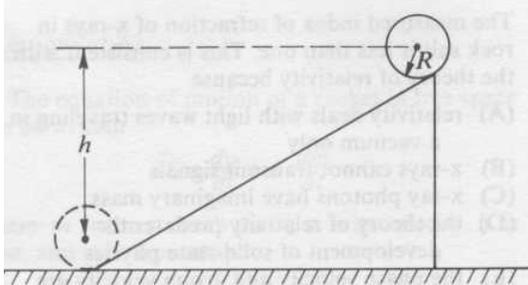


Problem 1:

The period of a hypothetical Earth satellite orbiting at sea level would be 80 minutes. In terms of the Earth's radius R_e , the radius of a synchronous satellite orbit (period 24 hours) is most nearly

- (A) $3 R_e$
- (B) $7 R_e$
- (C) $18 R_e$
- (D) $320 R_e$
- (E) $5800 R_e$

Problem 2:



A hoop of mass M and radius R is at rest at the top of an inclined plane as shown above. The hoop rolls down the plane without slipping. When the hoop reaches the bottom, its angular momentum around its center of mass is

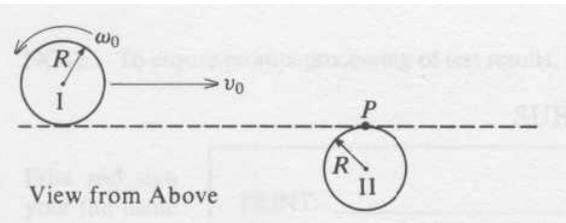
- (A) $MR\sqrt{gh}$
- (B) $\frac{1}{2}MR\sqrt{gh}$
- (C) $M\sqrt{2gh}$
- (D) Mgh
- (E) $\frac{1}{2}Mgh$

Problem 3:

A particle is constrained to move along the x -axis under the influence of the net force $F = -kx$ with amplitude A and frequency f , where k is a positive constant. When $x = A/2$, the particle's speed is

- (A) $2\pi fA$
- (B) $\sqrt{3}\pi fA$
- (C) $\sqrt{2}\pi fA$
- (D) πfA
- (E) $\frac{1}{3}\pi fA$

Problem 4:



Two uniform cylindrical disks of identical mass M , radius R , and moment of inertia $\frac{1}{2}MR^2$, as shown above, collide on a frictionless, horizontal surface. Disk I, having an initial counterclockwise angular velocity ω_0 and a center-of-mass velocity $v_0 = \frac{1}{2}\omega_0 R$ to the right, makes a grazing collision with disk II initially at rest. If after the collision the two disks stick together, the magnitude of the total angular momentum about the point P is

- (A) zero
- (B) $\frac{1}{2}MR^2\omega_0$
- (C) $\frac{1}{2}MRv_0$
- (D) MRv_0
- (E) dependent on the time of the collision

Problem 5:

A particle of mass m that moves along the x -axis has potential energy $V(x) = a + bx^2$, where a and b are positive constants. Its initial velocity is v_0 at $x = 0$. It will execute simple harmonic motion with a frequency determined by the value of

- (A) b alone
- (B) b and a alone
- (C) b and m alone
- (D) b , a , and m alone
- (E) b , a , m , and v_0

Problem 6:

The equation of motion of a rocket in free space can be written

$$m \frac{dv}{dt} + u \frac{dm}{dt} = 0$$

where m is the rocket's mass, v is its velocity, t is time, and u is a constant.

The constant u represents the speed of the

- (A) rocket at $t = 0$
- (B) rocket after its fuel is spent
- (C) rocket in its instantaneous rest frame
- (D) rocket's exhaust in a stationary frame
- (E) rocket's exhaust relative to the rocket

Problem 7:

The equation of motion of a rocket in free space can be written

$$m \frac{dv}{dt} + u \frac{dm}{dt} = 0$$

where m is the rocket's mass, v is its velocity, t is time, and u is a constant.

The equation can be solved to give v as a function of m . If the rocket has $m = m_0$ and $v = 0$ when it starts, what is the solution?

- (A) $u m_0 / m$
- (B) $u \exp(m_0 / m)$
- (C) $u \sin(m_0 / m)$
- (D) $u \tan(m_0 / m)$
- (E) None of the above.

