Problem 1-23. A missile is launched with an initial velocity of 1000 ms^{-1} at an elevation angle of 55^0.
Calculate the range the missile can theoretically reach and the maximum height of its theoretical trajectory.

[x = 95.7 km ; h = 34.1 km]

Problem 1-24. A particle makes a motion in a circle of radius r = 20 cm with a constant angular acceleration $\varepsilon = 2\,s^{-2}$.
Calculate the magnitudes of the tangential and the centripetal accelerations and also the total acceleration, each of these at the end of the fourth second of the motion.

$\left[a_t = 0.4ms^{-2},\ \ a_n = 12.80ms^{-2},\ \ a = 12.81ms^{-2}\right]$

Problem 1-25. What is the radius of a rotating wheel if its circumference point has a three times greater velocity than a point 10 cm closer to the rotation axis?

[r = 0.15 m]

Problem 1-26. A wheel starts to rotate from rest with a constant angular acceleration $\varepsilon = 2\,s^{-2}$.
Calculate its number of revolutions in the first 15 seconds.

[N = 35.8]

Problem 1-27. A wheel starts to make a uniformly accelerated rotation. In the time interval of the first 5 seconds it makes 12.5 revolutions.
Calculate its angular velocity at the end of the fifth second.

$\left[\omega = 10\pi\,s^{-1}\right]$

1.2 DYNAMICS

The first law of motion:

> **every body continues in its state of rest or of uniform speed in a straight line unless it is compelled to change that state by forces acting on it.**

Notes: a) This law states that if no net force is acting on a body it remains at rest, or if it is moving it continues moving with constant speed in a straight line.
b) The tendency of a body to maintain its state of rest or of uniform motion in a straight line is called inertia; that is why the first law of motion is often called the law of inertia.

The second law of motion:
the acceleration of an object is directly proportional to the net force acting on it and it is inversely proportional to its mass.

Notes: a) If a net force is exerted on a body its velocity will change. A net force gives rise to acceleration. The direction of the acceleration is in the direction of the applied net force.

b) By the net force we mean the vector sum of all forces acting on a body.

c) The more mass a body has the harder it is to change its state of motion; it is harder to set it in motion from rest or to stop it when it moves. We say that mass is a measure of the inertia of a body.

The second law of motion states the relationship between acceleration and force. The familiar statement of the second law of motion has the form

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt}$$

This is one of the most fundamental relationships in physics.

The **unit of force** is called a **newton** [N]. One newton is the force required to impart an acceleration of $1\,ms^{-2}$ to a mass of 1 kg.
Thus, $1\text{ N} = 1\,kg\,m\,s^{-2}$.

If m = constant, the second law of motion may be written as

$$\mathbf{F} = \frac{d}{dt}(m\mathbf{v}) = \frac{d\mathbf{p}}{dt}$$

where $\mathbf{p} = m\mathbf{v}$ is a **momentum vector**; $[\mathbf{p}] = kg\,m\,s^{-1}$.
Thus, the momentum vector **p** of a body is defined as the product of its mass *m* and its velocity vector **v**. Momentum is a vector quantity, for it is the product of a scalar and a vector.
The second law of motion can be now restated in terms of the concept of momentum:

The momentum of an isolated body is conserved; that is, it does not change in either magnitude or direction.

The third law of motion:

Forces always occur in pairs. If body *A* exerts a force on body *B*, an equal but opposite force is exerted by body *B* on body *A*.

This is the essence of the third law of motion - observations suggest that a force applied to any object is always applied by another object. Forces always occur in action-reaction pairs and act on different bodies, so that they can never balance each other.

The force due to gravity; Weight

The force of gravitational attraction of the earth for an object is called the **weight** of the object.

If we drop an object near the surface of the Earth and we can disregard air resistance so that the only force acting on the object is the force due to gravity, the object accelerates toward the Earth with acceleration $9.81 ms^{-2}$. At a given point in space this acceleration is the same for all objects independent of their mass.
The force due to gravity on an object is equal to

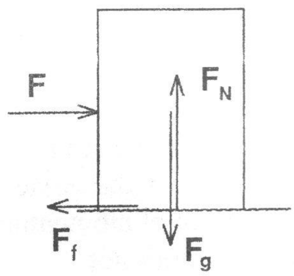
$$\mathbf{F} = m\mathbf{g}$$

where vector **g** is called the **gravitational field of the Earth.** It is the force per unit mass exerted by the Earth on any object. It is equal to the acceleration of gravity, i.e., the free fall acceleration experienced by an object when the only force acting on it is the gravitational field of the Earth and the acceleration of gravity has the same value

$$g = 9.81 N\, kg^{-1} = 9.81 ms^{-2}$$

The force of attraction of the Earth for an object varies with location. It does not have the same value everywhere. At points above the surface of the Earth, the force due to gravity varies inversely as the square of the distance from the centre of the Earth. The gravitational field also varies slightly with latitude because the earth is not exactly spherical but is flattened at the poles.
Note: the terms mass and weight are often confused with one another, but it is important to distinguish between them. Mass is a property of the body itself; weight, on the other hand, is a force, the force of gravity acting on a body.

