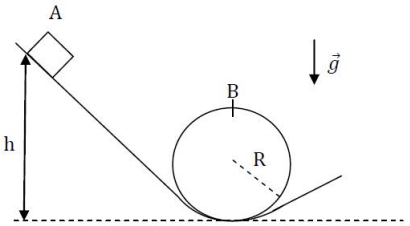
Group Number		Name		Type
List Number		Surname		A
Student ID		Signature		
E-mail				

ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

Questions 1-3

A block of mass m slides on the frictionless loop-to-loop track as shown in the figure. The block starts from rest at point A at a height h above the bottom of the loop.



1. What is the speed of the block at point B?

(a) $\sqrt{2g(h+2R)}$ (b) $\sqrt{2g(h-2R)}$ (c) $\sqrt{4g(h+2R)}$ (d) $\sqrt{4g(h-2R)}$ (e) $\sqrt{4gR}$

2. What is the condition satisfied by h (in terms of R) such that the block moves around the loop without falling off at the top point B?

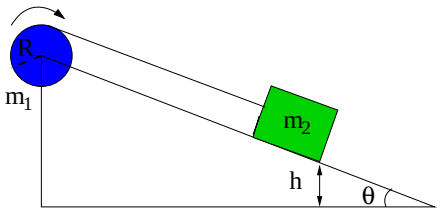
(a) $h > \frac{5}{2}R$ (b) $h > \frac{11}{5}R$ (c) $h > \frac{1}{2}R$ (d) $h > \frac{12}{5}R$ (e) $h > \frac{21}{10}R$

3. Find the normal force at point B for $h = 6R$.

(a) 15 mg (b) 7 mg (c) 9 mg (d) 11 mg (e) mg

Questions 4-6

A uniform cylinder of mass m_1=4 kg and radius R=40 cm is pivoted on frictionless bearings. A string wrapped around the cylinder connects to a mass m_2=6 kg, which is on a frictionless incline of angle θ=30^0 as shown in the figure. The system is released from rest with m_2 at height h=8 cm above the bottom of the incline. Moment of inertia of a cylinder rotating about its central axis is given as $\frac{1}{2}m_1R^2$. **(Take g=10 m/s^2, sin30=0.5)**



4. What is the acceleration of m_2 in m/s^2 after the system is released?

(a) 10 (b) 30/6.32 (c) 3.75 (d) 27/4 (e) 27/8

5. What is the tension in the string in *newton* after the system is released?

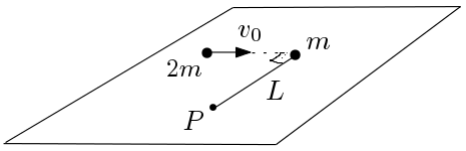
(a) 81/4 (b) 30 (c) 7.5 (d) 45 (e) 15

6. What is the angular speed of the cylinder when m_2 is at the bottom of the incline in rad/s?

(a) $\sqrt{15}$ (b) $\sqrt{60}$ (c) $\sqrt{10}$ (d) $\sqrt{7.5}$ (e) $\sqrt{30}$

Questions 7-9

A light rod of length L is fixed from one end at point P on a horizontal frictionless surface, and a point particle of mass m is attached to the other end, as shown in the figure. Another point particle of mass $2m$ with speed v_0 collides with m in a direction perpendicular to the rod.



7. If $2m$ sticks to m after the collision, what is the angular speed ω of the system just after the collision?

(a) $\frac{4v_0}{3L}$ (b) $\frac{v_0}{2L}$ (c) $\frac{v_0}{L}$ (d) $\frac{2v_0}{3L}$ (e) $\frac{v_0}{3L}$

8. If the mass $2m$ collides with speed v_0 and then bounces back with speed $v_0/2$ in the direction perpendicular to the rod, what is the angular speed ω of the rod and m just after the collision?

(a) $\frac{v_0}{3L}$ (b) $\frac{2v_0}{L}$ (c) $\frac{v_0}{4L}$ (d) $\frac{v_0}{L}$ (e) $\frac{3v_0}{L}$

9. If the rod is uniform and its mass is $M = 3m$, and $2m$ collides with speed v_0 and sticks to m after the collision, what is the angular speed ω of the system just after the collision? **(For a uniform rod of mass M and length L, $I_{cm} = \frac{1}{12}ML^2$)**

(a) $\frac{v_0}{L}$ (b) $\frac{v_0}{2L}$ (c) $\frac{4v_0}{3L}$ (d) $\frac{v_0}{5L}$ (e) $\frac{2v_0}{L}$

Questions 10-13

Suppose you want to place a weather satellite with mass m into a circular orbit of altitude $R_E/10$, where R_E is the radius of the earth. **PS:** Give your answers in terms of the parameter $\lambda = (GM_E)/R_E$ with G and M_E universal gravitational constant and the earth's mass respectively (take the potential energy to be zero at infinite distance).

