R1-2002 Q1(c)

c) A uniform beam AOB, O being the mid point of AB, mass M, rests on three identical vertical springs with stiffness constants k_1, k_2 and k_3 at A, O and B respectively. The bases of the springs are fixed to a horizontal platform. Determine the compression of the springs and their compressional forces in the case:

(i) $k_1 = k_3 = k$ and $k_2 = 2k$
(ii) $k_1 = k, k_2 = 2k$ and $k_3 = 3k$

[8]

R1-2002 Q1(d)

d) A rocket, total mass 1.00×10^4 kg, is launched vertically; eighty per cent of the mass being fuel. At ignition, time $t = 0$, the thrust equals the weight of the rocket. The ejected exhaust gases have a speed of 9.00×10^2 ms $^{-1}$. Assuming the rate of fuel consumption and the acceleration due to gravity are constant, calculate:

(i) the mass, m, of gases ejected per second
(ii) the acceleration, a_e, of the rocket when the fuel is almost exhausted at time t_e

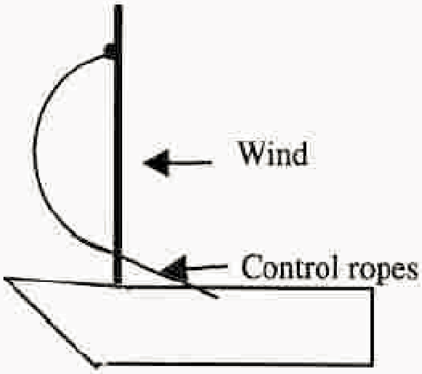
cont.

(iii) the mass, M, of the rocket at time t
(iv) the acceleration, a, of the rocket at time t, where $0 \le t \le t_e$
(v) Sketch a graph of the acceleration, a, of the rocket from $t = 0$ to $t = \infty$. [8]

R1-2004 Q1(l)

l)

Figure 1.5



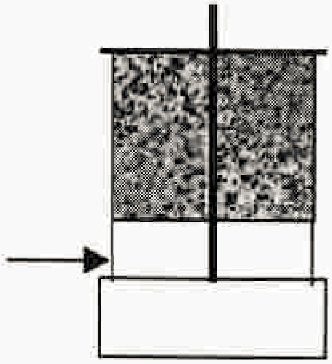


Figure 1.6

Figure 1.5 shows a side view of a simple sailing boat. Figure 1.6 is the same boat seen from the rear. The area of the sail is A. The wind velocity is v.

(i) Show that the force on the sail is kv^2, where k is a constant.

(ii) What are the dimensions of k?

(iii) How does k depend on the density of the air, ρ?

(iv) Explain why doubling the speed of the wind does not quadruple the speed of the boat.

[8]

R1-2004 Q1(m)

m) A cyclist is travelling with constant velocity along a straight road. The wheels of the bicycle roll, without slipping, along the road. Why is it easier to photograph, with clarity, those parts of the spokes nearest the ground?

[4]

R1-2006 Q1(a)

(a) Six identical numbered cubes, each of mass m, lie in a straight line on a smooth horizontal table, Figure 1.a, touching adjacent cubes. A constant force F is applied along the line of cubes.

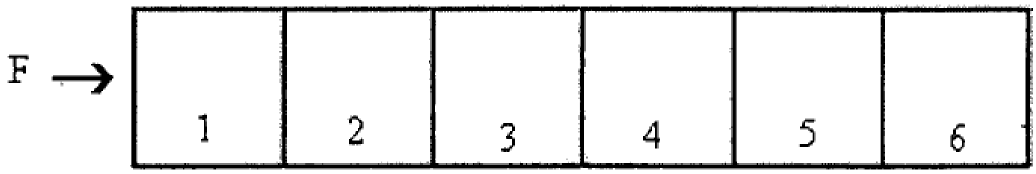


Figure 1.a

Determine:

(i) the acceleration of the system
(ii) the resultant force on each cube.
(iii) the force exerted on the fifth cube by the fourth cube.

[4]

R1-2006 Q1(j)

(j)

(i) Rain is falling vertically at 8.0 ms^{-1}. The rain drops make tracks on the side of a car window at an angle of 30° below the horizontal. Calculate the speed of the car, giving a full explanation.

(ii) Calculate the maximum speed at which a car could travel across a hump-backed bridge, having a radius of curvature of 40.0 m, without leaving the road at the top of the bridge.

