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How to find max acceleration from velocity graph

Chapter 15 Oscillations (Part 1: The Algebra-based Approach) Simple Harmonic Motion (SHM): A mass attached to a linear spring and set into up-and-down motion performs a motion that is called " simple harmonic motion, or SHM. " We need to first study the behavior of a linear spring. Linear Springs: A linear spring is one for which the change in length (Δx) is proportional to the change in the applied force (ΔF). $\Delta F = k \Delta x$, where, k, the proportionality constant, is called the " spring constant ." Example 1: A linear spring has an unstretched length of 18.0cm. When it is under a load of 125N, its total length is 20.5cm. Calculate (a) its constant, k, and (b) the load that makes it 25.0cm long. The Metric unit for k is N/m. Example 2: A linear spring has a length of 35.0cm when under a load of 225N and a length of 43.0cm when under a load of 545N. Find (a) its constant, and (b) its free (no load) length. Solution: To be solved by students. The Linear Spring Formula: Note that the formula $\Delta F = k \Delta x$ is a relation between the applied force (to the spring) and the change in the spring's length. The spring force (F_s) is always opposite to the applied force. As the following figures indicate, when Fapplied is to the right, Δx is positive, F_s pulls to the left and is negative, and when Fapplied is to the left, Δx is negative , F_s pushes to the right and is positive. Based on the above $F_s = - k x$ is the formula for a linear spring. When (x) is positive, F_s is negative and vise versa. This fact is reflected by the (-) sign in the formula. Note that F_s is not the applied force, it is the force that the spring exerts. Simple Harmonic Motion: (Note: for a review on radian, the Metric unit for angles, refer to the end of the chapter.) Recall the definition of angular speed ω : $\omega = \Delta \theta / \Delta t$ and for constant ω , we may write: $\omega = \theta / t$; therefore, $\theta = \omega t$. Now, picture mass M is performing a uniform circular motion in a vertical plane as shown. Its shadow on the x-axis performs a back-and-forth motion that is called simple harmonic motion. To understand the following figure, visualize that mass M moves slowly and counterclockwise in the circle (of radius A), and at different positions, picture its shadow on the floor. The angular position of mass M on the circle is measured by θ . Corresponding to every θ there is a shadow position measured by x from C to H (or O to K). It is possible to relate x to θ . Since $\theta = \omega t$; therefore, x can be related to ωt . The graph of x vs. θ is shown below with the assumption that at $t = 0$, $\theta = 0$ as well. This means that mass M starts its circular motion from the position for which $\theta = 0$. Note that the farthest distance Point K can go from Point O is as much as length A, the radius of the circle. A, the maximum deviation from the equilibrium position, is called the " Amplitude " of oscillations. Example 3: A bicycle wheel of radius 30.0cm is spinning at a constant angular speed of 180.0 rpm in a vertical plane. Find (a) its angular speed in rd/s. The shadow of a bump on its edge performs an oscillatory motion on the floor. Write (b) the equation of the oscillations of the shadow knowing that the shadow is at its maximum at $t = 0$. (c) determine the distance of the shadow from the equilibrium position at $t = 1.77$ seconds. Solution: (a) $\omega = 180.0$ (rev / min) (6.28rd / rev) (min / 60 sec) = 18.84 rd /s (b) The constants are known: $\omega = 18.84$ rd /s and $A = 30.0$ cm ; The variables are x and t . The equation of motion for oscillations is : $x = A \cos(\omega t)$; $x = 30.00 \cos (18.84 t)$ (c) Substituting for $t = 1.77$ sec, x becomes: $x = (30.00\text{cm}) \cos(18.84 \cdot 1.77 \text{ rd}) = -10.6\text{cm}$ Note that your calculator must be in radians mode for the last calculation. Example 4: The equation of motion of oscillations of a mass on a spring is given by $x = 3.23 \cos(12.56 t)$ where x is in (cm) and t in seconds. Find its (a) amplitude, (b) angular speed, (c) frequency and period of oscillations, and (d) its position at $t = 0.112\text{s}$. Solution: Comparing the given equation with the general form $x = A \cos(\omega t)$, it is clear that (a) $A = 3.23 \text{ cm}$; (b) $\omega = 12.56 \text{ rd/s}$; (c) $\omega = 2\pi f$; $f = \omega / 2\pi$; $f = 2.00\text{Hz}$; $T = 1 / f$; $T = 0.500 \text{ sec.}$; (d) $x = 3.23 \cos(12.56 \cdot 0.112 \text{ rd}) = 0.528\text{cm}$ Note that your calculator must be in radians mode for the last calculation. Mass-Spring System: As it was mentioned, when mass M attached to a linear spring is pulled and released, its up-and-down motion above and below the equilibrium level is called " simple harmonic motion ." In the absence of frictional forces, the graph of such motion as a function of time has a perfect "sine" shape. It is for this reason that the motion is called harmonic. Figure (a) below shows a spring that is not loaded. Figure (b) shows the same spring but loaded and stretched a distance (- h), and Figure (c) shows the loaded spring stretched further a distance (- A) and released. It shows that the attached mass M oscillates up and down to (+A) and (-A) above and below the equilibrium level. Example 5: A 102-gram mass hung from a weak spring has stretched it by 3.00cm. Let $g = 9.81\text{m/s}^2$ and calculate (a) the load on the spring and (b) the spring constant in N/m. If the mass-spring system is in static equilibrium and motionless, and the mass is pushed up by +2.00cm and released, calculate (c) its angular speed, (d) its frequency, (e) its period, (f) the amplitude of oscillations, and (g) the equation of motion of such oscillations. .Solution: (a) The load is $w = Mg$; $w = (0.102\text{kg})(9.81 \text{ m/s}^2) = 1.00\text{N}$ (b) $\Delta F = k \Delta x$; $k = (1.00\text{N}) / (0.0300\text{m}) = 33.3 \text{ N/m}$ (c) $\omega = \text{SQRT}(k / M) = \text{SQRT} [(33.3 \text{ N/m}) / (0.102 \text{ kg})] = 18.1 \text{ rd/s}$ (d) $f = \omega / (2\pi)$; $f = 2.88 \text{ Hz}$ (e) $T = 1 / f$; $T = 0.347 \text{ sec.}$ (f) The 2.00cm that the mass is pushed up above its equilibrium level (while hanging on the spring), becomes its amplitude. $A = +2.00\text{cm}$. (g) Knowing the constants $A = 2.00\text{cm}$ and $\omega = 18.1 \text{ rd/s}$, the equation of motion becomes: $x = [2.00\text{cm}] \cos(18.1 t)$ In this equation if we plug $t = 0$, we get $X = +2.00\text{cm}$. This is correct because at $t = 0$, the mass is released from $X = +2.00\text{cm}$. Example 6: The graph of x (the distance from the equilibrium position) versus time (t) for the oscillations of a mass-spring system is given below: For such oscillations, find (a) the amplitude, (b) the period, (c) the frequency, (d) the angular speed (frequency), (e) the spring constant (k) if the mass of the object is 250.0 grams, and (f) the equation of motion for the oscillations. Solution: This graph is that of $x = A \sin(\omega t)$. (a) $A = 2.00\text{cm}$; (b) $T = 2 (0.125\text{s}) = 0.250 \text{ s}$; (c) $f = 1 / T$; $f = 4.00 \text{ Hz}$ (d) $\omega = 2\pi f$; $\omega = 2\pi (4.00\text{s}) = 25.1 \text{ rd/s}$ (e) $\omega = (k / M) / (1/2)$; $\omega^2 = (k / M)$; $k = M\omega^2$; $k = (0.2500\text{kg}) / (25.1 \text{ rd/s})^2$; $k = 158 \text{ N/m}$ (f) $x = A \sin(\omega t)$; $x = [2.00\text{cm}] \sin (25.1 t)$. The given graph is a sine function. Linear Velocity and Acceleration in Simple Harmonic Motion: If an object is oscillating up and