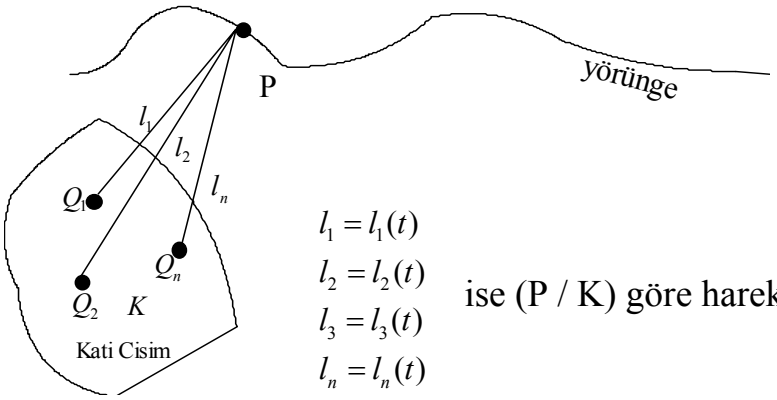
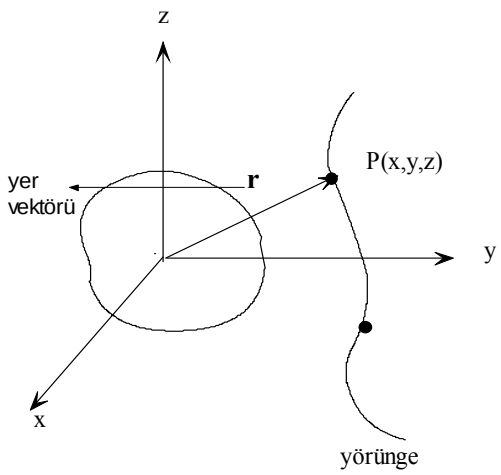
HAREKET VE DENGE



$l_1 = l_1(t)$
$l_2 = l_2(t)$
$l_3 = l_3(t)$
$l_n = l_n(t)$

ise (P / K) göre hareketlidir



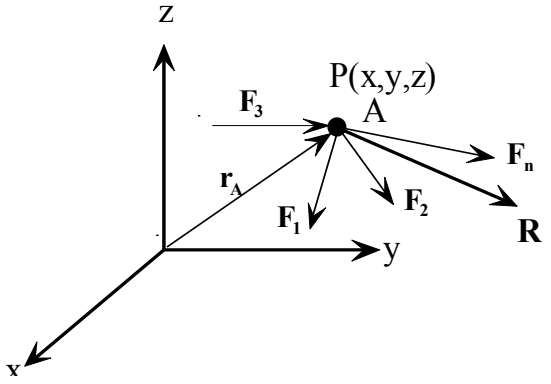
$t_1 \le t \le t_2$ zaman aralığında

$x = x(t)$
$y = y(t)$ ise (P/ oxyz) göre
$z = z(t)$

hareketlidir.

DENGE: Eğer $x=x_o=sbt$
$y=y_o=sbt$ ise (P/oxyz) göre dengededir.
$z=z_o=sbt$

SERBEST MADDESEL NOKTANIN DENGESİ



$t = t_0$ anında,

$\mathbf{R} = \mathbf{F_1} + \mathbf{F_2} + ... + \mathbf{F_n} = \sum_{i=1}^{n} \mathbf{F_i} = 0$ ve

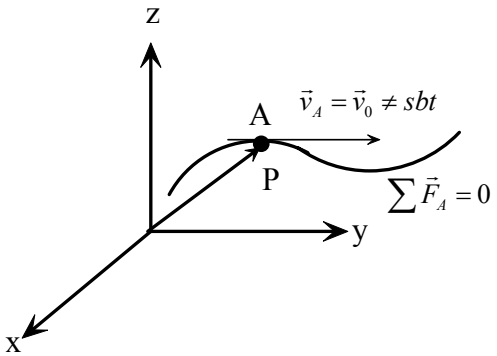
$\mathbf{v_A} = \mathbf{0}$ ise P noktası A konumunda dengededir.

İspat: P, A da dengede ise $\mathbf{v_A} = \mathbf{0}$ dır. $\mathbf{r_P} = \mathbf{r_A}$

$\mathbf{v} = \frac{d\mathbf{r}}{dt} \Rightarrow \mathbf{v_A} = \frac{d\mathbf{r_A}}{dt} = \frac{d\mathbf{r_P}}{dt}_{t=t_0} = 0 \Rightarrow \mathbf{r_P} = \mathbf{r_A} = \text{sbt}$ t=0 anında sağlanıyor. Her t anında da sağlanır yani $\mathbf{v_A}$=0 olur.

$\mathbf{a} = \frac{d\mathbf{v}}{dt} = \frac{d\mathbf{v_A}}{dt} = \frac{d^2\mathbf{r_A}}{dt^2} = 0 \Rightarrow m\mathbf{a} = \mathbf{F} \Rightarrow \mathbf{F_A} = 0$ bulunur. Karşıt teoremde doğrudur.

$\mathbf{v_A} = 0, \mathbf{F_A} = 0$ dengenin gerek ve yeter şartıdır. Aynı anda gerçeklenmeli.



NOT:

$\mathbf{v_A} = \frac{d\mathbf{r_A}}{dt} \neq 0$

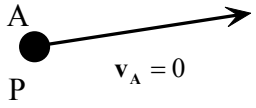
$\frac{d\mathbf{r_A}}{dt} = \mathbf{v_O} \Rightarrow$

$\mathbf{r_A} = \int \mathbf{v_O} dt + \mathbf{c} = \mathbf{v_O} t + \mathbf{c}$

şeklinde bir yer vektörü ortaya çıkar.

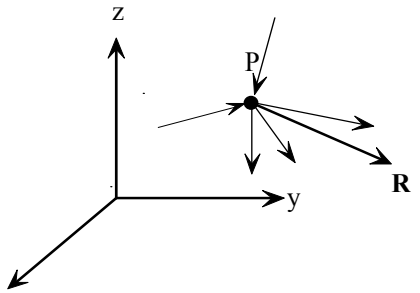
Maddesel nokta $\mathbf{v_O}$´ın doğrultusu ve yönünde hareket eder.

NOT:



$\mathbf{R} = \sum_{i=1}^{n} \mathbf{F}_i \neq 0$ ise ve bir engel yok ise maddesel nokta **R** doğrultusunda ve yönünde hareket eder.

Denge Denklemi:



$$\mathbf{R} = 0 \qquad \sum_{i=1}^{n} \mathbf{F}_i = 0 \quad \Rightarrow \quad X = \sum_{i=1}^{n} X_i = 0 \qquad Y = \sum_{i=1}^{n} Y_i = 0 \qquad Z = \sum_{i=1}^{n} Z_i = 0$$

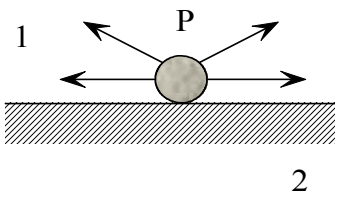
$P(x_P, y_P, z_P)$ bu üç denklemden çözülür.

NOT: Tüm kuvvetler maddesel noktada kasiştikleri için; denge denklemrinde moment denklemine gerek yoktur. (Varignon teoremi)

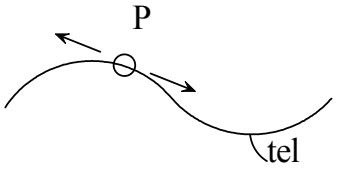
$$\mathbf{R} = \sum \mathbf{F} = (6x + 5y + 8z - 17)\mathbf{i} + (-2x + 2y - 3z - 25)\mathbf{j} + (14x - y + 10z - 100)\mathbf{k}$$

$$X = \sum \mathbf{F_X} = 6x + 5y + 8z - 17$$
$$Y = \sum \mathbf{F_Y} = -2x + 2y - 3z - 25 = 0$$ yazılarak P(x,y,z) çözülür.
$$Z = \sum \mathbf{F_Z} = 4x - y + 10z - 100 = 0$$

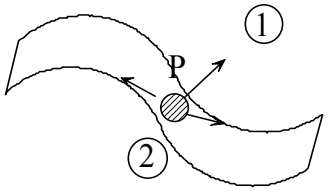
BAĞLI MADDESEL NOKTANIN DENGESİ



Tek taraflı bağ (temas)

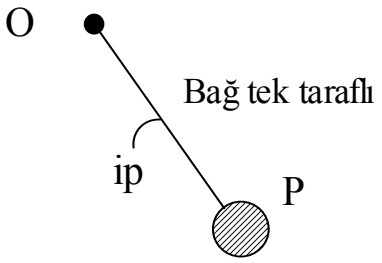


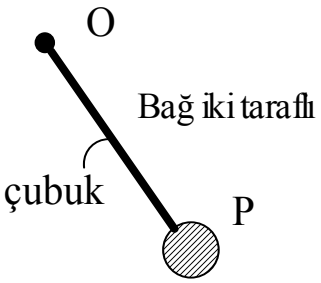
P, teli terk edemez
Bağ iki taraflı.