Normal force; Frictional force



When an object is at rest on a table the gravitational force does not disappear. From the second law of motion the net force on an object at rest is zero. There must be another force on the object to balance the gravitational force. For an object resting on a table, the table exerts this upward force and this force is usually referred to as the **normal force** $\mathbf{F}_N$.
A perfectly smooth surface exerts a force $\mathbf{F}_N$, but only in a direction normal, or perpendicular, to the surface.
A rough surface may exert an additional force which is tangent to its the surface; this force is termed the **frictional force** $\mathbf{F}_f$.
Consider a block which is being accelerated by a force **F** applied parallel to the surface (see Fig.). Its motion is opposed by the frictional force $\mathbf{F}_f$.
Thus the resulting acceleration has the magnitude

$$a = \frac{F - F_f}{m}$$

The magnitude of $\mathbf{F}_f$ has been found to differ for different substances and to vary with the condition of the contacting surfaces. For a given pair of surfaces, however, the magnitude of the parallel frictional force F_f is nearly proportional to the normal force

$$F_f = \mu_k F_N$$

where μ_k is a constant called the coefficient of kinetic friction.

Suppose the block is initially at rest, and the force **F** applied to it is at first too small to start it moving. Since the block is in equilibrium, the frictional force $\mathbf{F}_f$ and the applied force **F** must be equal in magnitude and opposite in direction. As **F** is increased, the force $\mathbf{F}_f$ also increases until it reaches a maximum **static value**

$$F_f = \mu_s F_N$$

where μ_s is the coefficient of static friction (generally, $\mu_s \rangle \mu_k$). Once the applied force **F** exceeds this maximum value of $\mathbf{F}_f$, the block will start to move. At very low speeds the frictional force will not differ appreciably from its static value $\mu_s F_N$, but as the speed increases, F_f decreases until it reaches its kinetic value $\mu_k F_N$ and thereafter it remains at this level.

Centripetal force

If a body moves with speed v in a circle of radius r, it has a centripetal acceleration of magnitude

$$a_n = \frac{v^2}{r}$$

or in terms of the angular velocity ω

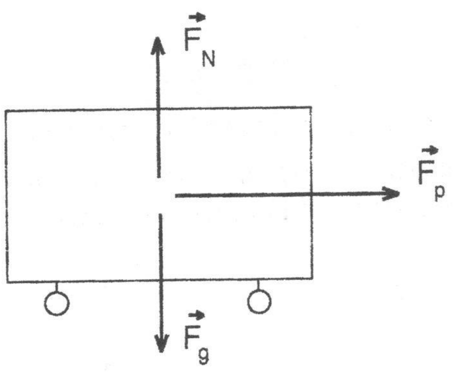
$$a_n = \omega^2 r$$

directed along the radius toward the centre of the circle.
This centripetal acceleration is related to a change in the direction of the velocity. As with any acceleration there must be a force in the direction of this centripetal acceleration to produce it. This force is called the **centripetal force** and its magnitude is equal to

$$F = ma_n = m\frac{v^2}{r} = m\omega^2 r$$

and this force is also directed along the radius toward the centre of the circle at any moment.

Problem 1-28. Calculate the force required to accelerate a 20 kg cart from rest to a velocity of 0.5 ms^{-1} in 2 s (friction is negligible).



Solution : There are three forces acting on the cart. The forward pushing force $\mathbf{F}_p$, the downward force of gravity $\mathbf{F}_g$ and the upward force $\mathbf{F}_N$ exerted by the floor. Since the cart is not accelerated vertically the sum of both vertical forces must be zero. Then the net force on the cart is simply $\mathbf{F}_p$.

