BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI (RAJ)

General Physics - PHY F112: Comprehensive Exam **(Closed Book)** : Sem-I (2023-2024)

Date : 13 Dec 2023

Max. Marks : 60 **Duration : 90 mins**

Each question carry 3 marks.
Use $g = 9.8$ m/s^2 and write numerical answers upto two decimal digits.

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1. A force $\vec{F}(x) = (cx - 3x^2)\hat{i}$ acts on a particle as the particle moves along an x axis, with $\vec{F}$ in newtons, x in meters, and c is a constant. At $x = 0$, the particle's kinetic energy is 22.0 J; at $x = 3.00$ m, it is 13.0 J. Find the value of the constant c.

2. A merry-go-round of radius 3 m, rotates from rest with an angular acceleration of 1.5 rad/s^2. The centripetal acceleration at 5 sec would be?

3. A block of mass 20 g is attached to a spring of spring constant k. At $t = 0$ the block is released from the stretched position. If the maximum displacement and acceleration of the block is 5 cm and 20 m/s^2 respectively. When the fist time the block's velocity would be -1 m/s?

4. A horizontal force of magnitude 35 N pushes a block of a mass 4 kg across a floor where the coefficient of kinetic friction is 0.6. During the displacement of the block by 3 m the thermal energy of the block increases by 40 J. What is the increase in the thermal energy of the floor?

5. A 12 N force with fixed orientation does work on a particle as the particle moves through $\vec{d} = 2\hat{i} - 4\hat{j} + 3\hat{k}$ meters. Angle between the force and the displacement if the change in the particle's kinetic energy is -30 J would be?

6. A 500 g block is released from the height h_0 on the vertical spring having the spring constant of 400 N/m and negligible mass. The block sticks to the spring and momentarily stops after compressing the spring by 20 cm. Calculate the value of h_0.

7. The potential energy of the diatomic molecule is given as $U(r) = A/r^{12} - B/r^6$, where r is the seperation of the two atoms of the molecule and A and B are the positive constants. Find the equilibrimum seperation of this atomic system. What should be units of constants A and B.

8. Three balls of mass 2 kg each are placed in the shape of traingle. First ball at the origin and other two along x and y axis respectively at a distance of 5 cm from the origin (along x and y axis). The position vector of Center-of-Mass will be?

9. A stone is dropped at $t = 0$. A second stone, with the twice the mass of the first, is dropped from the same point at $t = 100$ ms. How far below the release point is the center of the mass of the two stones at $t = 300$ ms?

10. In tae-kwon-do, a hand is slammed down onto a target at a speed of 13 m/s and comes to a stop during the 5 ms collision. Assume that during the impact the hand is independent of the arm and has a mass of 0.70 kg. What are the magnitudes of the impulse and average force on the hand from the target?

11. Consider a 5 g bullet at the rate of 100 bullets/min are shot on the target. The speed of each bullet is 500 m/s and they are reflected back by the same speed. What is the magnitude of the average force on target?

12. The floor of a railroad flatcar is loaded with loose crates having a coefficient of the static friction of 0.25 with the floor. If the train is initially moving at a speed of 48 km/h, in how short a distance can the train be stopped at constant acceleration without causing the crates to slide over the floor.

13. A person (weighing 915 N) stands on long railroad flatcar (weighing 2415 N) at it rolls at 18.2 m/s in the positive direction of a x axis, with negligible friction. Then the man runs along the flatcar in the negative x direction at 4 m/s relative to the flatcar. What is the resulting increase in the speed of flatcar?

14. Particles 1 and 2 of mass m are connected by a massless rod of (50 cm long) held horizontoally on a fulcrum and then released. Particle 1 is 10 cm and particle 2 is 40 cm from fulcrum. Calculate the accelerations of particle 1 and 2 when the assembly is released.

15. A disk with a rotational inertia of 7 kg m^2 rotates like a merry-go-round under the influence of a time-dependent torque given by $\tau = (5 + 2t)$ N m. At time $t = 1$ sec, its angular momentum is 10 kg m^2/s. What is its angular momentum at $t = 3$ sec?

16. A solid disk is pivoted at the rim of the disk and free to oscillate. If the radius of the disk is 5 cm then calculate the time period of the oscillations.

17. A solid rod of mass m and length ℓ is hanged from $\ell/4$ distance from its end and free to oscillate. How far from the pivot point its 'center of oscillation' will be located?

18. For a damped harmonic oscillator with $m = 250$ g, $k = 85$ N/m and $b = 70$ g/s. How long does it take for the amplitude and energy of the damped oscillations to drop to half its initial value?