Problem 8:

The weight of an object on the Moon is $1/6$ of its weight on the Earth. A pendulum clock that ticks once per second on the Earth is taken to the Moon. On the Moon the clock would tick once every

- (A) $1/6$ s.
- (B) $(1/6)^{1/2}$ s.
- (C) 1 s.
- (D) $6^{1/2}$ s.
- (E) 6 s.

Problem 9:

The potential energy function representing the attractive central force field can be written as $V(r) = -k/r$. At a certain time the particle has angular momentum \mathbf{L} and total energy E .

At some later time, which of the following statements will be true of the angular momentum \mathbf{L} and total energy E of the particle?

- (A) \mathbf{L} will have changed, but E will not.
- (B) E will have changed, but \mathbf{L} will not.
- (C) Neither \mathbf{L} nor E will have changed.
- (D) Both \mathbf{L} and E will have changed.
- (E) It is not possible to say what will happen to \mathbf{L} and E .

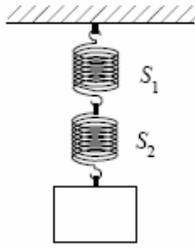
Problem 10:

The potential energy function representing the attractive central force field can be written as $V(r) = -k/r$. At a certain time the particle has angular momentum \mathbf{L} and total energy E .

For a given nonzero angular momentum, there is a minimum energy for which it is possible to find a solution to the equations of motion. At this minimum energy, the particle is moving in a

- (A) circular orbit.
- (B) noncircular elliptical orbit.
- (C) parabolic orbit.
- (D) hyperbolic orbit.
- (E) straight line.

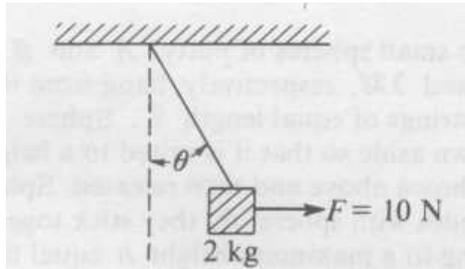
Problem 11:



Two springs, S_1 and S_2 , have negligible masses and the spring constant of S_1 is $1/3$ that of S_2 . When a block is hung from the springs as shown above and the springs come to equilibrium again, the ratio of the work done in stretching S_1 to the work done in stretching S_2 is

- (A) $1/9$
- (B) $1/3$
- (C) 1
- (D) 3
- (E) 9

Problem 13:



A 2-kilogram box hangs by a massless rope from a ceiling. A force slowly pulls the box horizontally to the side until the horizontal force is 10 newtons. The box is then in equilibrium as shown above. The angle that the rope makes with the vertical is closest to

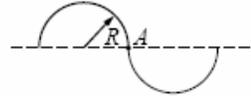
- (A) $\arctan 0.5$
- (B) $\arcsin 0.5$
- (C) $\arctan 2.0$
- (D) $\arcsin 2.0$
- (E) 45°

Problem 15:

The curvature of Mars is such that its surface drops a vertical distance of 2.0 meters for every 3600 meters tangent to the surface. In addition, the gravitational acceleration near its surface is 0.4 times that near the surface of Earth. What is the speed a golf ball would need to orbit Mars near the surface, ignoring the effects of air resistance?

- (A) 0.9 km/s
- (B) 1.8 km/s
- (C) 3.6 km/s
- (D) 4.5 km/s
- (E) 5.4 km/s

Problem 12:



The S-shaped wire shown above has a mass M , and the radius of curvature of each half is R . The moment of inertia about an axis through A and perpendicular to the plane of the paper is

- (A) $(1/2)MR^2$
- (B) $(3/4)MR^2$
- (C) MR^2
- (D) $(3/2)MR^2$
- (E) $2MR^2$

Problem 14:

A 5-kilogram stone is dropped on a nail and drives the nail 0.025 meter into a piece of wood. If the stone is moving at 10 meters per second when it hits the nail, the average force exerted on the nail by the stone while the nail is going into the wood is most nearly

- (A) 10 N
- (B) 100 N
- (C) 1000 N
- (D) 10,000 N
- (E) 100,000 N