To calculate how large $\mathbf{F}_p$ must be, we first calculate the acceleration required:

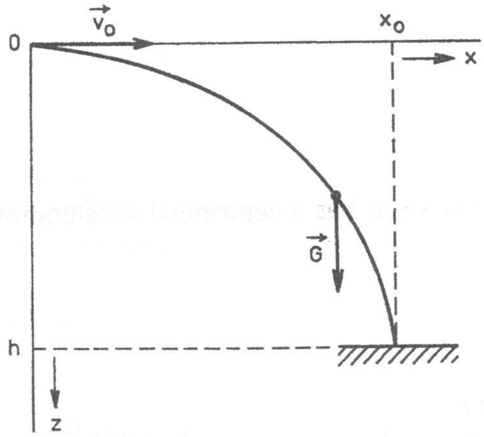
$$a = \frac{v}{t} = \frac{0.5}{2} = 0.25 ms^{-2}$$

Thus, the magnitude of the required force must be $F_p = ma = 5N$.

Problem 1-29. Build up and integrate equations of motion for the case of a horizontal projectile motion with an initial velocity vector $\mathbf{v}_0(v_0, 0, 0)$ and determine:

a) the horizontal range of the projection if its vertical height is *h;*

b) how long is this motion held ?



Solution: The origin of a co-ordinate system is set into the starting place of the motion. At any moment of the motion there is the only force acting on a projected object - the force of gravity $\mathbf{G}(0,0,mg) = \mathbf{mg}$ when m is the mass of the object.

The equations of motion now have the form:

$$\frac{d^2x}{dt^2} = 0, \quad \frac{d^2y}{dt^2} = 0, \quad \frac{d^2z}{dt^2} = g$$

Integration yields

$$x = A_1 t + A_2$$
$$y = A_3 t + A_4$$
$$z = \frac{1}{2} g t^2 + A_5 t + A_6$$

With respect to the given initial conditions the constants of integration will be equal

$$A_1 = v_0 \quad and \quad A_2 = A_3 = A_4 = A_5 = A_6 = 0$$

Thus, the solution of the equations of motion is as follows

$$x = v_0 t$$
$$y = 0$$
$$z = \frac{1}{2} g t^2$$

To obtain the trajectory of the motion we eliminate time t and then we can write

$$z = \frac{g}{2v_0^2} x^2$$

This is an equation of a parabola.

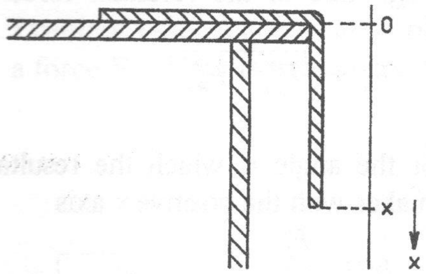
The range x_0 of the projection is obtained for $z = h$

$$x_0 = v_0 \sqrt{\frac{2h}{g}}$$

The total time t_0 of the projection is calculated as

$$t_0 = \sqrt{\frac{2h}{g}}$$

Problem 1-30. A part of a rope hangs over the edge of a desk (see Fig.). The total length of the rope is d . Due to the overhanging part the rope will start to move. No friction is assumed.
Find out the time dependence of the overhanging length if the initial length of the overhanging part is equal to d_0.



Solution: An instantaneous acceleration of the rope motion is given by the weight of the instantaneous length of its overhanging part

$$\frac{m}{d} g x$$

where m is the total mass of the rope.
The equation of motion has the form

$$\frac{m}{d} gx = m\frac{d^2x}{dt^2}$$

$$or \quad \frac{d^2x}{dt^2} - \frac{g}{d}x = 0$$

A general solution of this differential equation may be

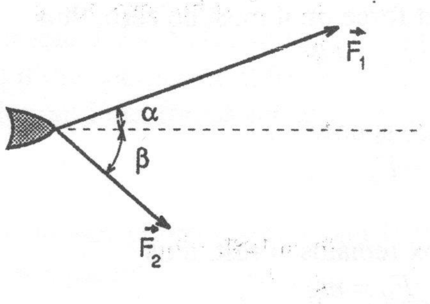
$$x(t) = Ae^{\sqrt{\frac{g}{d}}t} + Be^{-\sqrt{\frac{g}{d}}t}$$

Constants of integration are calculated from initial conditions:
for t = 0 $\quad$ x(0) = d_0 $\quad$ and $\quad$ v(0) = 0 .

Then, $A = B = \frac{d_0}{2}$ and the solution is written

$$x(t) = d_0 \cosh\sqrt{\frac{g}{d}}t$$

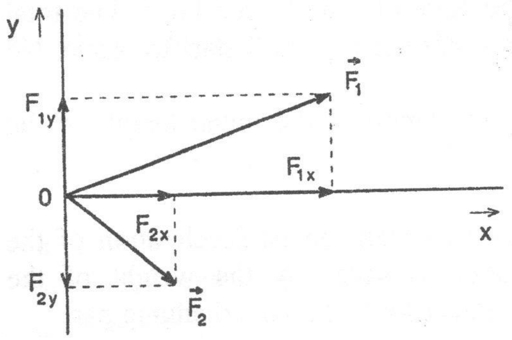
Problem 1-31. Calculate the sum of the two force vectors acting on the small boat in Fig.

