acts on each hand.

iv. Describe their subsequent motion after they separate.

8. **(PSPM 15/16)**

(a) What is meant by centripetal force?

(b) A cyclist rides on a horizontal circular track. With the aid of an appropriate labeled force diagram, explain why the cyclist has to lean towards the centre of the track

(c) Refer to cyclist in the previous question. Let v be the maximum speed of the cyclist, r be the radius of the tracks, μ be the friction coefficient between the tyres and track, and g be the gravitational acceleration. Determine μ in terms of v, r and g.

9. **(PSPM 16/17)**

(a) Sketch the change in velocity of an object due to changing positions on the path of a uniformly circular motion.

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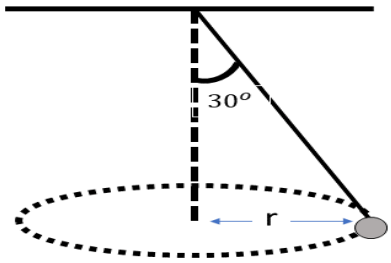
(b) A $250g$ bob suspended by a light string rotates as a conical pendulum, forming a horizontal circle of radius $30cm$ with a linear speed of $2ms^{-1}$.

i. Calculate the angle between the vertical axis and the string

ii. Calculate the tension in the string

iii. If the speed is increased, how would it affect the circular motion of the bob. Explain your Answer.

10. **(PSPM 17/18)**

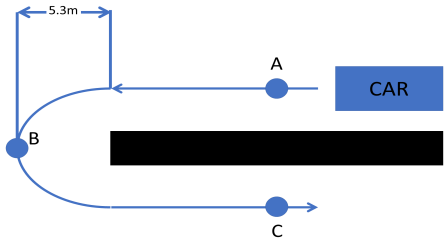


The diagram above shows a $4kg$ object attached to a vertical rod by 2 strings. The object rotates in a horizontal circle of radius $1.3m$ at a constant speed $6.0ms^{-1}$. Calculate the

(a) tension T_a in the upper string.

(b) tension T_b in the lower string.

11. **(PSPM 18/19)**



The diagram above shows the top view of a U turn of a car at a road divider. The radius of the circular curve is $5.3m$. A $950kg$ maintains a speed of $15.3ms^{-1}$ along points A to C

(a) Copy the path and indicate the directions of the velocity and acceleration of the car at point B

(b) Calculate the centripetal acceleration of the car at point B.

(c) Calculate the centripetal force on the car at point B.

(d) Determine the magnitude and direction of the frictional force on the car at point B.

2 Newtonian Gravity

1. **PSPM (05/06)**
MATSAT is a $2000kg$ satellite that is seen stationary to an observer on earth. It is orbiting with radius $r_1 = 42000km$ from the centre of the earth. The mass of the earth is $6 \times 10^{24}kg$.

(a) Why does the satellite appear stationary to the observer on earth? [**Ans:** Because the period and direction of the satellite orbiting the earth equal to the period and direction of the earth revolves about its axis.]

(b) Explain why the satellite accelerates whereas it is moving at constant speed? [**Ans:** When the satellite orbits the earth at constant speed, the direction of the satellite changes with time thus the change in the velocity occurred. Therefore the satellite will experience acceleration and its direction always toward the centre of the earth.]

(c) Calculate the acceleration of the satellite. [**Ans:** $a = 0.227ms^{-2}$ towards the centre of the earth]

(d) Calculate the escape velocity of the satellite from the earth atmosphere. [**Ans:** $v_e = 4365ms^{-1}$]

(e) Calculate the change in the potential energy of the satellite as it falls to an orbit of radius $r_2 = 21000km$ from the earth's centre. [**Ans:** $\Delta U = -1.91(10^{10})\ J$]

(f) Sketch a graph of gravitational potential V against distance r from r_2 to r_1.

2. **PSPM (06/07)**
A spherical asteroid has a radius of $12 \times 10^3 m$ and a mass of $4 \times 10^15 kg$.

(a) Calculate the gravitational acceleration at the surface of the asteroid. [**Ans:** $g = 1.85(10^{-3})\ ms^{-2}$]

(b) Sketch a labelled graph that shows the variation of the gravitational field strength, g, with distance, r from the centre of the asteroid.