(iii) A 45 m length of rope, mass 15 kg, hangs over a smooth horizontal peg. One side of the rope is 5 m longer than the other. It is released from rest. When it is initially no longer in contact with the peg, and has not reached the ground, calculate the change in potential energy and the speed of the chain.
What effect does doubling the mass of the rope have on the speed?

[10]

R1-2007 Q1(b)

(b) (i) A lorry is moving at a constant velocity along a road. It has rear wheel drive. Draw a diagram showing the forces exerted by the road on the wheels of the vehicle.

(ii) A jet plane, in level flight, is flying at constant velocity. Draw a diagram indicating the forces acting on the plane . State the nature of these forces and their relations.

[5]

R1-2007 Q1(o)

(o) A uniform plank, AB, mass m, of length $2l$ is supported at each end by vertical forces, S_A and S_B respectively. A man of mass M walks across the plank. Determine S_A and S_B when the man is a distance x from B. Plot ,on a single graph, the variation of S_A and S_B with x .

[6]

R1-2008 Q1(a)

(a) A cricket ball of mass 0.167 kg is thrown vertically upwards with an initial speed of 25.0 ms^{-1}. If the ball reaches a maximum height of 20.0 m, determine the percentage loss of energy caused by air resistance. [3]

R1-2008 Q1(e)

(e) An open cylindrical container, radius 18 cm, contains water of density 1000 kgm^{-3}. It has a hole in the base connected to a horizontal exit tube, Figure 1.e. The container is suspended by a spring, spring constant k, from a support, a vertical distance, H, from the water surface. As the water drains out of the container, what value of k is required to maintain the surface of the water at its initial distance H below the support ? [4]

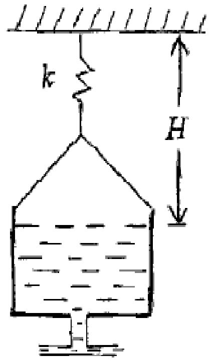


Figure 1.e

R1-2008 Q1(h)

(h) A constant horizontal acceleration is applied to a box, initially at rest, of mass 1.2 kg for 10.0 s. Its final speed is 0.40 ms^{-1}. What is the force, F, required ?

The box is maintained at this constant velocity on a frictionless track whilst a continuous vertical stream of sand is deposited on it at the rate of 5.0 gms^{-1}, impacting at 10 ms^{-1}. Determine the vertical force, F_V , on the box due to the falling sand and the horizontal force, F_H , required to maintain the constant velocity of the box . [7]

R1-2009 Q1(e)

(e) A machine gun fires bullets of mass 10g at a speed of 12 kms^{-1} . If the gunner can exert an average force of up to 80 N against the gun, calculate the maximum number of bullets that he can fire per minute.

Sketch a force – time graph of the recoil force of the gun on the shoulder of the gunner, and show, graphically, what is understood by the average force.

[5]

R1-2010 Q1(b)

(b) One end of a rope is fixed to a vertical wall, making an angle of 30^0 with the wall, and the other end is pulled by a horizontal force of 20N.. What is the mass of the rope?

[3]

R1-2010 Q1(j)

(j) A rocket stands vertically on its launch pad. Prior to ignition the mass of the rocket and its fuel is 4.1×10^3 kg. On ignition gas is ejected from the rocket at a speed of 2.5×10^3 ms^{-1} relative to the rocket and the fuel is consumed at a constant rate of 16 kgs^{-1}.

(i) Show that the rocket does not leave the pad immediately.
(ii) Calculate the time interval between ignition and lift off. [4]

R1-2010 Q1(m)

(m) A small positively charged ball B, mass *m,* is suspended by an insulating thread of negligible mass. Another identical ball, with the same charge, is moved slowly, from a great distance, to the original position of B. B rises by a distance *h*.

(i) What is the final tension in the thread?
(ii) Obtain an expression for the work done, *W*, and show that it is independent of the charges. (Hint: identify similar triangles) [8]

R1-2013 Q1(b)

(b) The pulley system in Figure 1.b consists of two pulleys of radii a and b rigidly fixed together, but free to rotate about a common horizontal axis. The weight W hangs from the axle of a freely suspended pulley P, which can rotate about its axle. If section A of a rough rope is pulled down with velocity V :

(i) Explain which way W will move.

(ii) With what speed will it move?