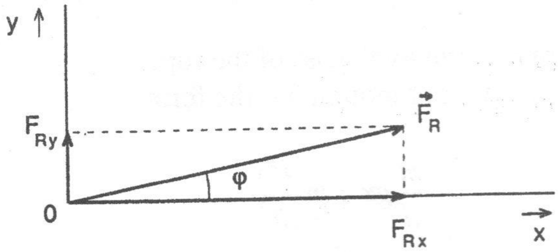


Solution: After resolving these two vectors we can express the components

$$F_{1x} = F_1 \cos\alpha$$
$$F_{1y} = F_1 \sin\alpha$$
$$F_{2x} = F_2 \cos\beta$$
$$F_{2y} = F_2 \sin\beta$$

As the angle β has a negative sign, the component F_{2y} is negative and it points along the negative y axis.





The components of the resultant force are given as the sum

$$F_{Rx} = F_{1x} + F_{2x}$$
$$F_{Ry} = F_{1y} + F_{2y}$$

The magnitude of the resultant force is equal to

$$F_R = \sqrt{F_{Rx}^2 + F_{Ry}^2}$$

and for the angle φ which the resultant force makes with the positive x axis

$$tg\varphi = \frac{F_{Ry}}{F_{Rx}}$$

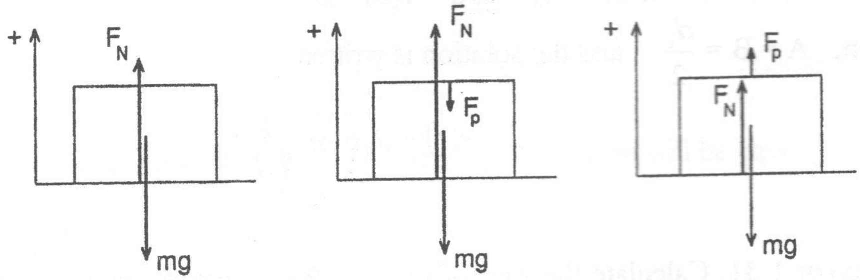
Problem 1-32. A box of mass m rests on the frictionless horizontal surface of a table.

a) Determine the weight of the box and the normal force acting on it.

b) A person pushes down on the box with a force F_p; determine again the box's weight and the normal force acting on it.

c) If a person pulls upward on the box with a force F_p less than weight, what is now the box's weight and the normal force on it ?

<u>Solution</u> :



a) b) c)

a) The weight of the box is mg. If we have chosen an upward direction as positive the net force on the box is $F = F_N - mg$; *where* F_N is the normal force exerted upward on it by the table. Since the box is at rest, the net force on it must be zero, thus

$$F_N - mg = 0 \quad or \quad F_N = mg$$

b) The weight of the box is still mg. The net force is now

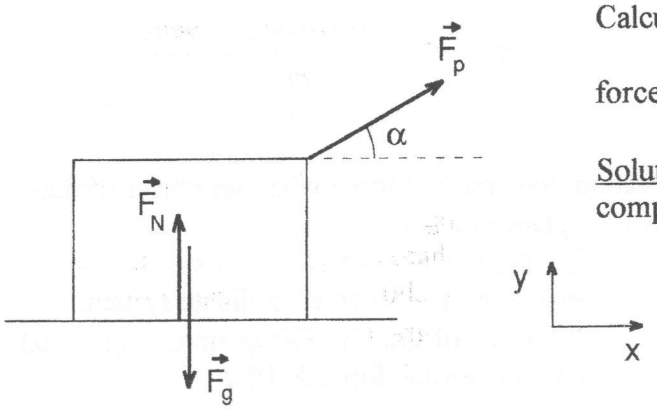
$$F = F_N - mg - F_p$$

The net force must be equal to zero since the box remains at rest, thus

$$F_N - mg - F_p = 0 \quad or \quad F_N = mg + F_p$$

c) The box's weight is still mg. The box does not move since the upward force is less than the weight.
The net force is now $$F = F_N + F_p - mg$$
and again it must be equal to zero, so
$$F_N + F_p - mg = 0 \quad or \quad F_N = mg - F_p$$

Problem 1-33. A box of mass m is pulled by a person along the surface of a table with a force $\mathbf{F}_p$. The force is applied at an angle α. The friction is assumed to be negligible.



