

Mechanics – Problem Set # 3

TABLE OF INFORMATION

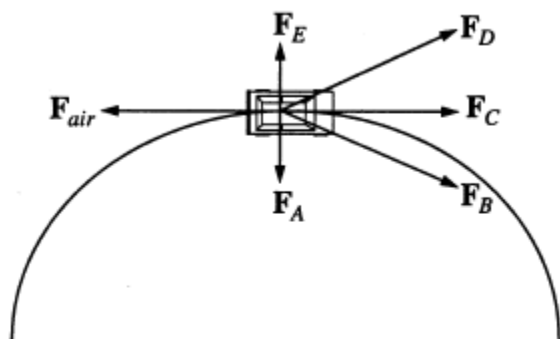
Rest mass of the electron	$m_e = 9.11 \times 10^{-31}$ kilogram = 9.11×10^{-28} gram
Magnitude of the electron charge	$e = 1.60 \times 10^{-19}$ coulomb = 4.80×10^{-10} statcoulomb (esu)
Avogadro's number	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant	$R = 8.31$ joules/(mole · K)
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ joule/K = 1.38×10^{-16} erg/K
Speed of light	$c = 3.00 \times 10^8$ m/s = 3.00×10^{10} cm/s
Planck's constant	$h = 6.63 \times 10^{-34}$ joule · second = 4.14×10^{-15} eV · second $\hbar = h/2\pi$
Vacuum permittivity	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb ² /(newton · meter ²)
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Universal gravitational constant	$G = 6.67 \times 10^{-11}$ meter ³ /(kilogram · second ²)
Acceleration due to gravity	$g = 9.80$ m/s ² = 980 cm/s ²
1 atmosphere pressure	1 atm = 1.0×10^5 newton/meter ² = 1.0×10^5 pascals (Pa)
1 angstrom	1 Å = 1×10^{-10} meter
	1 weber/m ² = 1 tesla = 10^4 gauss

Moments of inertia about center of mass

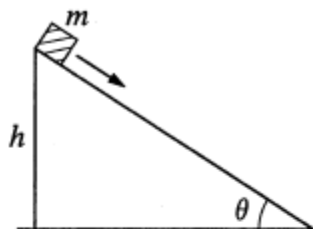
Rod $\frac{1}{12} M\ell^2$

Disc $\frac{1}{2} MR^2$

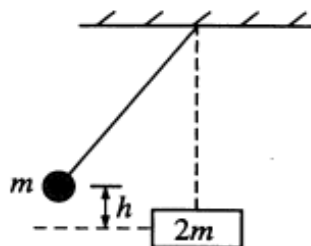
Sphere $\frac{2}{5} MR^2$



5. A car travels with constant speed on a circular road on level ground. In the diagram above, F_{air} is the force of air resistance on the car. Which of the other forces shown best represents the horizontal force of the road on the car's tires?
- (A) F_A
 (B) F_B
 (C) F_C
 (D) F_D
 (E) F_E



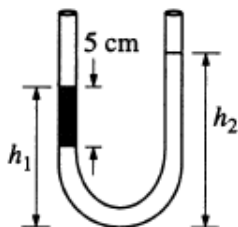
6. A block of mass m sliding down an incline at constant speed is initially at a height h above the ground, as shown in the figure above. The coefficient of kinetic friction between the mass and the incline is μ . If the mass continues to slide down the incline at a constant speed, how much energy is dissipated by friction by the time the mass reaches the bottom of the incline?
- (A) mgh/μ
 (B) mgh
 (C) $\mu mgh/\sin\theta$
 (D) $mgh\sin\theta$
 (E) 0
-



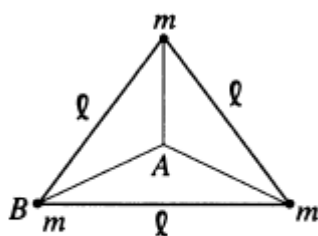
7. As shown above, a ball of mass m , suspended on the end of a wire, is released from height h and collides elastically, when it is at its lowest point, with a block of mass $2m$ at rest on a frictionless surface. After the collision, the ball rises to a final height equal to
- (A) $1/9 h$
 - (B) $1/8 h$
 - (C) $1/3 h$
 - (D) $1/2 h$
 - (E) $2/3 h$
-