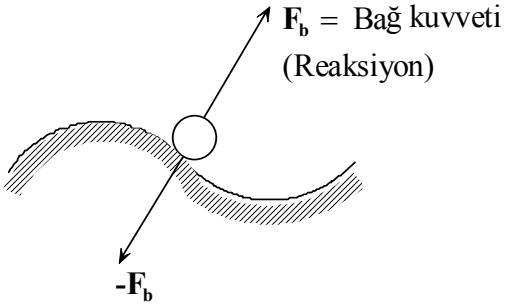
2 tarafına geçemez

Tanım: P temeas ettiği cismi hiçbir şaekilde terk edemiyorsa **bağ iki taraflıdır.** Tek tarafa doğru terk edebiliyorsa **bağ tek taraflıdır**.

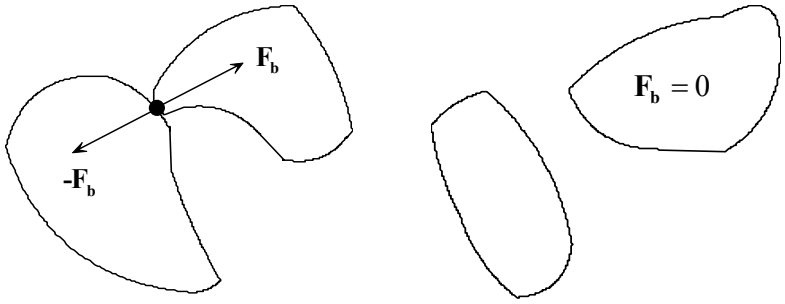




BAĞ KUVVETLERİ



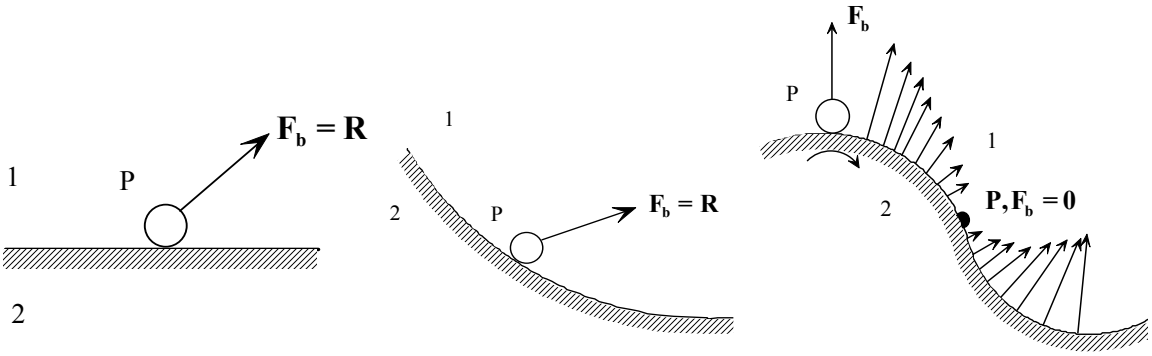
F_b , Statik ve dinamik problemlerinde bilinmeyendir



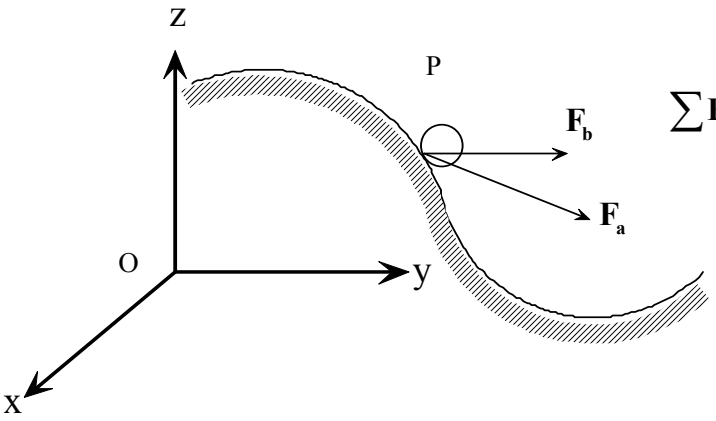
Temas kesilince bağ kuvveti sıfır olur.

Temas halinde ETKİ-TEPKİ prensibi geçerli.

NOT: Bağ kuvveti terk edilebilen tarafa doğru etkir.



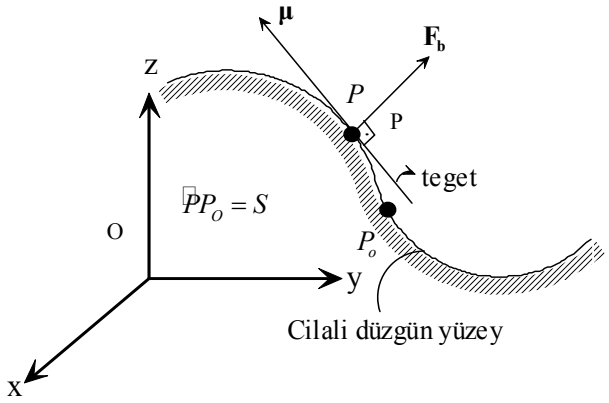
NOT: Bağ kuvveti olmayan ve verilen her türden kuvvete AKTİF kuvvet denir. Aktif kuvveti $\mathbf{F_a}$ ile göstereceğiz.



$\sum \mathbf{F} = \mathbf{F_a} + \mathbf{F_b}$, Denge konumunda:

(A) $X_a + X_b = 0$, $Y_a + Y_b = 0$, $Z_a + Z_b = 0$ Bağlı noktanın denge denklemleri

SÜRTÜNMESİZ

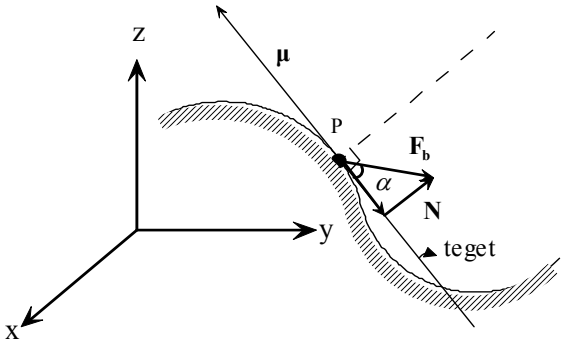


Bağ Kuvveti teğete diktir.

(B) $\mathbf{F_b} \cdot \boldsymbol{\mu} = 0$
$\mathbf{R} \cdot \mathbf{u} = \mathbf{0}$

NOT:
X_b, Y_b, Z_b ve S bilinmeyenlerdir. Bunları (A) ve (B) denklemleri ile çözeriz.

SÜRTÜNMELİ



Bağ kuvveti ile teğet arasındaki açı $\alpha \neq 90$ dir.

$\mathbf{F_b} = \mathbf{F} + \mathbf{N}$

F: sürtünme kuvveti
N: Normal tepki

$\sum \mathbf{F} =$ Bileşke Kuvvet

$\sum \mathbf{F} = \mathbf{F_a} + \mathbf{F_b} = \mathbf{F_a} + \mathbf{F} + \mathbf{N}$

Sürtünme Kanunları

1) $\mathbf{v} \neq \mathbf{0}$ için a) **F** ile **v** ters yönlü ve paralel (**F** // **v**)

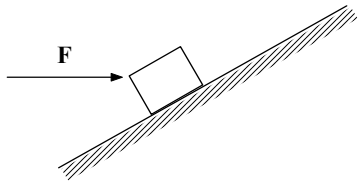
$\mathbf{F} \times \mathbf{v} = \mathbf{0}$ ve $\mathbf{F} \cdot \mathbf{v} < \mathbf{0}$

b) $|\mathbf{F}|$=F ; $|\mathbf{N}|$=N ise F=μ_dN dir

μ_d = Dinamik sürtünme katsayısıdır.
0<μ_d<1 dir. Hareket halinde (Kinematik ve dinamik problemlerinde) μ_d kullanılır.