down, for example, it is easy to see that its velocity becomes zero at the extreme points, i.e. at the highest and lowest points. This is simply because it has to come to stop at those points in order to change direction. It is also easy to see that velocity gains its maximum magnitude at the midpoint or the equilibrium level. We may therefore state that: " In Simple Harmonic Motion, maximum speed occurs at $x = 0$ (the equilibrium level or position), and speed is zero at the extreme ends ($x = +/- A$). " Of course, if we use the word "Velocity", the respective direction(s) must be determined. Acceleration has a different story. At the middle ($x = 0$), acceleration is zero. At the extreme ends, when a spring is at its maximum stretch or compress, the spring force is at its maximum magnitude, and therefore the acceleration it gives to the attached mass is maximum. We may therefore state that: " In Simple Harmonic Motion, the maximum of acceleration magnitude occurs at $x = +/-A$ (the extreme ends where force is maximum), and acceleration at the middle (at $x = 0$) is zero. " Using Calculus, if the equation for x is $x = A \cos(\omega t)$, then v, and a, are derived as follows: $v = (dx / dt) = -A\omega \sin(\omega t)$; and $a = (d^2x / dt^2) = -A\omega^2 \cos(\omega t)$. Maximum v and maximum a can be determined by setting $\cos(\omega t)$ and $\sin(\omega t)$ equal to their maximum value, i.e., one. V_{max} and a max become: $V_{\text{max}} = -A\omega$ a max $= -A\omega^2$ We may disregard the (-) signs if only the magnitudes are to be calculated. Example 7: The equation of motion of a 22-kg log oscillating on ocean surface is $x = 1.2 \sin(3.14 t)$ where x is in meters and t in seconds. Determine its, amplitude, angular speed(frequency), frequency, period, maximum speed, maximum acceleration (magnitude), and its position at $t = 0.19\text{s}$. Solution: $A = 1.2\text{m}$; $\omega = 3.14 \text{ rd/s}$; $f = \omega / (2\pi) = 0.50 \text{ s}^{-1}$; $T = 1 / f = 2.0\text{s}$ $V_{\text{max}} = A\omega$; $V_{\text{max}} = (1.2\text{m})(3.14 \text{ rd/s}) = 3.8 \text{ m/s}$ (occurs at the middle) a max $= A\omega^2$; a max $= (1.2\text{m})(3.14\text{rd/s})^2 = 11.8 \text{ m/s}^2$ Using the given equation, substituting for t, and putting the calculator in Radians Mode, we get: $x = 1.2 \sin [3.14 (0.19)] = 0.67\text{m}$ Chapter 15 Test Yourself 1: For answers, click here. 1) A linear spring is one for which the force-length change relation is (a) $F = k(\Delta x)^2$ (b) $F^2 = k(\Delta x)$ (c) $F = k(\Delta x)$ 2) The formula for the applied force, F to a spring and the change in its length Δx is (a) $F = k(\Delta x)$ (b) $F = - k(\Delta x)$ (c) neither a, nor b. 3) The relation between the spring force, F_s to (+A) and (-A) $F_s = k(\Delta x)$ (b) $- F_s = - k(\Delta x)$ (c) $F_s = - k(\Delta x)$ 4) The spring formula $F_s = - k(\Delta x)$ is normally written as $F_s = - kx$ (a) True (b) False click here .5) If a spring stretches 5.00cm under a load of 100.N, it has a constant of (a) 20.0N/cm. (b) 2000N/m. (c) both a & b. 6) A spring that stretches 7.05cm under a hanging-21.58-kg load has a constant of 20.N/cm. (b) 15N/m. (c) 30.N/cm. For the following questions, refer to the figure under "Simple Harmonic Motion" and suppose that the radius of the circle is $A = 10.0\text{cm}$ and mass M makes 5.00 rotations per minute. click here .7) When $\theta = 30.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) 5.00cm. (b) 8.66cm (c) 7.5cm. click here .8) When $\theta = 60.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) 8.00cm. (b) 7.66cm (c) 5.00cm. 9) When $\theta = 90.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) 0.00cm. (b) 5.00cm (c) 7.5cm. 10) When $\theta = 00.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) 10.0cm. (b) 8.66cm (c) 7.5cm. click here .11) When $\theta = 135.