Calculate: a) the acceleration of the box
b) the magnitude of the upward force $\mathbf{F}_N$ exerted by the table on the box

Solution: We resolve all forces into components:
$$\mathbf{F}_p = (F_p \cos\alpha, F_p \sin\alpha)$$
$$\mathbf{F}_g = (0, -mg)$$
$$\mathbf{F}_N = (0, F_N)$$

Since $\mathbf{F}_N$ *and* $\mathbf{F}_g$ have zero components in the horizontal x direction, we may write $$F_{px} = ma_x$$
and thus $$a_x = \frac{F_{px}}{m} = \frac{F_p \cos\alpha}{m}$$

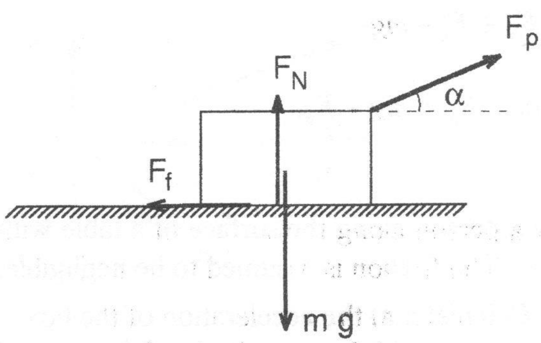
Since the box does not move vertically we may write

$$F_{Ny} + F_{py} + F_{gy} = 0 \quad or \quad F_N + F_p \sin\alpha - mg = 0$$
$$and \quad thus \quad F_N = mg - F_p \sin\alpha$$

Notice that F_N *is less than* F_g. The ground does not push against the full weight of the box since part of the pull force exerted by the person is in the upward direction.

Problem 1-34. Solve the previous problem when a friction force is to be considered and if the coefficient of friction is μ.
Solution: Four forces act on the object and we write the equation
$$\mathbf{G} + \mathbf{F}_p + \mathbf{F}_N + \mathbf{F}_t = m\mathbf{a}$$

In a chosen co-ordinate system (x,y) this vector equation may be rewritten into two scalar equations
$$F_p \cos\alpha - \mu F_N = ma$$
$$-mg + F_p \sin\alpha + F_N = 0$$



Solution of the equations yields

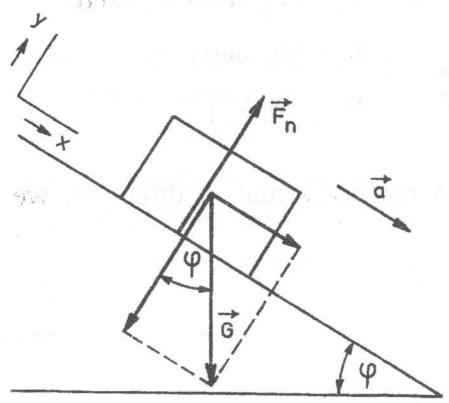
$$a = \frac{F_p \cos\alpha - \mu F_N}{m}$$

$$F_N = mg - F_p \sin\alpha$$

Thus, the acceleration of the motion is equal to

$$a = \frac{F_p(\cos\alpha + \mu\sin\alpha) - \mu mg}{m}$$

Problem 1-35. Determine the acceleration and normal force when an object of mass m moves along a perfectly smooth inclined plane at angle α .



Solution: There are two forces acting on the object in the chosen co-ordinate system: the force of gravity **G**(mg sinα, -mg cosα) and the normal force $\mathbf{F}_N(0, F_N)$.

We may write a vector equation of motion

$$\mathbf{G} + \mathbf{F}_N = m\mathbf{a}$$

This may be rewritten in a scalar form

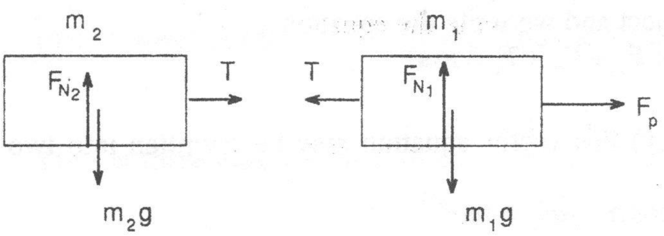
$$mg \sin\alpha = ma$$
$$-mg \cos\alpha + F_N = 0$$

And the solution is equal to

$$a = g \sin\alpha$$
$$F_N = mg \cos\alpha$$

Note: as long as $\alpha \rangle 0^0$ the normal force is less than object weight mg. For $\alpha \langle 90^0$ the motion acceleration is less than the gravitational acceleration.