2) v=0 için ;

a) F teğet doğrultusuna paralel ancak yönü belirsizdir ve sezgisel olarak serbest cisim diagramında gösterilir, hesaplarla doğruluğu kontrol edilir.



b)

1^0) $F < \mu_s N$ ise maddesel nokta dengededir.

μ_s, statik sürtünme katsayısıdır.

0<μ_s<1 ve $\mu_s > \mu_d$ dir.

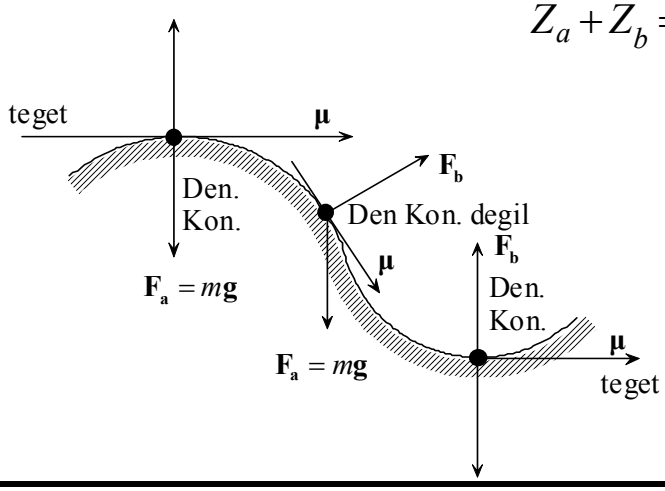
2^0) $F = F_{mak} = \mu_s N$ ise maddesel nokta dengededir fakat hareket etmek üzeredir.

3^0) $F > F_{mak} = \mu_s N$ durumunda denge yoktur hareket vardır.

ÖZET:

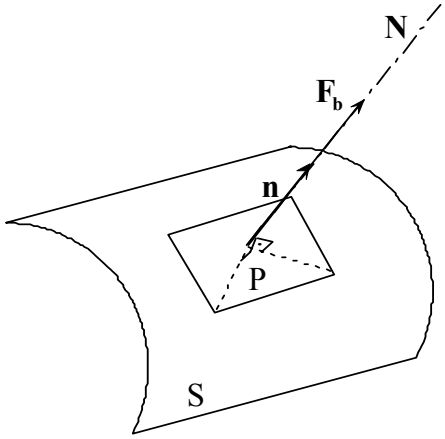
Sürtünmesiz hal

$$\sum \mathbf{F} = \text{Bileşke} = 0 \Rightarrow \mathbf{F_a} + \mathbf{F_b} = 0 \Rightarrow \begin{array}{l} X_a + X_b = 0 \\ Y_a + Y_b = 0 \\ Z_a + Z_b = 0 \end{array}$$



Teğet doğrusunun birim vektörü $\boldsymbol{\mu}(\alpha, \beta, \gamma)$ ise $\mathbf{F_b} \cdot \boldsymbol{\mu} = 0 \Rightarrow \alpha X_b + \beta Y_b + \gamma Z_b$ olmak üzere dört denklem var. X_b, Y_b, Z_b ve PP_O=S bilinmeyenleri için denklemler çözülür.

Yüzey: $\mathbf{F_b}$ yüzeyinher noktasında yüzey normaline (**n**) paralel ise(verilen noktadaki teğet düzleme dik ise); P ile S yüzeyi sürtünmesizdir denir.



Bilinenler:

$X_a + X_b = 0$

$Y_a + Y_b = 0$

$Z_a + Z_b = 0$

$\mathbf{F_b} // \mathbf{n} \Rightarrow \mathbf{F_b} \times \mathbf{n} = \mathbf{0}$

veya $\frac{X_b}{n_x} = \frac{Y_b}{n_y} = \frac{Z_b}{n_z} \Rightarrow$ iki skaler denklem verir

İstenenler:

X_b

Y_b ve P nin x,y,z konumu

Z_b

NOT:

$F(x,y,z) = 0$ veya $z = f(x,y)$ yüzey denkleminin normali:

$\mathbf{N} = \frac{\partial f}{\partial x}\mathbf{i} + \frac{\partial f}{\partial y}\mathbf{j} + \frac{\partial f}{\partial z}\mathbf{k}$ şeklindedir.

$$\mathbf{F_b} // \mathbf{n} // \mathbf{N} \Rightarrow \frac{X_b}{\frac{\partial f}{\partial x}} = \frac{Y_b}{\frac{\partial f}{\partial y}} = \frac{Z_b}{\frac{\partial f}{\partial z}} = \frac{X_b}{n_x} = \frac{Y_b}{n_y} = \frac{Z_b}{n_z}$$

BÖLÜM III

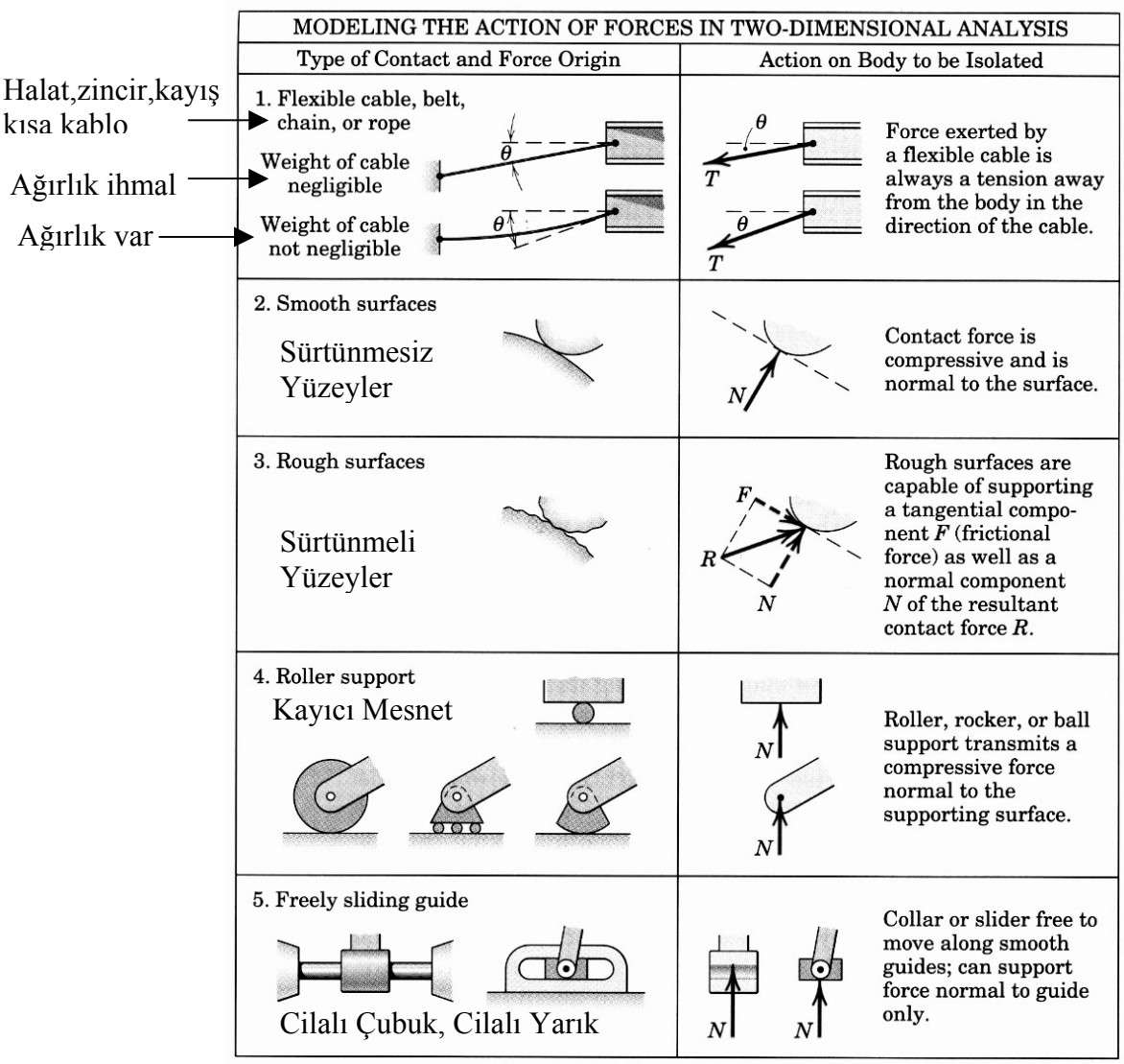
DENGE (EQUILIBRIUM)