[5]

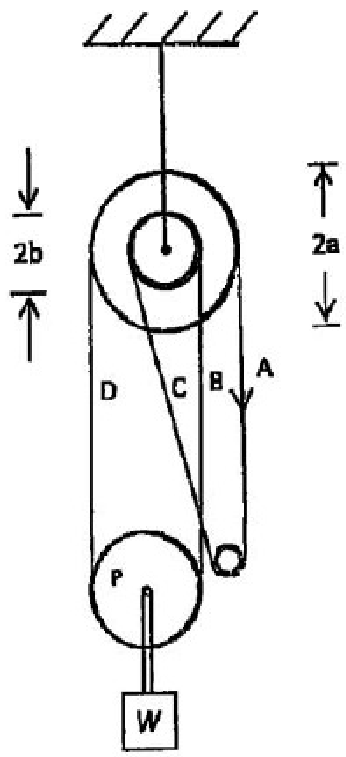


Figure 1.b

R1-2013 Q1(e)

(e) A horizontal bar, 8.0 m in length, has a 2.0 m rope attached at each end, with a small metal sphere at each end of each rope hanging under gravity, Figure 1.e. When the bar rotates about a vertical axis through its centre, the ropes are inclined at 30° to the vertical. Determine the period, T, of rotation of the system.

[5]

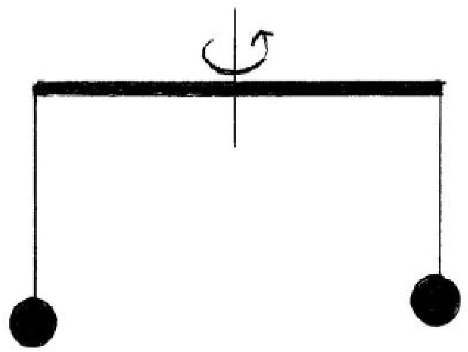


Figure 1.e

R1-2005 Q1(c(ii))

Why can a ladder be leaned at an angle on a rough floor against a smooth wall, but not on a smooth floor against a rough wall?

R1-2005 Q1(g)

g)

(i) A helium balloon has a volume of 512 m^3. What is the largest mass that can be raised by the balloon at STP if the balloon has negligible mass?

(ii) A child, restrained by a seat belt, is travelling at constant velocity in a bus and holds a vertical string with a helium balloon at the end. Explain what happens to the balloon when the bus decelerates and finally comes to rest.

[5]

R1-2012 Q1(c)

(c) You are challenged to construct a bridge using two identical uniform rectangular blocks, length 24 cm, which overhang a table as indicated in Figure 1.c. The lower block overhangs the table by *x* cm and the upper block overhangs the lower block by 6.0 cm. Under what condition will one or both blocks collapse?

[5]

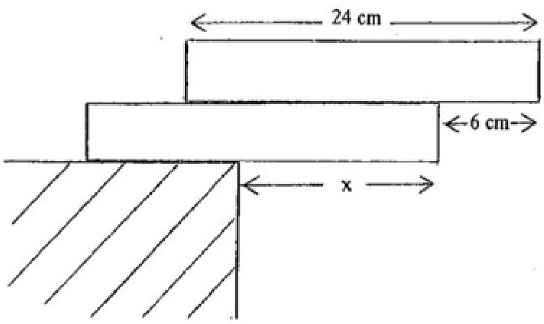


Figure 1.c

R1-2012 Q1(l)

(l) A rescue helicopter of mass 810 kg, supports itself in a stationary position by imparting a downward velocity, *v*, to the air in a circle of radius 4.0 m. The density of the air is 1.20 kg m^{-3}.

Calculate:

(i) the value of *v*

(ii) the power, *P*, required to support the helicopter

[5]

R1-2011 Q1(d)

d) A uniform cable has a mass of 100 kg and is suspended between two fixed points A and B, at the same horizontal level, (*Figure 1.d*). At the support points the cable makes angles of 30°.

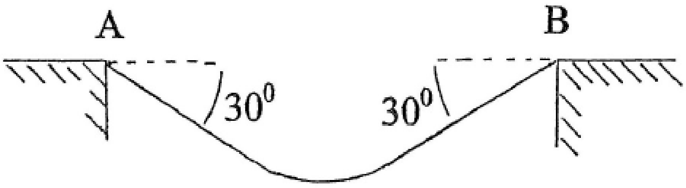


Figure 1.d

What is :

(i) The force exerted on each support?
(ii) The tension in the cable at its lowest point?

[5]

R1-2011 Q3(b)

b) A stream of particles, each of mass m and kinetic energy E, is collimated into a parallel beam of cross-sectional area A. The particles are incident, at a rate of n per second, on a smooth plane surface and rebound elastically.