(c) Suppose the asteroid spins about an axis through its centre with an angular speed,ω. What is the value of ω when a loose rock at the asteroid's equator begins to fly off its surface. [**Ans:** $\omega = 3.93(10^{-4})\ rad\ s^{-1}$]

3. **PSPM (07/08)**
At what altitude from the surface of the earth will the acceleration due to gravity be reduced

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by 10 percent? (Radius of the earth = $6.4 \times 10^6 m$) [**Ans:** $h = 3.5(10^5)m$]

4. **PSPM (08/09)**
Calculate the centripetal acceleration of an object at the equator due to rotation of earth. The radius of earth is 6.4×10^6 m. [**Ans:** $a_c = 3.39 \times 10^{-2} ms^{-2}$]

5. **PSPM 09/10**
Given the masses of the sun and the earth are $1.99 \times 10^{30} kg$ and $5.98 \times 10^{24} kg$ respectively. Calculate the gravitational force between them when their centers are $1.50 \times 10^{11} m$ apart. [**Ans:** $F = 3.53 \times 10^{22} N$]

6. **PSPM 11/12**
A $1000kg$ satellite in an orbit $350km$ above the earth surface. Calculate the
   (a) speed of the satellite. [**Ans:** $v = 7.7(10^3) ms^{-1}$]
   (b) period of the satellite. [**Ans:** $T = 5.51(10^3) s$]
   (c) radial acceleration of the satellite. [**Ans:** $a_r = 8.78 ms^{-2}$]

7. **PSPM 11/12**
Mass m_1 positioned between two masses, $m_2 = 40kg$ and $m_3 = 60kg$. m_2 and m_3 are separated by $15m$. m_1 is placed at a distance x from m_2. Determine the position of m_1 when m_1 will experience zero net gravitational force. [**Ans:** $x = 6.74m$ from m_2]

8. **PSPM 13/14**
The mass and radius of the earth are $5.974 \times 10^{24} kg$ and $6371km$ respectively. Calculate the period of revolution of a satellite that is $100km$ above the earth surface. [**Ans:** $T = 5181.3s$]

9. **PSPM 14/15**
Calculate the acceleration of Earth's gravity at a distance of $500km$ above the Earth's surface. The radius and the mass of the Earth are $6.4 \times 10^6 m$ and $5.98 \times 10^{24} kg$ respectively. [**Ans:** $g = 8.38\ ms^{-1}$]

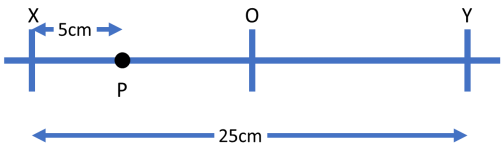
10. **PSPM 14/15**
A satellite orbits the Earth in a period of 24 hours so that it is always at the same point above the Earth's surface. Calculate the radius of the orbit. The radius and the mass of the Earth are $6.4 \times 10^6 m$ and $5.98 \times 10^2 4kg$ respectively. [**Ans:** $r = 3.59(10^7)\ m$]

3 SHM

1. A beam oscillates according to $x = (2m)sin(\pi t)$. What are the amplitude, maximum velocity, maximum acceleration, frequency, and period?

2. A spring makes 10 vibrations in 20 seconds. Calculate the period and frequency of the vibration. If the spring vibrates with an amplitude of $3cm$ and starts at the origin, write down the general equation relating displacement to time.

3. **PSPSM 13/14**



The figure above shows a bead executing a simple harmonic motion with a period of $1.8s$, along a straight line between points, X and Y, which are 25cm aparts. Point O is at the midpoint between X and Y.

   (a) Write an equation for the displacement of the bead.
   (b) Calculate the magnitude of acceleration **and** velocity of the bead at point P.
   (c) Calculate the positions along XY when the kinetic energy and the potential energy of the bead are equal.

4. **PSPSM 13/14**
A vertical spring extends by $3cm$ when a $100g$ mass is suspended at its end.
   (a) Calculate the period of oscillation of the spring when a mass of 150g is added to the system.
   (b) If the spring with the same load is allowed to oscillate horizontally on a frictionless surface, will the period decrease, same or increase?

5. **PSPSM 14/15**
A $25g$ block connected to one end of a spring is displaced $15cm$ from its equilibrium position and released. The spring constant is $180Nm^{-1}$.
   (a) Write the acceleration a of the SHM equation of the block in term of displacement x.

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(b) Sketch the graph of displacement versus time of the block. Label the amplitude and the period of oscillation on the graph.

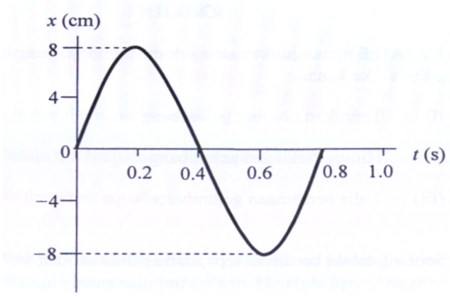
(c) Calculate the instantaneous speed of the block at a distance $11cm$ from the equilibrium position.

(d) Calculate the total energy of the system.

(e) On the same graph, sketch and label the variation of kinetic energy and potential energy versus displacement. On the graph, indicate maximum velue of each curve (if any) and the amplitude.