Bir kuvvet sisteminde,

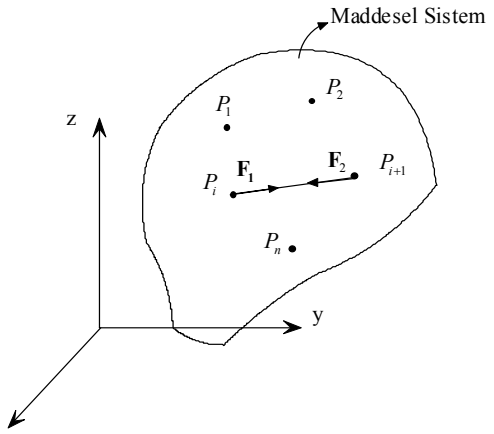
$$\mathbf{R} = \Sigma\mathbf{F} = 0$$

$$\mathbf{M} = \Sigma\mathbf{M} = 0$$

ise, bu kuvvet sistemi dengededir denir.
Bir cisme etki eden dış kuvvetler ve cismin diğer cisimlerden izole edilmesi sonucunda bulunan bağ kuvvetlerinin tamamını gösteren diyagrama ***Serbest Cisim Diyagramı*** (Free Body Diagram) denir. Denge denklemleri serbest cisim diyagramına uygulanır. Aşağıdaki şekillerde, cisimlere uygulanan değişik kuvvet şekilleri görülmektedir.



KATI CİSMİN DENGESİ
(Maddesel Sistemlerin Statiği)



Kuvvetler:
I:
a)Aktif Kuvvetler
b) Bağ Kuvvetleri
II:
a)İç Kuvvetler
b)Dış Kuvvetler

İç Kuvvetler*:* İkişer ikişer etki prensibine göre oluşurlar.
Tek bir maddesel noktanın iç kuvveti yoktur.

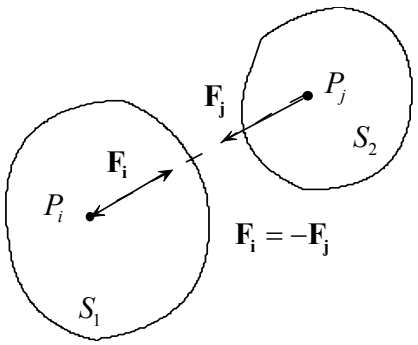
Teorem: İç kuvvetler sıfıra denk bir kuvvet sistemi oluştururlar.

$$\mathbf{R_{iç}} = \sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{F_i} = 0,\ \mathbf{M_O}^{\mathbf{iç}} = \sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{OA_i} \times \mathbf{F_i}^{\mathbf{iç}} = 0$$

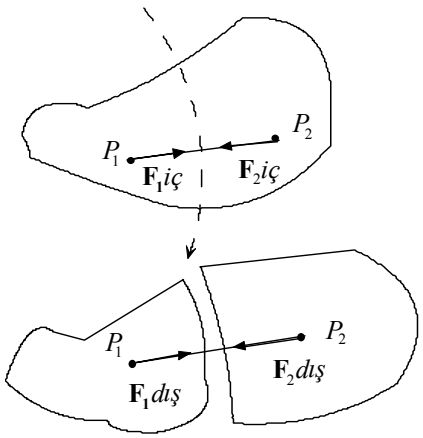
$$(\mathbf{S}) \begin{cases} \mathbf{R} = \mathbf{0} \\ \mathbf{M_O} = \mathbf{0} \end{cases} \text{ ise } (\mathbf{S}) \equiv (\mathbf{0})$$

Yani kuvvet sisteminin maddesel sisteme öteleme veya dönme gibi herhangi bir hareket yaptırma yeteneği yoktur.

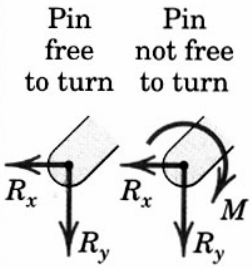
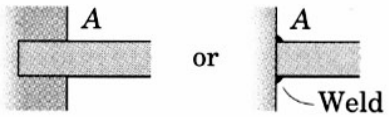
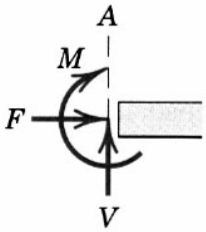
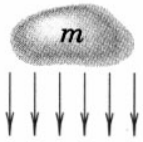
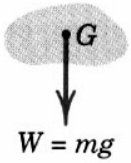
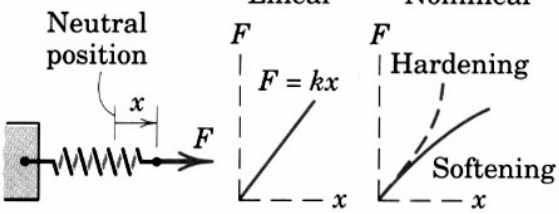
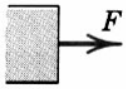
Dış Kuvvetler:



Uzaktan uzağa etkiyen dış kuvvetler



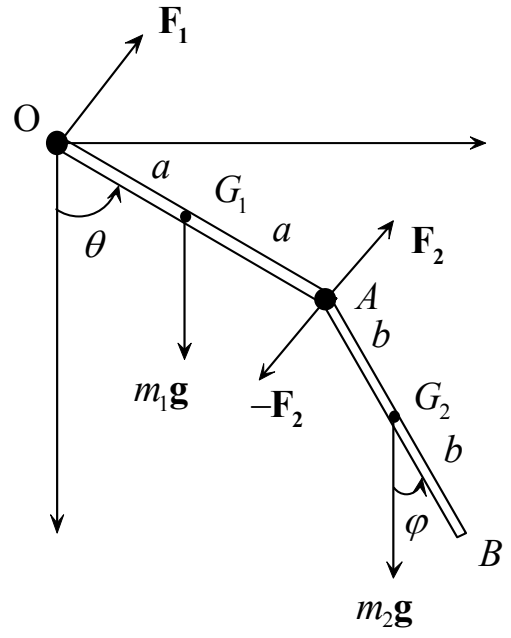
DÜZLEMSEL KUVVETLER

MODELING THE ACTION OF FORCES IN TWO-DIMENSIONAL ANALYSIS (*cont.*)	
Type of Contact and Force Origin	Action on Body to be Isolated
6. Pin connection MAFSAL 	 A freely hinged pin connection is capable of supporting a force in any direction in the plane normal to the axis; usually shown as two components R_x and R_y. A pin not free to turn may also support a couple M.
7. Built-in or fixed support GÖMME VEYA SABİT MESNET  ANKASTRE (GÖMME) SABİT (KAYNAKLI)	 A built-in or fixed support is capable of supporting an axial force F, a transverse force V (shear force), and a couple M (bending moment) to prevent rotation.
8. Gravitational attraction YERÇEKİMİ 	 The resultant of gravitational attraction on all elements of a body of mass m is the weight $W = mg$ and acts toward the center of the earth through the center mass G.
9. Spring action YAY ETKİSİ 	 Spring force is tensile if spring is stretched and compressive if compressed. For a linearly elastic spring the stiffness k is the force required to deform the spring a unit distance.

