1001

A man of weight w is in an elevator of weight w. The elevator accelerates vertically up at a rate a and at a certain instant has a speed V.

(a) What is the apparent weight of the man?

(b) The man climbs a vertical ladder within the elevator at a speed v relative to the elevator. What is the man's rate of expenditure of energy (power output)?

(*Wisconsin*)

1002

An orbiting space station is observed to remain always vertically above the same point on the earth. Where on earth is the observer? Describe the orbit of the space station as completely as possible.

(*Wisconsin*)

1003

In an amusement park there is a rotating horizontal disk. A child can sit on it at any radius (Fig. 1.1). As the disk begins to "speed up", the child may slide off if the frictional force is insufficient. The mass of the child is 50 kg and the coefficient of friction is 0.4. The angular velocity is 2 rad/s. What is the maximum radius R where he can sit and still remain on the disk?

(*Wisconsin*)

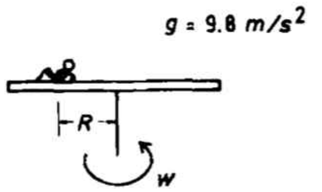

Fig. 1.1.

1004

A cord passing over a frictionless pulley has a 9 kg mass tied on one end and a 7 kg mass on the other end (Fig. 1.2). Determine the acceleration and the tension of the cord.

(*Wisconsin*)

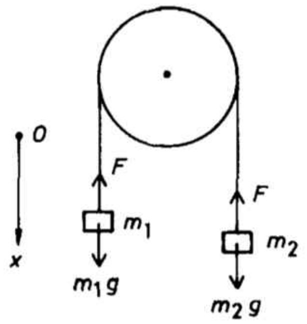

Fig. 1.2.

1005

A brick is given an initial speed of 5 ft/s up an inclined plane at an angle of 30° from the horizontal. The coefficient of (sliding or static) friction is $\mu = \sqrt{3}/12$. After 0.5 s, how far is the brick from its original position? You may take $g = 32$ ft/s^2.

(*Wisconsin*)

1006

A person of mass 80 kg jumps from a height of 1 meter and foolishly forgets to buckle his knees as he lands. His body decelerates over a distance of only one cm. Calculate the total force on his legs during deceleration.

(*Wisconsin*)

1007

A mass M slides without friction on the roller coaster track shown in Fig. 1.4. The curved sections of the track have radius of curvature R. The mass begins its descent from the height h. At some value of h, the mass will begin to lose contact with the track. Indicate on the diagram where the mass loses contact with the track and calculate the minimum value of h for which this happens.

(Wisconsin)

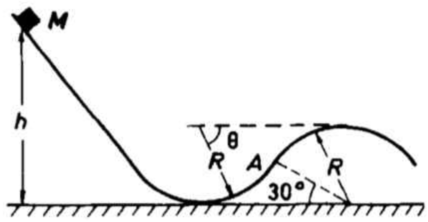

Fig. 1.4.

1008

Consider a rotating spherical planet. The velocity of a point on its equator is V. The effect of rotation of the planet is to make g at the equator 1/2 of g at the pole. What is the escape velocity for a polar particle on the planet expressed as a multiple of V?

(Wisconsin)

1009

A small mass m rests at the edge of a horizontal disk of radius R; the coefficient of static friction between the mass and the disk is μ. The disk is rotated about its axis at an angular velocity such that the mass slides off the disk and lands on the floor h meters below. What was its horizontal distance of travel from the point that it left the disk?

(Wisconsin)

1010

A marble bounces down stairs in a regular manner, hitting each step at the same place and bouncing the same height above each step (Fig. 1.5). The stair height equals its depth (tread=rise) and the coefficient of restitution e is given. Find the necessary horizontal velocity and bounce height (the coefficient of restitution is defined as $e = -v_f/v_i$, where v_f and v_i are the vertical velocities just after and before the bounce respectively).

(*Wisconsin*)

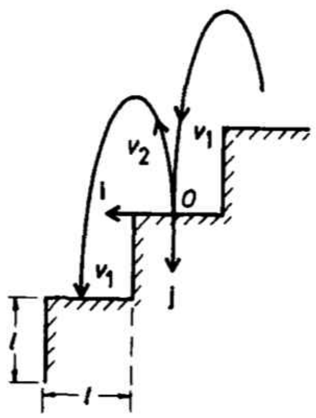

Fig. 1.5.

1011

Assume all surfaces to be frictionless and the inertia of pulley and cord negligible (Fig. 1.6). Find the horizontal force necessary to prevent any relative motion of m_1, m_2 and M.

(*Wisconsin*)

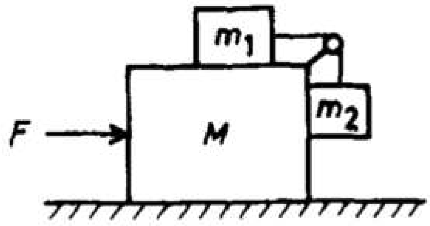

Fig. 1.6.