(f) The spring is removed and then the $25g$ block is connected to a **string**. The string-block system oscillates as a simple pendulum system. What effect on the peeriod of oscillations if the mass of the block is reduced by half. Explain your answer.

6. **PSPSM 15/16**



A $0.2kg$ object performs SHM with displacement, x from the equilibrium point as in the figure above.

(a) Determine the amplitude.

(b) Calculate the angular velocity.

(c) Calculate the total energy of the system.

7. **PSPSM 15/16**
The displacement x of a particle varies with time, t is given by $x(t) = 4cos(2\pi t + \frac{\pi}{2})$ where x is in cm and t is in s. Calculate the

(a) frequency of the motion.

(b) velocity of the particle at $t = 2s$.

(c) acceleration of the particle at $t = 2s$.

8. **PSPSM 17/18**
In an engine, a $200g$ piston oscillates in a simple harmonic motion with displacement varying according to $x(t) = 5cos(2t)$ where x is in metres and t is in seconds.

(a) Write the exression for the vibrational velocity as a function of time, $v(t)$.

(b) Sketch the graph of velocity against time of the piston for the first complete cycle starting from $t = 0$

(c) Calculate the maximum acceleration of the system.

(d) Calculate the total energy of the system

9. **Extra:**
A massive block resting on a tabletop is attached to an anchored horizontal spring. There is negligible friction between the massive block and the tabletop. The oscillation frequency is f.
A much less massive block is placed on top of the large block. The coefficient of static friction between the two blocks is μ_s. Show that the largest amplitude of oscillation of the large block which permits the small block without slipping is

$$A_{max} = \frac{\mu_s g}{4\pi^2 f^2}$$

where g is the gravitational acceleration.

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4 Waves

1. **PSPM 13/14**

   (a) A progressive wave is represented by the equation

   $$y(x,t) = 1200sin\ (314t - 0.42x)$$

   where x and y are in cm and t is in second.Determine the

   i. velocity of wave [Ans: $v_{wave} = 7.48ms^{-1}$]

   ii. maximum velocity of the particle [Ans: $v_{max} = 3768ms^{-1}$]

   (b) A mechanical wave propagates at $550ms^{-1}$ along a string stretched to a tension of $800N$. The string oscillates at fundamental frequencyn $440Hz$. Calculate the

   i. mass per unit length of the string [Ans: $\mu = 2.64(10^{-3})kg\ m^{-1}$]

   ii. length of the string [Ans: $l = 0.63m$]

   iii. frequency of the second overtone [Ans: 3^{rd} Harmonic, $f_3 = 1330Hz$] **and** sketch the waveform of the overtone

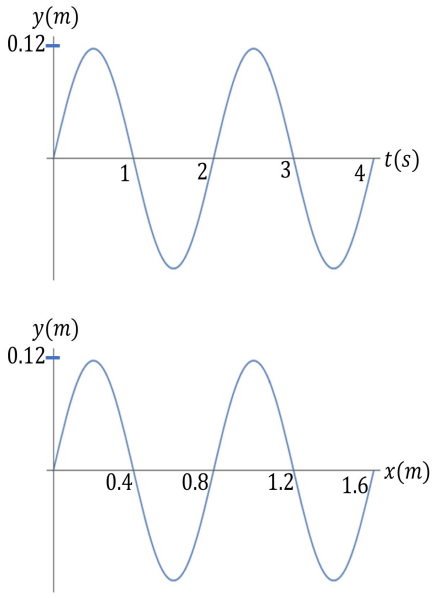
   (c) Define

   i. sound intensity

   ii. Doppler effect

2. **PSPM 14/15**

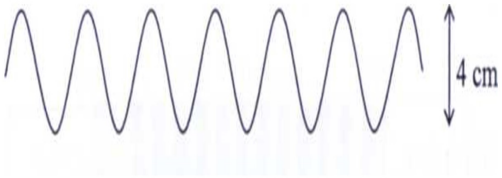
   (a)



   The figure above shows the graphs of displacement versus distance and displacement versus time of a progressive wave travelling in the positive x-direction. Write the wave equation. [$y(x,t) = 0.12\ sin\ (\pi t - 2.5\pi x)$]

   (b) A teenager would like to to double the fundamental frequency of his steel guitar string. Should he keep the same string but double the tension or used another string of the same material and tension but change the diameter of the string? Explain your answer. [**Ans:** $d \rightarrow 0.5d$]

3. **PSPM 15/16**



   (a)

   The figure above shows a progressive wave travelling at a speed of 24 ms^{-1} to the right.

   i. Determine the wave number. [$50\pi m^{-1}$]

   ii. Calculate the frequency of the wave. [$f = 600Hz$]

   iii. Write the wave equation. [$y = 0.02\ sin\ (1200\pi t - 50\pi x)$]

   (b) A man stands by the roadside when an ambulance passes by him with constant velocity 18 m s-1. The ambulance emits siren with frequency $256Hz$. The speed of sound is $340ms^{-1}$.

   i. Calculate the apparent frequency of the siren heard by the man before the ambulance passes by him. [**Ans:** $270Hz$]

   ii. Sketch a graph of the apparent frequency against distance travelled.

   iii. Sketch a graph of siren intensity against distance.