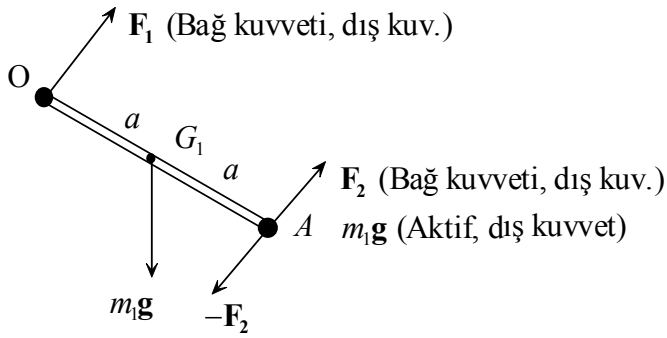
Serbest Cisim Diyagramının Çizilmesi

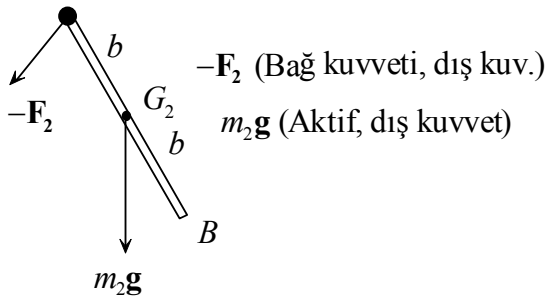
I. Adım : Öncelikle hangi cismin izole edileceği, bunun getireceği bilinmeyen kuvvetleri de dikkate alarak kararlaştırılır.

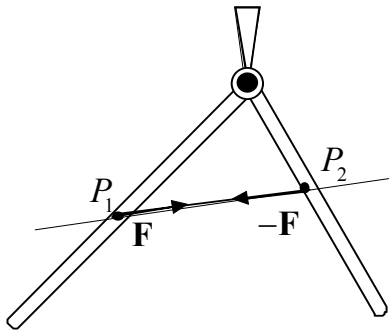
II. Adım : İzole edilmesi kararlaştırılan cisim, dış çevresini alarak izole edilir. Bu dış çevre, cismin diğer bütün cisimlerle temasını kaldıracak şekilde seçilir.



$\mathbf{F}_1$: Bağ kuvveti ve dış kuvvet
$\mathbf{F}_2$ ve $-\mathbf{F}_2$ Bağ kuvveti ve iç kuvvet
$m_1\mathbf{g}$: Aktif dış kuvvet
$m_2\mathbf{g}$: Aktif dış kuvvet







F ve –F Pergel için iç aktif kuvvettir.
Evrensel çekim kanununa göre :

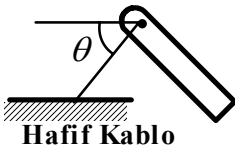
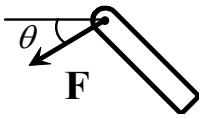
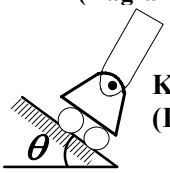
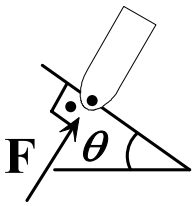
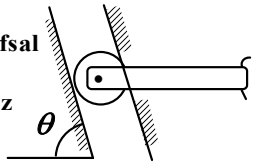
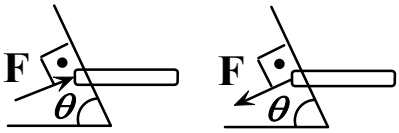
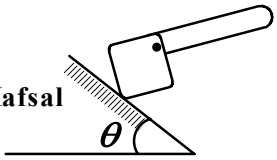
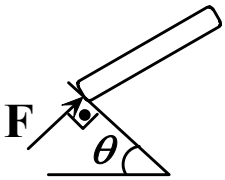
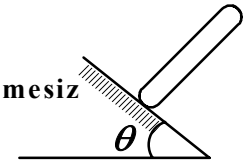
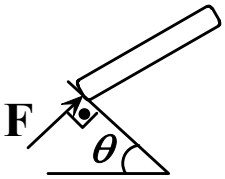
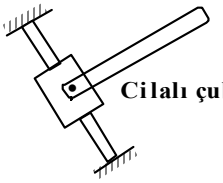
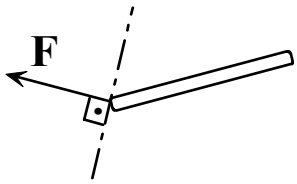
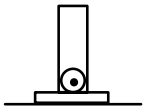
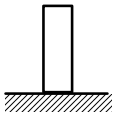
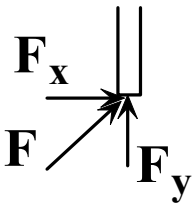
$$F = |\mathbf{F}| = |-\mathbf{F}| = k\frac{m_1 m_2}{r^2} \text{ dir.}$$

Diğer aktif kuvvetlerin yanında çok küçüktür, ihmal edilir.

Maddesel sistemin dengede olması için gerek şart; sisteme etkiyen tüm dış kuvvetlerin sıfıra denk bir kuvvet sistemi oluşturmasıdır.

KATI CİSİM BAĞLANTILARI

(İKİ BOYUTLU KUVVET SİSTEMLERİ)

Bağlantı Tipi	Reaksiyon	Bilinmeyen Sayısı
 Hafif Kablo		**F**
Ağırlıksız Kol (Bağlantı)		**F**
 Kayıcı Mafsal (Roller)		**F**
 Kayıcı Mafsal veya Sürtünmez Pin		**F**
 Kayıcı Mafsal (Rocker)		**F**
 Sürtünmesiz yüzey		**F**
 Cilalı çubuk Cilalı yarık		**F**
 Mafsal (Pin)  Pürüzlü yüzey		**F** veya $\mathbf{F_x}$ ve $\mathbf{F_y}$

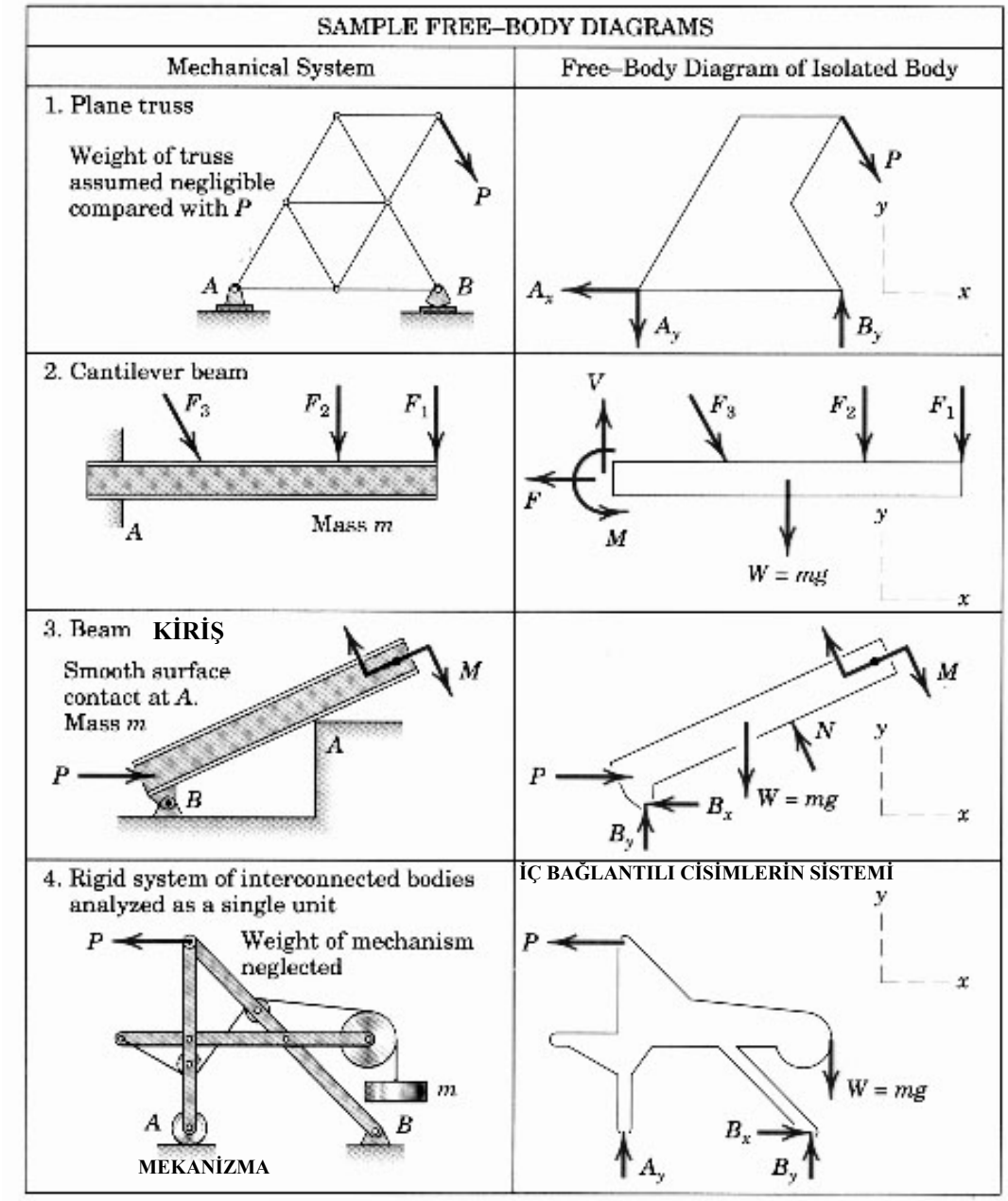
III. Adım : İzole edilmiş cismin diğer cisimlerden ayrılan konumlarına, bağ şekline uygun olarak gerekli bütün bağ kuvvetleri ilave edilir. Cisme etki eden ve bilinen bütün dış kuvvet ve momentler işaretlenir.