Problem 1-36. Two boxes connected by a lightweight cord are resting on a table. The boxes have masses m_1 *and* m_2. A horizontal force F_p starts to be applied to the right box as shown in Fig. (friction is disregarded).



Find the following: a) the acceleration of the motion of the boxes

b) the tension in the cord.

Solution: Let us draw a force diagram for each of the boxes. We disregard the mass of the cord relative to the mass of the boxes.
The force F_p acts on box m_1. Box m_1.exerts a force T on the connecting cord and the cord exerts a force ($-T$) back on the box m_1 (third law of motion). Because the cord is considered to be massless the tension at each end is the same. Thus the cord exerts a force T on box m_2. The acceleration of both boxes is the same.

For the horizontal motion we may write:
for box m_1: $F_p - T = m_1 a$
for box m_2: $T = m_2 a$

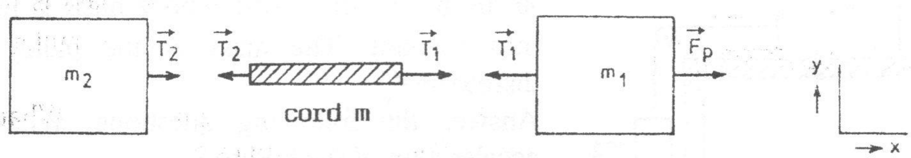
Thus, $$m_2 a = F_p - m_1 a$$

and $$a = \frac{F_p}{m_1 + m_2}$$

For tension T we get $$T = m_2 a = \frac{m_2}{m_1 + m_2} F_p$$

Problem 1-37. Suppose the cord in the previous problem is a heavy rope of mass m. Calculate the acceleration and the tension in the rope.

Solution:



Since the mass of the cord is now taken into account the product ma will not be zero, and so the forces (tensions) at either end will not be the same and we may write

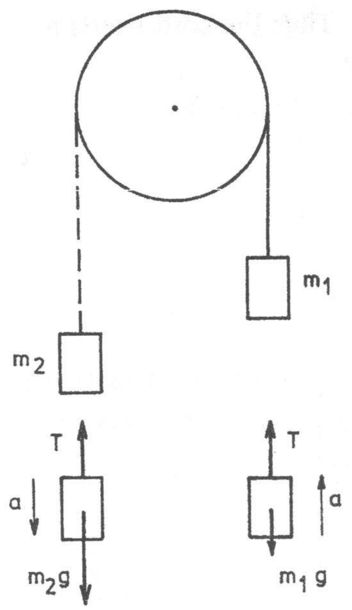
$$T_1 - T_2 = ma$$

when T_1 is the magnitude of the force that box m_1 exerts on the cord and that the cord exerts back on box m_1 and T_2 is the magnitude of the force that the cord exerts on box m_2 and that box m_2 exerts back on the cord.

For box m_1 we may write $F_p - T_1 = m_1 a$
and for box m_2 $T_2 = m_2 a$

We have three equations in three unknowns T_1, T_2 and a to be calculated.

Problem 1-38. Two different boxes ($m_2 \rangle m_1$) hang over a frictionless massless pulley (see Fig.). The mass of the cord is not taken into account.
Calculate the acceleration of the boxes and the tension in the cord.



Solution: Since the cord is massless, tension T is the same at its two ends. As box m_2 is heavier it moves downward and box m_1 moves upward.
Taking the upward direction as positive we write the second law of motion for both boxes

$$T - m_1 g = m_1 a$$
$$T - m_2 g = -m_2 a$$

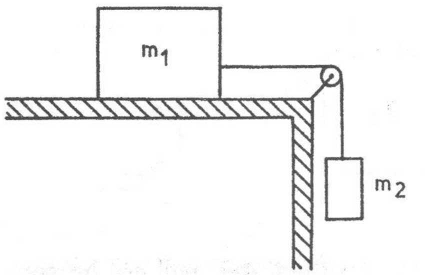
The solution for acceleration yields

$$a = \frac{m_2 - m_1}{m_1 + m_2} g$$

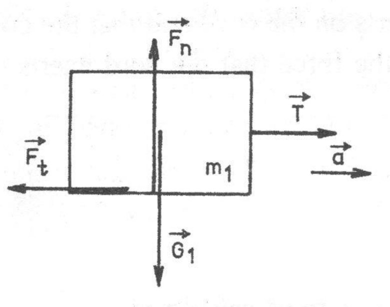
And for tension we get

$$T = (a + g) m_1 \quad or \quad T = (g - a) m_2$$

Problem 1-39. A body of mass m_1 moves on the horizontal plane. The coefficient of friction is equal to μ. Another body of mass m_2 is freely hung over a pulley and is coupled to mass m_1 by means of a rope whose mass is not taken into account. The mass of the pulley is also disregarded.
Answer the following questions: What is the acceleration of the bodies ?
State the mass m_2 for the bodies to move in general.