10. What is the speed of the satellite in this orbit?

(a) $\sqrt{\lambda}$ (b) $\sqrt{20\lambda}$ (c) $\sqrt{\frac{20\lambda}{21}}$ (d) $\sqrt{210\lambda}$ (e) $\sqrt{\frac{10\lambda}{11}}$

11. What is the radial acceleration of the satellite in this orbit?

(a) $\frac{\lambda}{R_E}$ (b) $\left(\frac{10}{11}\right)^2 \frac{\lambda}{R_E}$ (c) $100\frac{\lambda}{R_E}$ (d) $400\frac{\lambda}{R_E}$ (e) $\left(\frac{100}{21}\right)^2 \frac{\lambda}{R_E}$

12. What is the total mechanical energy of the satellite when it is in this orbit?

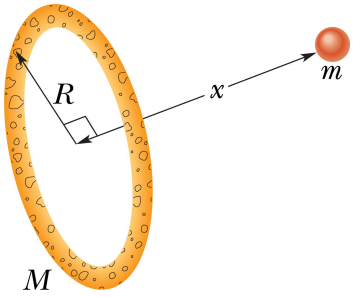
(a) $-5\lambda m$ (b) $-\frac{20}{11}\lambda m$ (c) $+\frac{5}{11}\lambda m$ (d) $+\lambda m$ (e) $-\frac{5}{11}\lambda m$

13. How much work has to be done to place this satellite in this orbit?

(a) $11\lambda m$ (b) $\frac{41}{11}\lambda m$ (c) $\frac{6}{11}\lambda m$ (d) $2\lambda m$ (e) $10\lambda m$

Questions 14-16

Consider the ring-shaped body of uniformly distributed mass M in the figure. A particle with mass m is placed a distance x from the center of the ring, along the line through the center of the ring and perpendicular to its plane.



14. What is the gravitational potential energy of this system? (Take the potential energy to be zero when the two objects are far apart.)

(a) $-\frac{GMm}{(x^2+R^2)}$ (b) $-\frac{GMm}{(x^2+R^2)^{3/2}}$ (c) $-\frac{GMm}{(x^2+R^2)^2}$ (d) $-\frac{GMm}{(x^2+R^2)^{1/2}}$
(e) $-\frac{GMm}{(x^2+R^2)^{5/2}}$

15. What is the magnitude of the gravitational force exerted by the ring on the point particle?

(a) $\frac{GMmx}{(x^2+R^2)^2}$ (b) $\frac{GMmx}{(x^2+R^2)^{3/2}}$ (c) $\frac{GMmx}{(x^2+R^2)^{1/2}}$ (d) $\frac{GMm}{(x^2+R^2)^{1/2}}$ (e) $\frac{GMmx}{(x^2+R^2)^{5/2}}$

16. What is the magnitude of the gravitational force exerted by the ring on the point particle when x is very large compared to the radius of the ring?

(a) $\frac{GMm}{x^{3/2}}$ (b) $\frac{GMm}{x}$ (c) $\frac{GMm}{x^3}$ (d) $\frac{GMm}{x^{1/2}}$ (e) $\frac{GMm}{x^2}$

Questions 17-20

A spring-mass system is composed of a block with mass m and a massless spring of force constant k obeying Hooke's Law, and the whole system is located on a horizontal frictionless table. The block makes oscillations about the equilibrium position $x = 0$. The total mechanical energy and the maximum speed of the block are 10 J and 1 m/s, respectively. The amplitude of the oscillations and the phase constant are given as 0.1 m and $\pi/4$ rad, respectively.

17. What is the spring constant?

(a) 1000 N/m (b) 100 N/m (c) 1500 N/m (d) 2000 N/m (e) 1200 N/m

18. What is the period of the oscillations?

(a) $\frac{2\pi}{5}$ s (b) $\frac{2\pi}{15}$ s (c) $\frac{\pi}{5}$ s (d) $\frac{\pi}{15}$ s (e) $\frac{4\pi}{5}$ s

19. What is the mass of the block?

(a) 200 kg (b) 120 g (c) 200 g (d) 120 kg (e) 20 kg

20. What is the initial position of the block at $t = 0$?

(a) $\frac{\sqrt{2}}{200}$ m (b) $\frac{\sqrt{2}}{120}$ m (c) $\frac{\sqrt{2}}{20}$ m (d) $\frac{3\sqrt{2}}{200}$ m (e) $\frac{5\sqrt{2}}{20}$ m