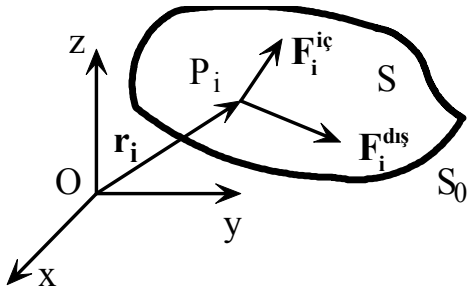
IV. Adım : Uygun eksen takımı seçilir.

Bir cismin dengesini inceleyebilmek için serbest cisim diyagramının doğru çizilmesi en önemli adımdır.

Aşağıdaki şekillerde bazı örnek serbest cisim diyagramları görülmektedir.

ÖRNEK SERBEST CİSİM DİYAGRAMLARI





S maddesel sistemi S_0 konumunda hızsız ise S, sistemine etkiyen toplam kuvvetin sıfıra denk bir sistem oluşturduğunu görelim:

$$\mathbf{r}_i = \mathbf{r}_i^0 = sb \Rightarrow \mathbf{V}_i^0 = \frac{d\mathbf{r}_i}{dt} = \frac{d\mathbf{r}_i^0}{dt} = 0$$

Bu sonuç sitemin tüm noktaları için geçerlidir.

$$\mathbf{a}_i = \frac{d\mathbf{V}_i}{dt} = \frac{d^2\mathbf{r}_i}{dt^2} \Rightarrow \mathbf{a}_i = \frac{d\mathbf{V}_i^0}{dt} = 0$$

$m\mathbf{a} = \mathbf{F} \Rightarrow \sum \mathbf{F} = \mathbf{F} = \mathbf{F}_{iç} + \mathbf{F}_{dış} = 0$ olur.

$\mathbf{F}_{iç} = \sum_{i=1}^{n} \mathbf{F}_i^{iç} = 0$ olduğundan

$\mathbf{F}_{dış} = \sum_{i=1}^{n} \mathbf{F}_i^{dış} = 0$ elde edilir.

$\mathbf{F}_{iç} = \sum_{i=1}^{n} \mathbf{F}_i^{iç} = 0$ olduğundan

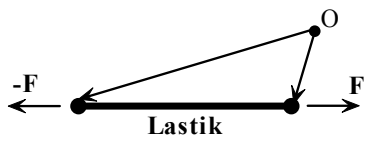
$\mathbf{F}_{dış} = \sum_{i=1}^{n} \mathbf{F}_i^{dış} = 0$ elde edilir. Bu birtek P_i noktası için geçerli olduğu gibi sistemin tüm noktaları için de geçerlidir.

$$\mathbf{F}_{dış} \overset{\text{Denk.}}{=} (0) \begin{cases} \mathbf{R} = \sum_{i=1}^{n} \mathbf{F}_i^{dış} = 0 \\ \mathbf{M}_0 = \sum_{i=1}^{n} \mathbf{OA}_i \times \mathbf{F}_i^{dış} = 0 \end{cases} \quad \text{A}$$

Denklemleri Maddesel Sistemin denge denklemleridir.

NOT: Maddesel system bir katı cisim ise A denklemleri Katı cismin dengede olmasının gerek ve yeter şartıdır.

NOT: Maddesel cisim Katı cisim değilse A gerektir fakat yetmez.

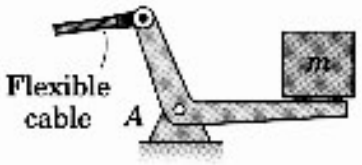
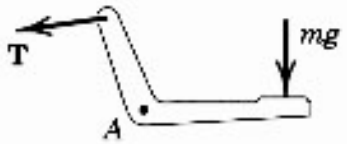
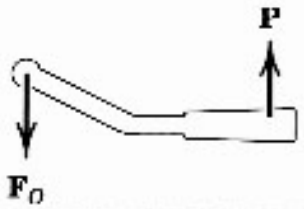
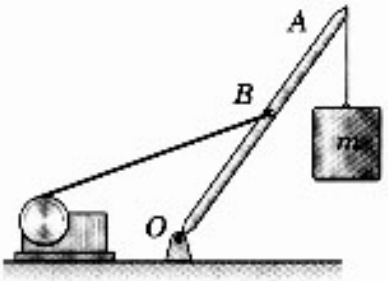
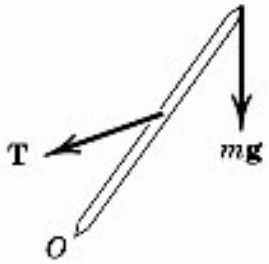
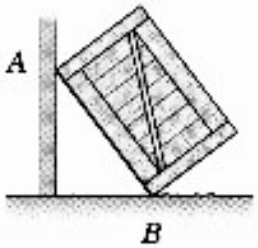
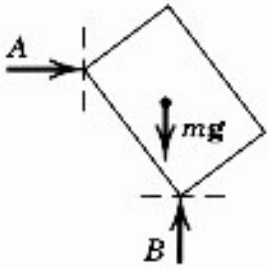
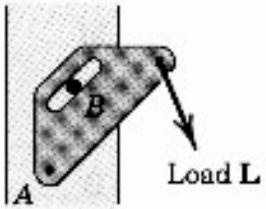
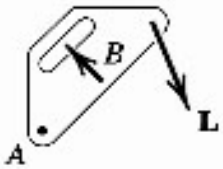


$\mathbf{M_0} = 0$; $\mathbf{R} = 0$ olur.

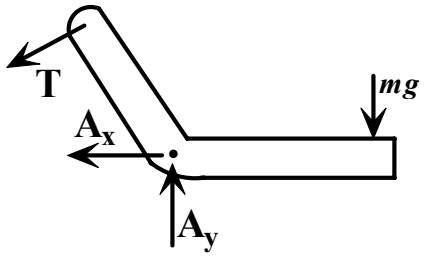
Fakat Lastik dengede değildir.

Örnek serbest cisim diyagramları

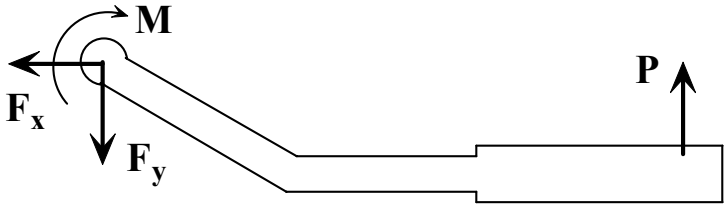
EKSİK KUVVETLERİ TAMAMLAYINIZ

KRANK	Body	Incomplete *FBD*
1. Bell crank supporting mass m with pin support at A.		
KONTROL KOLU 2. Control lever applying torque to shaft at O.		
3. Boom OA, of negligible mass compared with mass m. Boom hinged at O and supported by hoisting cable at B.		
4. Uniform crate of mass m leaning against smooth vertical wall and supported on a rough horizontal surface.		
5. Loaded bracket supported by pin connection at A and fixed pin in smooth slot at B.		