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) -10.0cm. (b) 8.66cm (c) -7.07cm. 12) When $\theta = 225.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) -7.07cm. (b) 8.66cm (c) -10.0cm. 13) When $\theta = 330.0^\circ$, the distance from the position of the shadow, K, to the equilibrium position, O is (a) -7.07cm. (b) 8.66cm (c) -10.0cm. click here .14) Reading the problem's statement again, the angular speed, ω , of mass M is (a) 5.00rpm (b) 0.523 rd/s (c) both a & b. 15) The amplitude of oscillations is (a) 8.66cm. (b) 0.707cm. (c) 10.0cm. click here .16) The equation of the shadow's oscillations is (a) $x = [10.0\text{cm}] * \cos(0.523 t)$ (b) $x = (1/2)(0.523 t^2)$ (c) neither one. 17) Setting $t = 0$ in this equation, gives us the position of the shadow at $t = 0$. Doing this, we get (a) $x = 0.0$. (b) $x = 10.0\text{cm}$. (c) $x = 8.66\text{cm}$. click here 18) Setting $t = 1.10\text{s}$ in this equation, gives us the position of the shadow at $t = 1.00$. Doing this, we get (a) $x = 0.0$. (b) $x = 10.0\text{cm}$. (c) $x = 0.0\text{cm}$. click here .20) Since $\omega = 0.523\text{rd/s}$, and we know that $\omega = 2\pi f$, the value f, or the number of turns per second, is (a) $f = 0.0833 \text{ s}^{-1}$. (b) $f = 0.0833 \text{ Hz}$ (c) $f = 0.0833 \text{ Hz}$ (d) $f = 0.0833 \text{ Hz}$ (e) a, b, c, & d 21) Based on f, the value of period, T, is (a) 12.0s (b) 12.0min. (c) 1.2s. click here 22) We could have also found the period, T from the info in the problem's statement that says 5.00 turns per minute. If in every minute 5.00 full turns are completed, then the time for completion of each turn, T, is (a) 12.0s (b) 2.00s. (c) 8.00s. Problem: The equation of motion for the oscillations of a mass attached to a spring is $x = [4.00\cos(18.78 t)]$ where x is in cm and t is in seconds. Based on the equation. click here .23) the amplitude of oscillations is (a) 8.00cm (b) 4.00cm (c) 2.00cm 24) the angular frequency ω that is the # of radians traveled (or repeated) per second is (a) 18.78 rd/min (b) 18.78 rd/s (c) 18.78 degrees per second. click here .25) The frequency of oscillations, f (the # of turns per second or the # of back-and-forth motions per second) is (a) 3.00/s (b) 3.00s-1. (c) 3.00Hz (d) a, b, & c. 26) The period of oscillations, T is (a) (1/3)s (b) (1/3)min (c) (1/3)yr. click here .27) The position of the object from its equilibrium position at $t = 0$ is (a) 2.00cm. (b) 6.00cm. (c) 4.00cm. 28) The position of the object from its equilibrium position at $t = 2.945\text{s}$ is (a) 2.28cm. (b) 1.28cm. Problem: Refer to the figure of Example 6. There are 12 segments (time intervals) on the x-axis. Use the equation of motion found under (f) to calculate the following. Compare your calculations with the vertical line segments (x values) to see if they make sense. Make sure to perform all calculations with you calculator in the correct mode. click here 30) The time interval corresponding to each segment is (a) .04167s (b) 0.02083s (c) 0.01042s 31) Each vertical line under the sine-curve shows the distance of the object from (a) the equilibrium position. (b) the mid-point. (c) both a & b. click here 32) The maximum distance you may calculate for vertical segments is (a) 1.00cm (b) infinity (c) 2.00cm 33) The distance from the equilibrium at $t = 1(0.02083\text{s})$ is (a) 2.00cm. (b) 1.00cm. (c) 3.00cm 34) The distance from the equilibrium at $t = 2(0.02083\text{s})$ is (a) 1.20cm. (b) 1.73cm. (c) 0.0cm. click here 35) The distance from the equilibrium at $t = 3(0.02083\text{s})$ is (a) 0.80cm. (b) 2.00cm. (c) 0.00 36) The distance from the equilibrium at $t = 4(0.02083\text{s})$ is (a) 0.60cm. (b) 1.73cm. (c) 0.50 37) The distance from the equilibrium at $t = 5(0.02083\text{s})$ is (a) 