Solution: In the chosen co-ordinate system we express all the acting forces and state the equations of motion.



1) **body** m_1 :
There are four forces acting on it:
force of gravity $\mathbf{G}_1(0, -m_1 g)$
normal force $\mathbf{F}_n(0, F_n)$
rope pull force $\mathbf{T}(T,0)$
friction force $\mathbf{F}_f(-\mu F_n, 0)$

The vector form of the equation of motion for body m_1 is

$$\mathbf{G}_1 + \mathbf{F}_n + \mathbf{T} + \mathbf{F}_f = m_1\mathbf{a}$$

where $\mathbf{a}(a,0)$ is the acceleration vector of the body.

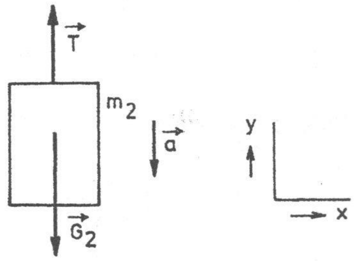
We rewrite this equation into the component form

$$T - \mu F_n = m_1 a \qquad (I)$$

$$-m_1 g + F_n = 0 \qquad (II)$$

2) **body** m_2:

there are two forces acting on it:
force of gravity $\mathbf{G}_2(0,-m_2 g)$
rope pull force $\mathbf{T}(0,T)$



The vector form of the equation of motion is

$$\mathbf{G}_2 + \mathbf{T} = m_2\mathbf{a}$$

where $\mathbf{a}(0,-a)$ is the acceleration vector of the body.
Rewriting into the scalar form

$$-m_2 g + T = -m_2 a \qquad (III)$$

We have three equations for the three unknowns: a, T, F_n.
Their solution yields

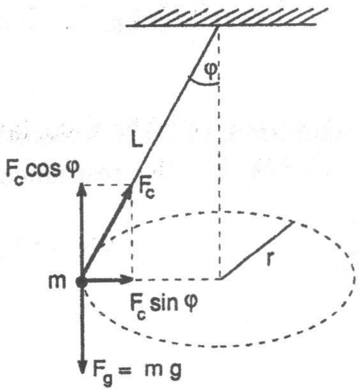
$$F_n = m_1 g$$

$$T = m_1 m_2 g \frac{1+\mu}{m_1 + m_2}$$

$$a = g\frac{m_2 - \mu m_1}{m_1 + m_2}$$

It is seen that for $m_2 \rangle \mu m_1$ the system of these bodies makes an accelerated motion.

Problem 1-40. A particle of mass m suspended by a cord of length L revolves in a circle of radius r = L sinφ, where φ is the angle the cord makes with the vertical (see Fig.). Calculate the speed and period of its motion.



Solution: The forces acting on the particle are its weight $F_g = mg$ and the force exerted by the cord F_c which has horizontal and vertical components of $F_c \sin\varphi$ *and* $F_c \cos\varphi$, respectively.

Let us apply the second law of motion to the horizontal and vertical directions. In the vertical direction there is no motion of the particle, so the acceleration is zero and we can write

$$F_c \cos\varphi - mg = 0$$

In the horizontal direction there is only one force of magnitude $F_c \sin\varphi$, which acts toward the centre of the circle and gives rise to centripetal acceleration, so we can write

$$F_c \sin\varphi = m\frac{v^2}{r}$$

Using the first equation

$$v = \sqrt{\frac{rF_c \sin\varphi}{m}} = \sqrt{\frac{r}{m}\left(\frac{mg}{\cos\varphi}\right)\sin\varphi}$$

Since r = L sinφ

$$v = \sqrt{\frac{Lg\sin^2\varphi}{\cos\varphi}}$$

The period T of the motion is the time required to make one revolution of distance 2πr = 2πL sinφ. Thus

$$T = \frac{2\pi L\sin\varphi}{v} = 2\pi L\sin\varphi\sqrt{\frac{\cos\varphi}{Lg\sin^2\varphi}} = 2\pi\sqrt{\frac{L\cos\varphi}{g}}$$

Problem 1-41. What force causes a carriage of mass $1.5\times10^4\,kg$ to reach the velocity of $3ms^{-1}$ in time 90 s ?