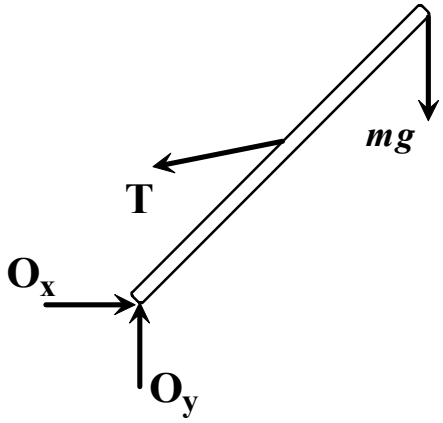
1. Krank



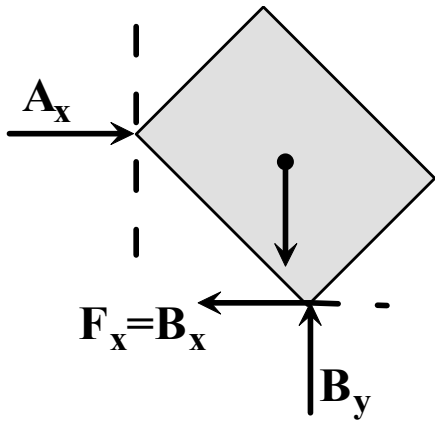
2. Kontrol Kolu



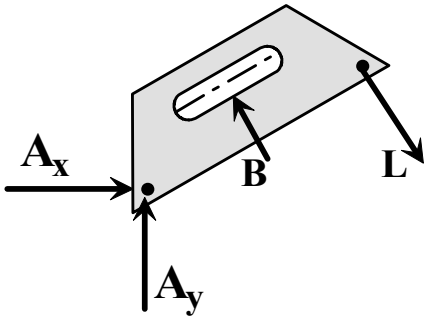
3. Kaldırma Çubuğu



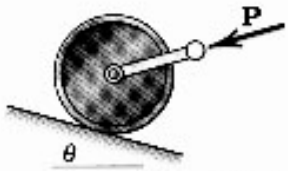
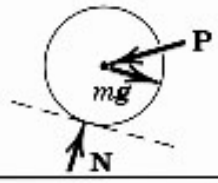
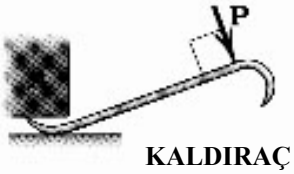
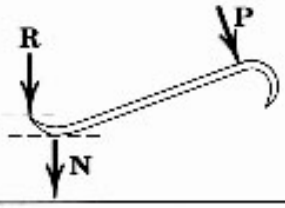
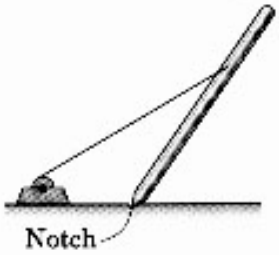
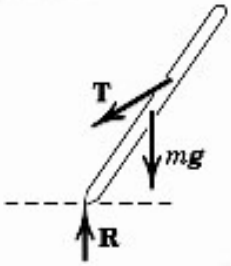
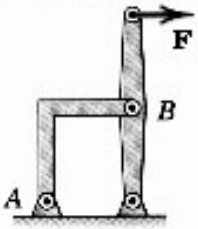
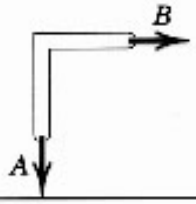
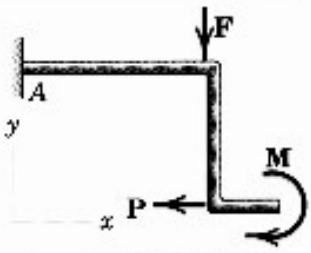
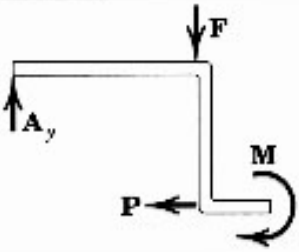
4. Homojen Sandık



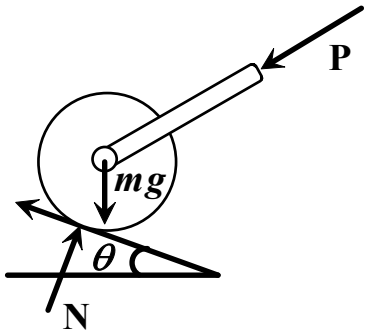
5. Yüklü Konsol



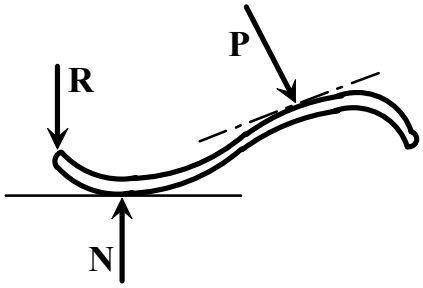
Örnek serbest cisim diyagramları
HATALI VEYA EKSİK ÇİZİMLER

	Body	Wrong or Incomplete *FBD*
1. Lawn roller of mass m being pushed up incline θ.		
2. Pry bar lifting body A having smooth horizontal surface. Bar rests on horizontal rough surface.		
3. Uniform pole of mass m being hoisted into position by winch. Horizontal supporting surface notched to prevent slipping of pole.		
4. Supporting angle bracket for frame. Pin joints		
5. Bent rod welded to support at A and subjected to two forces and couple.		

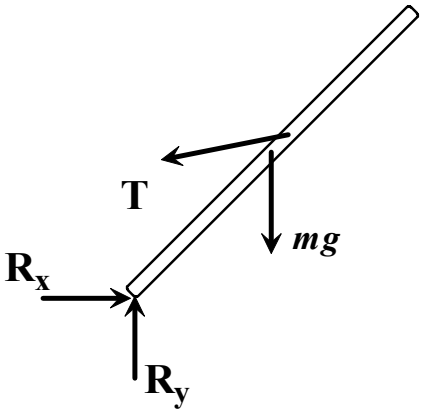
1. Çim biçme



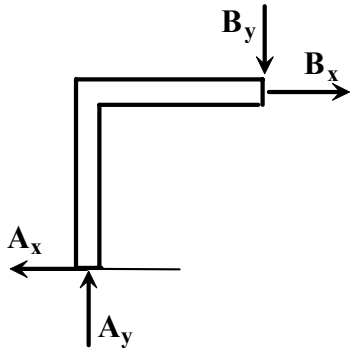
2. Manivela (Kaldırma) Kolu



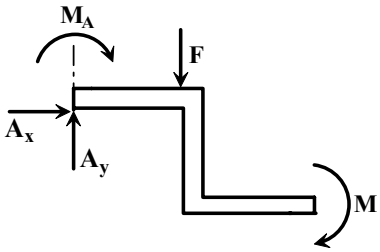
3. Düzgün Çubuk



4. Dik Destek Konsolu



5. Bükülme Çubuğu

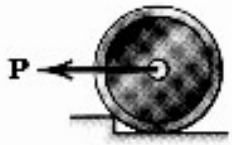


Örnek serbest cisim diyagramları

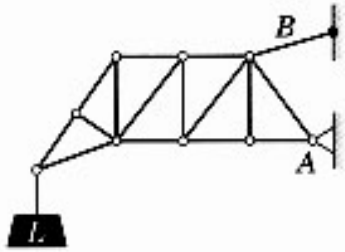
SERBEST CİSİM DİYAGRAMLARINI TAM VE DOĞRU ÇİZİNİZ

1. Uniform horizontal bar of mass m suspended by vertical cable at A and supported by rough inclined surface at B.

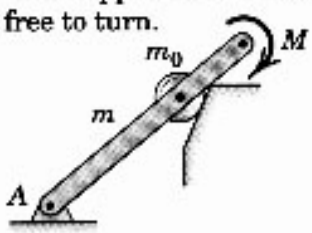
2. Wheel of mass m on verge of being rolled over curb by pull **P**.



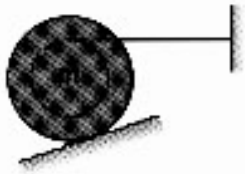
3. Loaded truss supported by pin joint at A and by cable at B.