0.70cm. (b) 1.00cm. (c) 0.90. click here 38) The maximum linear velocity of a particle in oscillatory motion is (a) $V = A\omega$ (b) $V = A\omega t$ (c) $V = A\omega t^2$ 39) A, the amplitude in oscillatory motion is the same thing as R, the radius, in circular motion. (a) True (b) False 40) In Example 6, the maximum linear speed of the mass is (a) 25.1 m/s. (b) 50.2 rd/s. (c) 50.2 cm/s. 41) Maximum linear speed of an oscillating mass occurs at (a) +A (b) -A (c) 0, the midpoint. click here 42) In Example 6, the maximum linear acceleration of the mass is (a) $a = A\omega^2$ (b) $a = A\omega t$ (c) $a = A\omega t^2$ 43) Maximum linear acceleration of an oscillating mass occurs at (a) +A (b) -A (c) 0, the midpoint. (d) both a & b. 44) In Oscillatory motion, max. acceleration occurs at +/-A. For an oscillating mass-spring system, for example, the reason is that (a) the velocity at ed points is zero. (b) the force at end points has maximum magnitude and causes maximum acceleration. (c) At end points, the spring is at maximum squeeze or maximum stretch. (d) b & c. click here 45) In oscillations of a mass, if maximum linear velocity or acceleration vectors are sought, rather than just the max. speed or magnitude of max. acceleration, then with the (+) and (-) signs, we may indicate maximum or minimum. (a) True (b) False. Oscillations (Part 2: Calculus-based Approach) The general form of the equation for oscillatory motion is $x = A \sin(\omega t + \phi)$ where ϕ is called the phase angle. Angle ϕ simply determines how far ahead or behind the oscillations are compared to $x = A \sin(\omega t)$ taken as reference. The equation of velocity can be obtained by taking the derivative of $x = A \sin(\omega t + \phi)$ with respect to time (t). Using $v = dx/dt$, the velocity v becomes: $v = A\omega \cos(\omega t + \phi)$ Comparing this equation to $v = v_{\text{max}} \cos(\omega t + \phi)$, results in the value of maximum speed in SHM, simply $v_{\text{max}} = A\omega$. It was discussed that vmax occurs at the middle ($x = 0$) as the oscillating object passes the equilibrium position. To find the equation for acceleration, we need to use $a = dv/dt$ that means taking the time derivative of the speed equation. Doing this, results in $a = -A\omega^2 \sin(\omega t + \phi)$ Again, comparing this with $a = a_{\text{max}} \sin(\omega t + \phi)$, results in the value of maximum acceleration in SHM, simply $a_{\text{max}} = A\omega^2$. It was discussed that amax occurs at the end points. When $x = -A$, the object is ready to go to the right and the acceleration is maximum. When $x = +A$, the object is ready to go to the left, the acceleration has again the same highest magnitude, but toward the left, and therefore is minimum. Example 8: A 225-gram small mass is hung from a linear spring and has stretched it by 6.4cm from its no-load length. Find (a) the spring constant. It is then further pulled down by 3.0cm and released. Find (b) its angular frequency, ω , (c) the frequency, f, (d) period, T, and the phase angle, ϕ , of the resulting oscillations. Solution: (a) In the vertical direction, $F = ky$; $Mg = ky$; $(0.225\text{kg})(9.81\text{m/s}^2) = k (0.064\text{m})$; $k = 34.5 \text{ N/m}$ (b) $\omega = \text{SQRT}(k/m) = \text{SQRT} [(34.5 \text{ N/m}) / 0.225\text{kg}] = 12.4 \text{ rd/s}$ (c) $\omega = 2\pi f$; $f = [(12.4 \text{ rd/s}) / 2\pi] = 1.97 \text{ Hz}$ (d) $T = 1 / f$; $T = 1 / (1.97\text{s}^{-1}) = 0.506 \text{ s}$ (e) To find ϕ , write the general form of the equation of motion for oscillations: $y = A \sin(\omega t + \phi)$. We already know the values of A and ω . Substituting in the general form, we get : $y = [0.030\text{m}] \sin(12.4 t + \phi)$ Since at $t = 0$ (time of release) $y = -3.0\text{cm} = -0.030\text{m}$; therefore, by substituting these values