(i) Derive an expression for the pressure on the surface.
(ii) Why would the pressure differ if the surface were rough?

[6]

R1-2002 Q5(a)

Q5
a)

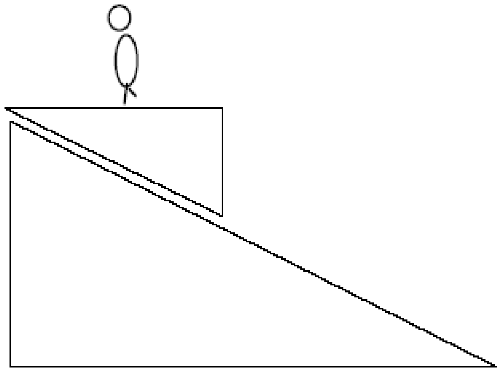


Figure 5.1

A student, mass 80 kg, stands on a horizontal set of bathroom scales, of negligible mass, attached to a massless platform that slides down a 30° incline, Figure 5.1. The scales read 75 kg. Calculate:

(i) the vertical acceleration a_v of the student
(ii) the acceleration of the student down the slope a_s
(iii) the coefficient of dynamic friction μ between the platform and the slope, where μ is the ratio of the frictional force to the normal reaction.

[10]

R1-2004 Q3

A 2.00 m light rigid rod is suspended from the ceiling by two vertical wires, A and B, each having a natural length of $\ell = 1.00$ m, attached to each end of the rod. A is a copper wire with a Young's modulus $Y_A = 12.4 \times 10^{10}$ Pa, diameter 1.60 mm, and B is a brass wire with a Young's modulus $Y_B = 9.00 \times 10^{10}$ Pa, diameter 1.00 mm.

a) An 80 kg mass is attached to the midpoint of the rod, calculate:

(i) the tension in each wire, assuming the rod is horizontal
(ii) the consequent extension of A
(iii) the consequent extension of B
(iv) the angle the rod makes with the horizontal

[8]

b) The attachment of the 80 kg mass is moved to a point D, a distance x from A, along the rod.

Calculate:

(i) the extension of A
(ii) the extension of B
(iii) the distance x for the rod to be horizontal.

[12]

R1-2006 Q4

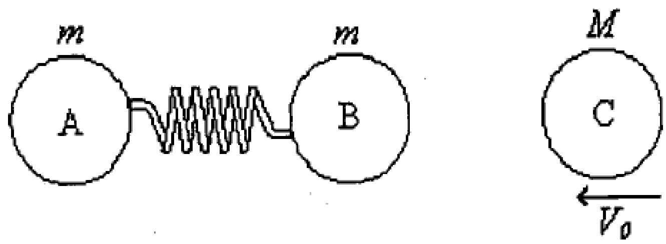


Figure 4.1

Two identical balls, A and B, each of mass m are joined by a massless spring, spring constant k, Figure 4.1. They are at rest on a smooth horizontal surface. A ball C, mass M and velocity V_o, strikes B. All balls are constrained to move along a straight line.

(a)

(i) Write down the energy and momentum equations for the collision in which, immediately after impact, the velocities of the balls are V_A, V_B and V_C in the direction of V_o.

(ii) Verify, by substituting into the equations, that there are two solutions:

$$V_C = V_o, \qquad V_B = 0, \qquad V_A = 0$$

and

$$V_C = \frac{M-m}{M+m}V_0, \qquad V_B = \frac{2M}{M+m}V_0, \qquad V_A = 0$$

(iii) Why must the first solution be rejected? Explain why $V_A = 0$

(iv) Deduce the velocity, after the collision, of the centre of mass of the system consisting of A and B.

[10]

(b) Consider the subsequent motion of A and B in their centre of mass system. Assume that their displacements, in their centre of mass system, about their initial positions following the impact are given by:

$$x = A\sin\omega t,$$

where x is measured in the direction of the centre of mass, A is the amplitude, ω is the angular frequency and t is the time measured from the instant of collision.
Determine:

(i) ω
(ii) A
(iii) Write down the position of B, x_B, in the laboratory system of coordinates, measured from the instant of collision.