4. **PSPM 16/17**

   (a) Explain the formation of a stationary wave.

   (b) a violin string has mass per unit length $0.01kgm^{-1}$ and experiences a tension of $0.36N$. Calculate the wavelength if it vibrates at a frequency of $8Hz$.

   (c) The first overtone standing wave is formed at a $30cm$ closed pipe. Sketch the wave and calculate its frequency. The speed of sound is $340ms^{-1}$

   (d) What is the Doppler effect for sound wave?

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(e) A car is travelling at $25ms^{-1}$ emits a sound of frequency $1100Hz$ approaches a stationary observer. Calculate the apparent frequency heard by the observer. The speed of sound is $340ms^{-1}$.

5. **PSPM 17/18**

(a) How does the sound intensity change with distance from a point source?

(b) In a longitudinal wave in a horizontal spring, the coils move back and forth in the direction of the wave motion. If the coil speed is increased, does the wave propagation speed decrease, remain the same or increase? Explain your answer.

(c) A progressive transverse wave travelling on a wire has amplitde of $0.2mm$ and a frequency of $500Hz$ with speed of $196ms^{-1}$.

i. Write the displacement equation of the wave. [**Ans:**$0.002\ sin\ (1000\pi t - 16x)$]

ii. If the mass per unit lenght of the wire is $4.2\ g\ m^{-1}$. Calculate the tension of the wire. [**Ans:** $157.5N$]

(d) A submarine that travels in the water at a speed of $8ms^{-s}$ and emits a sonar wave of frequency $1400Hz$ is approaching another stationary submarine. Given the speed of sound in water is $1530ms^{-1}$, calculate the apparent frequency as detected by an observer in the stationary submarine. [**Ans:**$f_{app} = 1407Hz$]

6. **PSPM 18/19**

(a) A progressive wave is described by $y = 5\ sin\ (2\pi(10t - \frac{x}{5}))$ where x, y are in cm and t in s. Calculate the

i. speed of the wave. [**Ans:** $50cm\ s^{-1}$]

ii. vibrational velocity at the time 0, for the particle at $x = 5.0\ cm$. [**Ans:** $314ms^{-1}$]

(b) A wire of mass $30g$ is stretched between two points $100cm$ apart with tensional force of $70N$. When the wire is plucked, standing waves are formed in the wire.

i. Calculate the fundamental frequency and the third overtone frequency of the wire. [**Ans:** $24.15Hz$, $96.6Hz$]

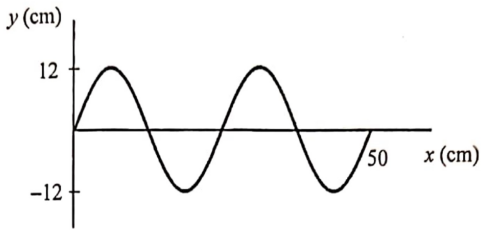
ii. If the tensional force of the wire is doubled, determine the new fundamental frequency. [**Ans:** $34.15Hz$]

(c) A stationary loudspeaker radiates sound with a frequency of $1000Hz$ uniformly in all directions. At a distance of $4.0m$, the intensity of sound is $0.95Wm^{-2}$. Calculate the

i. power of the loudspeaker [**Ans:** $191.01W$]

ii. frequency of the sound heard by a child if he approaches thesound at the speed of $10ms^{-1}$. [**Ans: 1030.3**Hz]

7. **PSPM 19/20**



(a) The figure above shows a graph of displacement y against distance x for a progressive wave propagating to the right in a string with mass $920g$, length $3m$ and tension $15N$. Determine the progressive wave equation. [**Ans:** $y(x,t) = 0.12\ sin\ (1.75(10^2)t - 25.13x)\ m$]

(b) A $1.53m$ closed pipe makes a humming sound at frequency $282Hz$ when the wind blows across the open end. The speed of sound in air is $343ms^{-1}$. With the help of a Diagrams, determine the number of nodes in the standing wave. [**Ans:** 3]

(c) The frequency of whistle by a moving train and the frequency heard by a stationary observer are $520Hz$ and $460Hz$ respectively. If the speed of sound in the air is $343ms^{-1}$, calculate the speed of the train. [$v = 44.74ms^{-1}$]