into the last equation, we get -0.030m = $[0.030\sin(12.4 \cdot 0 + \phi)]$; $\sin(12.4 \cdot 0 + \phi) = -1$; $\sin(\phi) = \sin(-90^\circ)$; This makes the acceptable answer to be $\phi = -90^\circ$. Plugging into the general form, the equation of the oscillations becomes: $y = 0.03\sin(12.4 t -1.57)$. Note that the 1.57mrad that is $3.14/2$ or simply $\pi/2$ or 90° . The Mass-Spring System (Calculus-Based Approach): Referring to the above figure for the horizontal oscillations of mass M by the linear spring k on a frictionless surface, we may think that as the mass is oscillating the force of the spring on it at any instant is $F_s = -kx$. This varying F_s , generates a varying acceleration a in mass M that according to Newton's 2nd law is $F_s = Ma$. Since $a = d^2x/dt^2$, we may write: $F_s = Md^2x/dt^2$. We may also write: $-kx = Md^2x/dt^2$. This may be written as: $Md^2x/dt^2 + kx = 0$ or, $d^2x/dt^2 + (k/M)x = 0$. The solution to this differential equation gives x as a function of t as follows: $x(t) = A \sin(\omega t + \phi)$ where Energy in Simple Harmonic Motion As was discussed, for a mass-spring system, when mass M is at its equilibrium position, it has its maximum speed, but the spring is neither compressed nor stretched. This means that, in this case, all energy (or the total energy of the system) is of kinetic type and potential energy is zero. On the other hand, when mass M is at an end point, since it momentarily comes to stop, its K.E. is zero, but its P.E. is maximum, because the spring is at its maximum stretch or compress. In other words, the same total energy is of potential type in this case. This can be shown mathematically as well. It is shown below: Let U denote the potential (stored) energy in the spring that means $U = 0.5kx^2$. Since $x = A \sin(\omega t + \phi)$, the expression for U becomes: $U = 0.5kA^2\sin^2(\omega t + \phi)$. (1) The kinetic energy, on the other hand is $K.E. = 0.5Mv^2$. Since $v = A\omega \cos(\omega t + \phi)$, the expression for K.E. becomes: $K.E. = 0.5MA^2\omega^2 \cos^2(\omega t + \phi)$. (2) Adding Equations (1) and (2) gives the total energy at any given instant. It is easy to verify that this total energy is equal to the maximum P.E. that is also equal to the maximum K.E. Example 9: Add Equations (1) and (2) above to show that the total energy of an oscillator, at any given instant is Total Energy = $U + K.E. = 0.5kA^2$. Simple Pendulum Another good example of SHM is the "Simple Pendulum." Such device is made of a string connected to a tiny heavy and solid sphere hung from a fixed point and set into oscillation as shown. It is easy to calculate the period of oscillation of a simple pendulum (T) as outlined below: Example 10: The length of a simple pendulum is 2.35m. Use $g = 9.81 \text{ m/s}^2$ to find the period for the earliest t > 0 and (b) the earliest time after t = 0.0 at which $x = +15\text{cm}$ and $v < 0$. click here 2) Mass M is attached to a linear spring of constant k on a horizontal frictionless surface. At $t = 0.00$, the mass is pulled to position $x = +A$ and released. During the first cycle, at what positions and times do the following occur: (a) $|v| = 0.500v_{\text{max}}$ and (b) $|a| = 0.500a_{\text{max}}$. Assume 3 sig. fig. on all variables. click here 3) The frequency of a mass-spring system set into oscillation is 2.50Hz. With an additional mass of 85.0 grams, the frequency reduces to 2.20Hz. Find mass M and the spring constant k. click here 4) The equation of oscillation of a mass-spring system is $x(t) = 0.3\cos(4t - 0.7)$ where x is in meters and t in seconds. The spring constant is 15N/m. Find (a) the amount of mass M, (b) the total energy, (c) the earliest time (t >0) when K.E. = 0.5 P.E., and (d) the acceleration of the mass at $t = 0.08\text{s}$. Assume 3 