20. A helium atom, mass $4u$, travels with nonrelativistic speed v normal to the surface of a certain material, makes an elastic collision with an (essentially free) surface atom, and leaves in the opposite direction with speed $0.6v$. The atom on the surface must be an atom of
- (A) hydrogen, mass $1u$
 - (B) helium, mass $4u$
 - (C) carbon, mass $12u$
 - (D) oxygen, mass $16u$
 - (E) silicon, mass $28u$
-

21. The period of a physical pendulum is $2\pi\sqrt{I/mgd}$, where I is the moment of inertia about the pivot point and d is the distance from the pivot to the center of mass. A circular hoop hangs from a nail on a barn wall. The mass of the hoop is 3 kilograms and its radius is 20 centimeters. If it is displaced slightly by a passing breeze, what is the period of the resulting oscillations?
- (A) 0.63 s
 - (B) 1.0 s
 - (C) 1.3 s
 - (D) 1.8 s
 - (E) 2.1 s
22. 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
-
23. Suppose that the gravitational force law between two massive objects were $\mathbf{F}_{12} = \hat{\mathbf{r}}_{12}Gm_1m_2/r_{12}^{2+\epsilon}$, where ϵ is a small positive number. Which of the following statements would be FALSE?
- (A) The total mechanical energy of the planet-Sun system would be conserved.
 - (B) The angular momentum of a single planet moving about the Sun would be conserved.
 - (C) The periods of planets in circular orbits would be proportional to the $(3 + \epsilon)/2$ power of their respective orbital radii.
 - (D) A single planet could move in a stationary noncircular elliptical orbit about the Sun.
 - (E) A single planet could move in a stationary circular orbit about the Sun.
-



30. An open-ended U-tube of uniform cross-sectional area contains water (density $1.0 \text{ gram/centimeter}^3$) standing initially 20 centimeters from the bottom in each arm. An immiscible liquid of density $4.0 \text{ grams/centimeter}^3$ is added to one arm until a layer 5 centimeters high forms, as shown in the figure above. What is the ratio h_2/h_1 of the heights of the liquid in the two arms?
- (A) $3/1$
 (B) $5/2$
 (C) $2/1$
 (D) $3/2$
 (E) $1/1$
-
31. A sphere of mass m is released from rest in a stationary viscous medium. In addition to the gravitational force of magnitude mg , the sphere experiences a retarding force of magnitude bv , where v is the speed of the sphere and b is a constant. Assume that the buoyant force is negligible. Which of the following statements about the sphere is correct?
- (A) Its kinetic energy decreases due to the retarding force.
 (B) Its kinetic energy increases to a maximum, then decreases to zero due to the retarding force.
 (C) Its speed increases to a maximum, then decreases back to a final terminal speed.
 (D) Its speed increases monotonically, approaching a terminal speed that depends on b but not on m .
 (E) Its speed increases monotonically, approaching a terminal speed that depends on both b and m .
-



32. Three equal masses m are rigidly connected to each other by massless rods of length l forming an equilateral triangle, as shown above. The assembly is to be given an angular velocity ω about an axis perpendicular to the triangle. For fixed ω , the ratio of the kinetic energy of the assembly for an axis through B compared with that for an axis through A is equal to

(A) 3
 (B) 2
 (C) 1
 (D) $1/2$
 (E) $1/3$

44. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to

$$v(x) = \beta x^{-n},$$

where β and n are constants and x is the position of the particle. What is the acceleration of the particle as a function of x ?

(A) $-n\beta^2 x^{-2n-1}$
 (B) $-n\beta^2 x^{-n-1}$
 (C) $-n\beta^2 x^{-n}$
 (D) $-\beta x^{-n+1}$
 (E) $-\beta x^{-2n+1}$

65. A man of mass m on an initially stationary boat gets off the boat by leaping to the left in an exactly horizontal direction. Immediately after the leap, the boat, of mass M , is observed to be moving to the right at speed v . How much work did the man do during the leap (both on his own body and on the boat) ?

(A) $\frac{1}{2} Mv^2$

(B) $\frac{1}{2} mv^2$

(C) $\frac{1}{2} (M + m) v^2$

(D) $\frac{1}{2} \left(M + \frac{M^2}{m} \right) v^2$

(E) $\frac{1}{2} \left(\frac{Mm}{M + m} \right) v^2$