[10]

R1-2008 Q4(a)

Q4

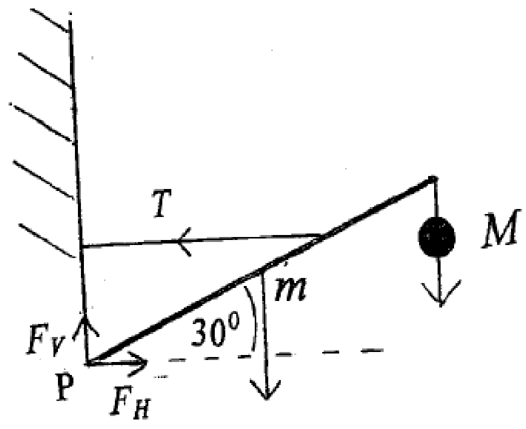


Figure 4.a

(a) A mass $M = 100$ kg hangs from one end of a uniform beam of length 3.00 m and mass $m = 2.00$ kg. The other end is hinged to a vertical wall at P. A horizontal cable, of negligible mass, is attached to the beam at a point 2.00 m from P to hold the beam in equilibrium at an angle of 30^0 to the horizontal, Figure 4.a.

Determine:

(i) the tension T in the cable

(ii) the horizontal and vertical components of the forces of the hinge on the beam, F_H and F_V respectively.

[8]

R1-2009 Q3

(a)

A man of height $h_0 = 2.00$ m and mass m is to bungee jump from a platform situated at a height $h = 25.0$ m above a lake. One end of an elastic rope is attached to his foot and the other end is fixed to the platform. He falls vertically.

The unstretched length of rope is l_0 and its force constant is k. The rope is chosen so that his speed will be reduced to zero the instant his head reaches the water surface.

When he is at rest, in equilibrium, at the end of the rope, his head is 8.00 m above the water. Assume the centre of gravity of the man is half way up his body.

Write down an algebraic expression for :

(i) the energy equation at his lowest point

(ii) the force equation at equlibrium

(iii) Determine l_0 numerically. [10]

(b)

Determine the man's maximum:

(i) speed

(ii) acceleration

[10]

R1-2010 Q3

The ends of a uniform wire of cross-sectional area 1.00×10^{-6} m^2 and negligible mass are attached to fixed points A and B which are 1.00 m apart, in the same horizontal line. The wire is initially straight and unstretched. A mass of 0.50 kg is attached to the mid-point of the wire and hangs in equilibrium with the mid-point at a distance of 10 mm below AB.
Calculate the Young's modulus for the wire.

[10]

A man, mass 90 kg, begins to climb a 4.0 m ladder of mass 10 kg. The ladder rests against a wall at A. The foot of the ladder, B, is 2.0 m from the wall.

(i) Draw a diagram indicating all the forces present in terms of their vertical and horizontal components using the notation F_{AV}, F_{AH}, F_{BV} and F_{BH} for components at A and B; the vertical components have subscripts *V* and the horizontal components have subscripts *H*.

(ii) What conditions must be satisfied by the forces, and the moment of the forces about A, if the man is to climb a distance *x* up the ladder when it is against a smooth wall?

(iii) If the man is to climb to the top of the ladder, what is the minimum value of the coefficient of friction, μ, required on the ground?

[10]

R1-2011 Q5

a) A taut horizontal wire, with zero tension, has length 2L and elastic constant k. A mass M is attached to its mid point O and the system is allowed to come to equilibrium. The wire is stretched by an amount $2y_e$, much less than $2L$, O is displaced vertically by an amount x_e, and the wire is at an angle θ (*Figure 5.a*).

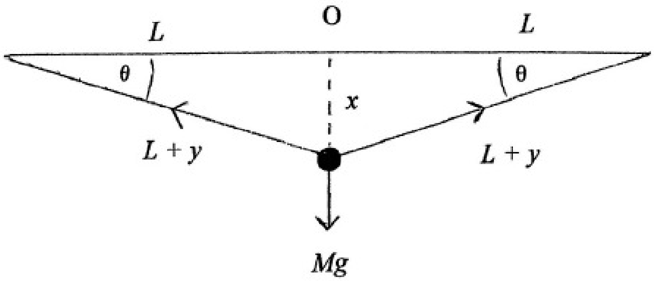


Figure 5.a

(i) Derive, using Pythagoras's theorem, the approximate relation

$$(x_e/L)^2 = 2(y_e/L).$$

(ii) Determine the equilibrium displacement x_e, in terms of M, L and k.

[10]

b) If mass M is released from its initial rest position, with the wire horizontal:

(i) Give its equation of motion in terms of the vertical coordinate, x.
(ii) Write down an expression for the kinetic energy of the mass in terms of x
(iii) Deduce the maximum value of x, x_m.

[10]

For z much smaller than unity the approximation,

$$(1+z)^n = 1 + nz + \ldots \text{ can be applied.}$$