sig. fig on all quantities. click here 5) The mass of an atom oscillating at a frequency of 8.6x1011Hz in its lattice is 1.2x10-26kg. If the amplitude of its oscillations is 0.045nm, find (a) its total energy in joules and eV, (b) its maximum speed, (c) its maximum acceleration, and (d) its equivalent spring constant. Note: 1eV = 1.6x10-19J. 6) What should be the length of a simple pendulum so that its period of oscillations is 2.00s? Let $g = 9.81\text{m/s}^2$. click here 7) In an experiment to measure the acceleration of gravity (g) a simple pendulum of length 1.58m is used. The time for 100.0 oscillation is measured to be 254s. Calculate the "g" value in this experiment. click here 8) Refer to the figure for Example 1: One radian of angle is the central angle in any circle whose opposite arc is equal to the radius of that circle. If a piece of string is cut equal to the radius of a circle and then placed on the end of that circle as shown, the central angle corresponding (or opposite) to that arc is called one "radian." Example 11: Naming 3.14r as " π ", calculate angles 360°, 180°, 90°, 60°, 45°, and 30° in terms of π . Solution: Fraction: 1 full circle 1/2 circle 1/4 circle 1/6 circle 1/8 circle 1/12 circle Degrees: 360° 180° 90° 60° 45° 30° Radians: 2 π = 6.28rd π $\pi/2$ $\pi/3$ $\pi/4$ $\pi/6$ Arc Length-Central Angle Formula: There is an easy formula that relates any central angle (θ) to its opposite arc (s) and the radius (R) of a circle. This formula is valid only if the central angle is measured or expressed in radians. Example 12: Referring to the above figure, suppose angle θ is 148° and $R = 1.25 \text{ in}$. Calculate the length of arc AB. Solution: Using $S = R \theta$, and converting degrees to radians, yields: $S = (1.25 \text{ in})(148^\circ)(3.14rd / 180^\circ) = 3.2 \text{ in}$. Angular Speed (ω) : This symbol (ω) is the lower case of symbol (Ω) pronounced "omega." Angular speed (ω) is defined as the change in angle per unit of time. Mathematically, it may be written as $\omega = \Delta \theta / \Delta t$. A preferred unit for angular speed is (rd / s). A commercial unit is (rpm) or revolutions per minute. Note that each revolution is 6.28 radians. Example 13: A car tire spins at 240rpm. Calculate (a) its angular speed in the preferred unit of (rd /s), (b) the angle that a typical radial line on it (such as a spoke) sweeps in 44 seconds, and (c) the arc length that a point on its outer edge travels during this time knowing that R = 14 in. . Make sure that you completely solve this problem on paper using horizontal fraction bars everywhere. Solution: 240rpm is ω itself, the angular speed. All we need to do in part (a) is to convert it from rpm to rd/s. (a) $\omega = 240$ (rev / min) = $240 (6.28 \text{ rd} / 60\text{sec}) = 25 \text{ rd/sec}$. Note: 1rev = 6.28 rd, and 1min = 60 sec. (b) $\omega = \Delta \theta / \Delta t$ or $\Delta \theta = \omega \Delta t$ or $\Delta \theta = (25 \text{ rd/sec})(44 \text{ sec})$ or $\Delta \theta = 1100 \text{ rd}$ (c) $s = R\theta$ or $s = (14 \text{ in})(1100 \text{ rd}) = 15400 \text{ in}$. In feet, 1283 ft. In miles, 0.24 miles. Linear Speed - Angular Speed Formula: The same way S and θ are related, we have a formula that relates v to ω . The formula is: $v = R\omega$. Writing these two similar formulas together helps their recall. $s = R\theta$ and $v = R\omega$. The derivation is easy. All you need to do is to take the time-derivative of both sides of $s = R\theta$. This means: (ds/dt) = R (d θ /dt) (ds/dt) is v, the change in distance over time, and (d θ /dt) is ω , the change in angle over time; therefore, $v = R\omega$. Example 14: The radius of a car tire is 14 in. Calculate (a) the linear speed (v) of a point on its outer edge, if it spins at an angular speed of 25 rd/sec. (b) Find the linear distance (arc length) the point travels in 44 sec.. Solution: (a) Using $v = R\omega$, yields: $v = (14 \text{ in})(25 \text{ rd/sec}) = 350 \text{ in/sec}$. (b) $s = vt$ or $s = (350 \text{ in/sec})(44 \text{ sec.