19. A 0.12 kg body undergoes simple harmonic motion of amplitude 8.5 cm and period 0.20 s. What is the magnitude of the maximum force acting on it?

20. Two particles execute simple harmonic motion of the same amplitude and frequency along close parallel lines. They pass each other moving in opposite directions each time their displacement is half their amplitude. What is their phase difference?

Wish you all the best !

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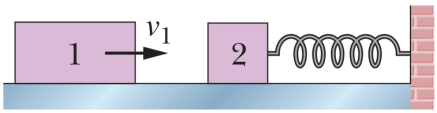
1. As shown in the figure, a block 2 (mass m_2) is at rest on the frictionless floor and touching the end of an unstretched spring of spring constant k. The other end of the spring is fixed to wall. Block 1 (mass m_1), travelling at speed v_1, collides with block 2, and two blocks stick together.

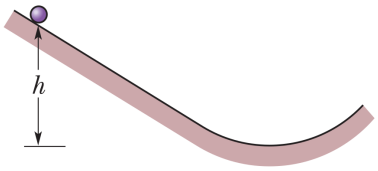


(a) When the blocks momentarily stop, by what distance the spring is compressed?

(b) If the slope between compressed length (x-axis) and initial velocity v_1 (y-axis) is 20 s^{-1} then calculate the spring constant if $m_1 = 0.5m_2$ and initially the normal force acting on the block 1 is 10 N.

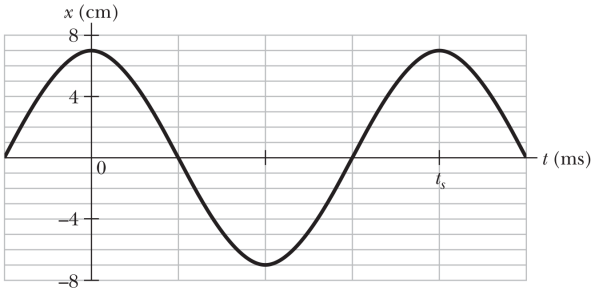
[8+4]

2. A ball of mass M and radius R_{ball} rolls smoothly from rest down a ramp and onto a circular loop of radius R_{loop}. The initial height of the ball is h. At the loop bottom, the magnitude of the normal force on the ball is $2Mg$. The ball consists of the outer shell of other density as the core of the same. The rotational inertia of the ball can be expressed as $I = \beta MR^2$, but β is not 0.4 as its for uniform density ball. Calculate the value of the beta in terms of the h and R_{loop} and for which value of R_{loop} the value of the $\beta = 1$ given the same normal force of $2Mg$ acts at the bottom of loop?



[10+2]

3. This figure gives the position of a 20 g block oscillating in SHM on the end of a spring. The horizontal axis scale is set by $t_s = 40.0$ ms.



(a) What is maximum kinentic energy of the block?

(b) The number of times per second that maximum is reached?

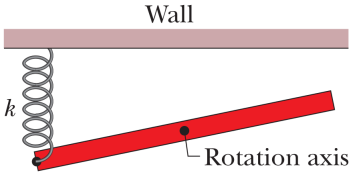
(c) Obtain the value of the spring constant.

(d) Magnitude of the radial acceleration of particle in the corresponding uniform circular motion?

(e) If in case at $t = 0$, $x_m = 3$ cm then the phase difference between two cases would be?

[2+2+2+2+4]

4. A long uniform rod of mass m is free to rotate in a horizontal plane abobt a vertical axis through its center. A spring having k spring constant is connected between one end of the rod and a fixed wall. When the rod is in equilibrium, it is parallel to the wall.



(a) Obtain the required differential equation to explain the SHM.

(b) Calculate the time period of the oscillation. Is the frequency of oscillation depends on the length of the rod?

[9+3]

Please turn over

5.In downhill speed skiing a skier is retarded by both the air drag force on the body and the kinetic frictional force on the skis. Suppose the slope angle is $\theta = 40^\circ$, the snow is dry snow with a coefficient of kinetic friction $\mu_k = 0.04$, the mass of the skier and equipment is $m = 85.0$ kg, the cross-sectional area of the (tucked) skier is $A = 1.30$ m^2, the drag coefficient is $C = 0.15$, and the air density is 1.20 kg/m^3. (a) What is the terminal speed? (b) If a skier can vary C by a slight amount dC by adjusting, say, the hand positions, what is the corresponding variation in the terminal speed?

[5+7]

Wish you all the best!