1012

The sun is about 25,000 light years from the center of the galaxy and travels approximately in a circle with a period of 170,000,000 years. The earth is 8 light minutes from the sun. From these data alone, find the approximate gravitational mass of the galaxy in units of the sun's mass. You may assume that the gravitational force on the sun may be approximated by assuming that all the mass of the galaxy is at its center.

(*Wisconsin*)

1013

An Olympic diver of mass m begins his descent from a 10 meter high diving board with zero initial velocity.

(a) Calculate the velocity V_0 on impact with the water and the approximate elapsed time from dive until impact (use any method you choose).

Assume that the buoyant force of the water balances the gravitational force on the diver and that the viscous force on the diver is bv^2.

(b) Set up the equation of motion for vertical descent of the diver through the water. Solve for the velocity V as a function of the depth x under water and impose the boundary condition $V = V_0$ at $x = 0$.

(c) If $b/m = 0.4\ \text{m}^{-1}$, estimate the depth at which $V = V_0/10$.

(d) Solve for the vertical depth $x(t)$ of the diver under water in terms of the time under water.

(*Wisconsin*)

1014

The combined frictional and air resistance on a bicyclist has the force $F = aV$, where V is his velocity and $a = 4$ newton-sec/m. At maximum effort, the cyclist can generate 600 watts propulsive power. What is his maximum speed on level ground with no wind?

(*Wisconsin*)

1015

A pendulum of mass m and length l is released from rest in a horizontal position. A nail a distance d below the pivot causes the mass to move along the path indicated by the dotted line. Find the minimum distance d in terms of l such that the mass will swing completely round in the circle shown in Fig. 1.8.

(*Wisconsin*)

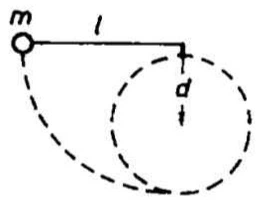

Fig. 1.8.

1016

A mass m moves in a circle on a smooth horizontal plane with velocity v_0 at a radius R_0. The mass is attached to a string which passes through a smooth hole in the plane as shown in Fig. 1.9. ("Smooth" means frictionless.)

(a) What is the tension in the string?

(b) What is the angular momentum of m?

(c) What is the kinetic energy of m?

(d) The tension in the string is increased gradually and finally m moves in a circle of radius $R_0/2$. What is the final value of the kinetic energy?

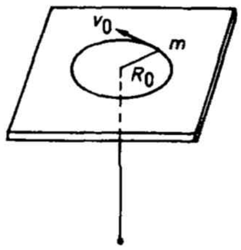

Fig. 1.9.

(e) Why is it important that the string be pulled gradually?

(*Wisconsin*)

1017

When a 5000 lb car driven at 60 mph on a level road is suddenly put into neutral gear (i.e. allowed to coast), the velocity decreases in the following manner:

$$V = \frac{60}{1 + \left(\frac{t}{60}\right)} \text{ mph} ,$$

where t is the time in sec. Find the horsepower required to drive this car at 30 mph on the same road.
Useful constants: $g = 22$ mph/sec, 1 H.P. = 550 ft.lb/sec, 60 mph = 88 ft/sec.

(*Wisconsin*)

1018

A child of mass m sits in a swing of negligible mass suspended by a rope of length l. Assume that the dimensions of the child are negligible compared with l. His father pulls him back until the rope makes an angle of one radian with the vertical, then pushes with a force $F = mg$ along the arc of a circle until the rope is vertical, and releases the swing. For what length of time did the father push the swing? You may assume that it is sufficiently accurate for this problem to write $\sin\theta \approx \theta$ for $\theta < 1$.

(*Wisconsin*)

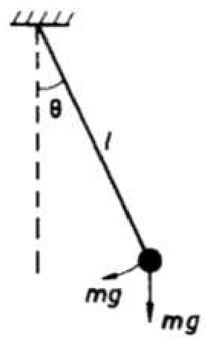

Fig. 1.10.

1019

A particle of mass m is subjected to two forces: a central force $\mathbf{f}_1$ and a frictional force $\mathbf{f}_2$, with

$$\mathbf{f}_1 = \frac{\mathbf{r}}{r} f(r),$$
$$\mathbf{f}_2 = -\lambda \mathbf{v} \qquad (\lambda > 0) ,$$

where $\mathbf{v}$ is the velocity of the particle. If the particle initially has angular momentum $\mathbf{J}_0$ about $r = 0$, find its angular momentum for all subsequent times.

(*Wisconsin*)

1020

(a) A spherical object rotates with angular frequency ω. If the only force preventing centrifugal disintegration of the object is gravity, what is the minimum density the object must have? Use this to estimate the minimum density of the Crab pulsar which rotates 30 times per second. (This is a remnant of a supernova in 1054 A.D. which was extensively observed in China!)

(b) If the mass of the pulsar is about 1 solar mass ($\sim 2 \times 10^{30}$ kg or $\sim 3 \times 10^5 M_{\text{earth}}$), what is the maximum possible radius of the pulsar?

(c) In fact the density is closer to that of nuclear matter. What then is the radius?

(*CUSPEA*)