}) = 15400 \text{ in}$. Use horiz. fraction bars when you solve. Note: In (b) equation $s = (1/2)\omega t^2 + Vt$ it is used where a = 0 and x is replaced by s. This is because the arc length over the tire is like a long string wrapped around it and as the car moves, it leaves the unwrapped stretch on the ground as a straight line for which equation $s = Vt$ or $s = Vt$ is valid. Chapter 15 Test Yourself 2: 1) Radian is a unit of (a) length. (b) angle. (c) area. click here 2) A central angle is an angle that has its vertex at the center of a (a) triangle. (b) square. (c) circle. 3) In any circle, the size of a central angle is equal to (a) the arc opposite to it when expresses in radians. (b) half of the arc opposite to it. (c) the radius of that circle. 4) Draw a circle and select two central angles in it, one equal to 90° and one equal to 45°. Since 90° is 1/4 of 360°, verify that the arc-length opposite to the 90°-angle you chose is also 1/4 of the whole circle. Also, verify that the 45°-angle you chose is equal to arc that is exactly 1/8 of the whole circle. What conclusion do you draw? State Is your conclusion in line with the correct answer to Question 3? click here 5) 1rd is the central angle whose opposite arc length equals (a) the radius of the circle. (b) the diagonal of the circle. (c) the perimeter of the circle. 6) The central angle whose opposite arc equals the perimeter of the circle is (a) 360°. (b) 2 π radians. (c) both a and b. 7) The central angle whose opposite arc equals half of the circle is (a) 120°. (b) 180°. (c) 3.14radians. (d) both b and c. 8) 2.00 radians of angle is equivalent to (a) 114.6°. (b) 120°. (c) 170°. click here 9) S = R θ calculates the arc length that is opposite to central angle θ only if θ is expressed in (a) degrees (b) radians (c) grads. 10) The arc length opposite to a 2.00rd central angle in a circle whose radius is $R = 6.00"$ is (a) 12.0°. (b) 8.00°. (c) 18.0°. 11) The arc length opposite to a 114.6° central angle in a circle whose radius is $R = 6.00"$ is (a) 18.0°. (b) 28.0°. (c) 12.0°. 12) Angular speed is defined as (a) the arc length traveled per unit of time. (b) the angle traveled per unit of time. (c) the arc swept by a radius per unit of time. (d) both b and c. click here 13) If angular change is $\Delta \theta$ and time change is Δt , then angular speed, ω , is (a) $\Delta \theta / \Delta t$. (b) $\Delta t / \Delta \theta$. (c) $\Delta \theta \Delta t$. 14) The angular speed formula $\omega = \Delta \theta / \Delta t$ is the counterpart of the linear speed formula $v = \Delta x / \Delta t$. (True) or (False)? 15) A spoke on a bicycle wheel travels or sweeps 150. rd of angle every minute. Its angular speed is (a) 150.rd/s (b) 150.rd/min (c) 2.50rd/s (d) both b and c. click here 16) RPM is (a) a unit of angle (b) a unit of angular acceleration. (c) a commercial unit of angular speed. 17) rd/s is (a) a commercial unit for angle. (b) the SI unit for angular speed. (c) neither a nor b. click here 18) 180 rpm is the same thing as (a) 3.0 rps. (b) 3.0 revolutions per second. (c) 3.0 turns per second. (d) a, b, and c. 19) 240 rpm is the same thing as (a) 240 turns per minute (b) 4.0 turns per second. (c) both a and b 20) 1 rpm is the same thing as 6.28 rd/min. True or False? click here 21) 3600 rpm is equivalent to (a) 60 rev/sec. (b) 606x.28rd / sec. (c) 377 rd/s (d) a, b, and c. how to find maximum acceleration on a velocity time graph. how to find acceleration from velocity graph. how to get acceleration from velocity graph

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