[F = 500 N]

Problem 1-42. A body starts to move. The force acting on the body is equal to 0.02 N. In the first four seconds the body travels a path of 3.2 m.

State: a) its mass

b) the velocity that the body has at the end of the fifth second of its motion

[m = 0.05 kg, $v = 2\,ms^{-1}$]

Problem 1-43. A car of mass 800 kg is driven by constant force of 2 kN. Calculate the path on which the car will reach the velocity of 45 km h^{-1} (all resistances are disregarded).

[x = 31.3 m]

Problem 1-44. The gradient of a railway is 3 ‰ and the acceleration of a train has the negative value -0.015 ms^{-2}. A train of mass $4\times10^5\,kg$ is being driven by a force of 30 kN. What percentage of the train's weight goes to passive resistance ?

[0.6 %]

Problem 1-45. A train was stopped from velocity *v* in time *t*. The mass of the train is *m*, the number of wheels is *n*, the coefficient of friction between a wheel and the track is μ_1 and the coefficient of friction between the wheel and the friction brake is μ_2. Calculate the braking force needed to one wheel for the train to stop.

$$\left[F = \frac{m(v-\mu_1 gt)}{n\mu_2 t}\right]$$

Problem 1-46. A train moves with constant velocity on a path with a gradient α. The mass of the train is $5\times10^5\,kg$ and the tractile force of the engine is equal to $5\times10^4\,N$. Determine the gradient α if all friction forces are disregarded.

[α = 35 ']

Problem 1-47. Two blocks, mass m_1 *and* m_2, are connected by a light spring on a horizontal frictionless table. Find the ratio of their accelerations after they are pulled apart and then released.

$$\left[\frac{a_1}{a_2} = \frac{m_2}{m_1}\right]$$

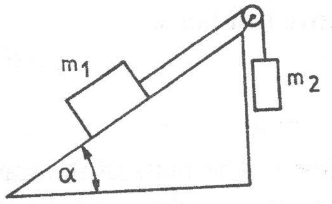
Problem 1-48. An electron travels in a straight line from the cathode of a vacuum tube to its anode, which is 1 cm away. It starts with zero speed and reaches the anode with a speed of $6\times10^6\,ms^{-1}$.
Assume constant acceleration and compute the force on the electron. This force is electrical in origin. Take the electron's mass to be $9.1\times10^{-31}\,kg$.

$$\left[1.6\times10^{-15}\,N\right]$$

Problem 1-49. A block slides down an inclined plane of slope angle φ with constant velocity. It is then projected up the same plane with an initial speed v_0.
How far up the incline will it move before coming to rest ? Will it slide down again ?

$$\left[\frac{v_0^2}{4g\sin\varphi}\ ,\ No\right]$$

Problem 1-50. What is the acceleration of the blocks in Fig.? What is a tension of the cord ? When will the blocks be at rest ? The mass of the cord is disregarded. Assume the incline to be perfectly smooth.



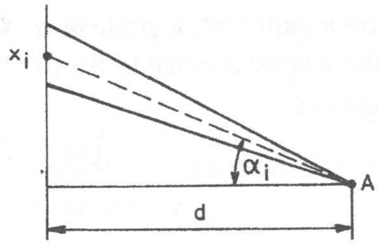
$$\left[a = \frac{m_2 - m_1 \sin\alpha}{m_1 + m_2}\right]$$

$$\left[T = \frac{m_1 m_2}{m_1 + m_2}(1 + \sin\alpha)g\right]$$

$$\left[m_2 = m_1 \sin\alpha\right]$$

Problem 1-51. A particle moves on an inclined plane. The force of gravity is the only force acting on it.

Determine the angle α_i for the particle to travel the path $x_i A$ in the shortest time.



$$\left[\alpha_i = 45^0\right]$$

Problem 1-52. An elevator moves up with a constant acceleration of $1.2\ ms^{-2}$. Its mass is 3600 kg.

State: a) The rope tension if the elevator is empty.

b) The force exerted on a person by the elevator floor. The mass of the person is 70 kg.

$$\left[a)\ 3.96 \times 10^4\ N \quad b)\ 770\,N\right]$$

Problem 1-53. An elastic ball of mass 200 g falls on a wall. The incident angle $\alpha = 60^0$ and the ball's velocity $v = 20\ ms^{-1}$.

Calculate the impulse that the wall gives to the ball.

[I = 4 kg m s^{-1}]

Problem 1-54. A ball of mass 100 g was given a velocity of 10 m s^{-1}. What force was acting on it if the shock imparted by a foot took the time 0.01 s ?

[F = 100 N]