4. Uniform bar of mass m and roller of mass m_0 taken together. Subjected to couple M and supported as shown. Roller is free to turn.

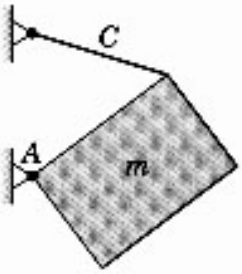


5. Uniform grooved wheel of mass m supported by a rough surface and by action of horizontal cable.

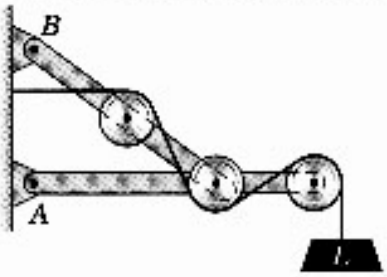


6. Bar, initially horizontal but deflected under load **L**. Pinned to rigid support at each end.

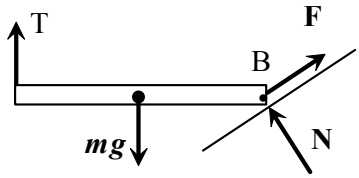
7. Uniform heavy plate of mass m supported in vertical plane by cable C and hinge A.



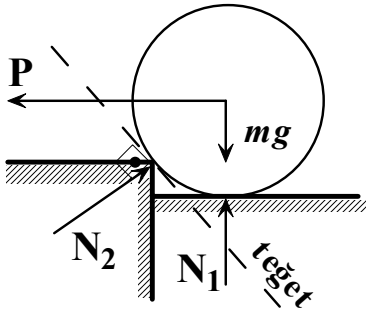
8. Entire frame, pulleys, and contacting cable to be isolated as a single unit.



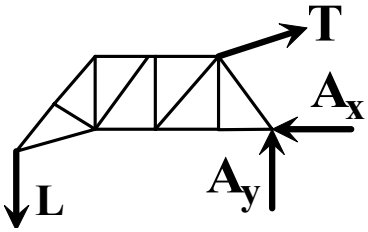
1. Düzgün Çubuk



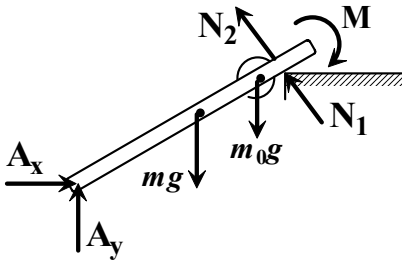
2. Köşeye Dayanan Tekerlek



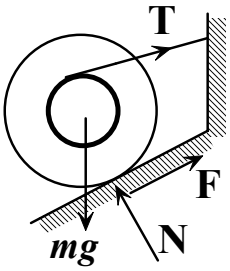
3- Yüklü kafes



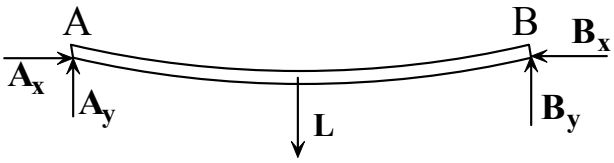
4- Düzgün Çubuk



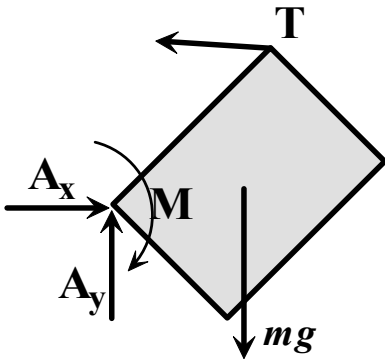
5- Düzgün Disk



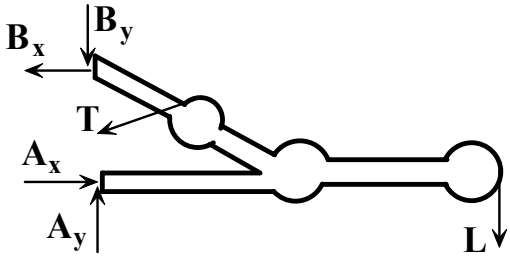
6- **L** Yükü ile esnek çubuk



7- Düzgün Levha



8- Tüm Çerçeve



Denge Şartları : (Düzlemsel kuvvet Sistemi)

$$\Sigma F_x = 0 \qquad \Sigma F_y = 0 \qquad \Sigma M_O = 0$$

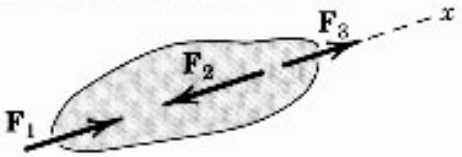
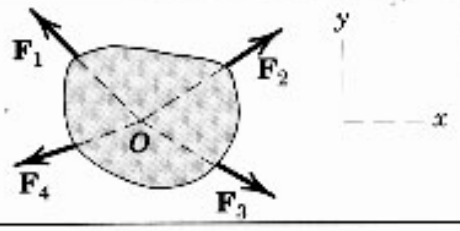
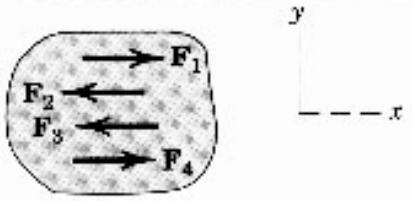
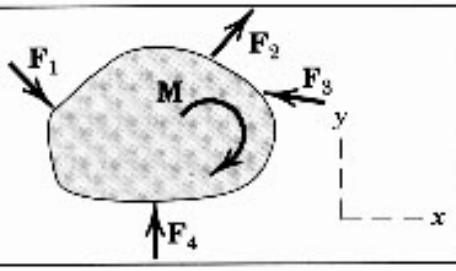
Değişik Düzlemsel Kuvvet Sistemlerinde Denge Şartları

1- Aynı Doğrultudaki Kuvvetlerin Dengesi

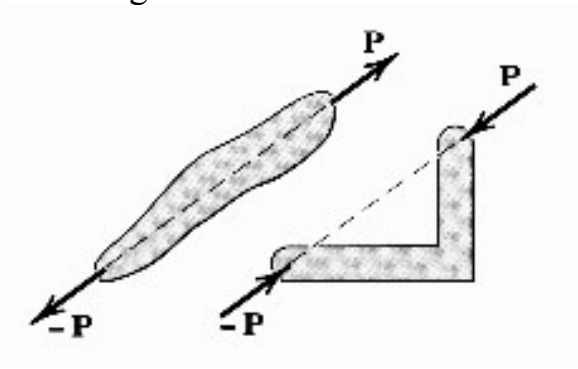
2- Aynı noktada Kesişen Kuvvet Sisteminin Dengesi

3- Paralel Kuvvet Sisteminin Dengesi

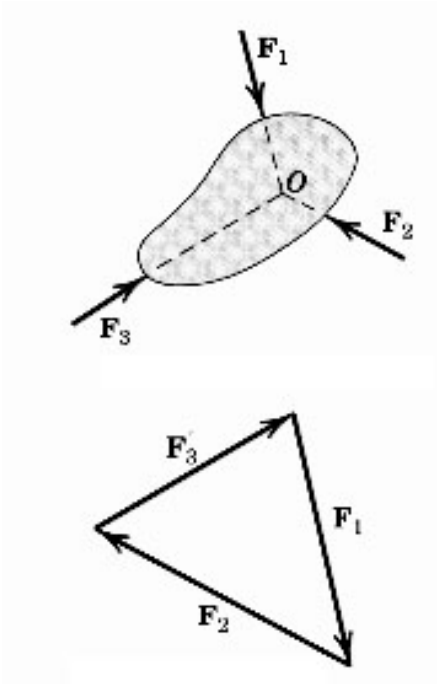
4- Genel Halde Düzlemsel Kuvvet Sisteminin Dengesi

CATEGORIES OF EQUILIBRIUM IN TWO DIMENSIONS		
Force System	Free–Body Diagram	Independent Equations
1. Collinear		$\Sigma F_x = 0$
2. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$
3. Parallel		$\Sigma F_x = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma M_z = 0$ $\Sigma F_y = 0$

İki Kuvvetli Elemanların Dengesi



Üç Kuvvetli Elemanların Dengesi



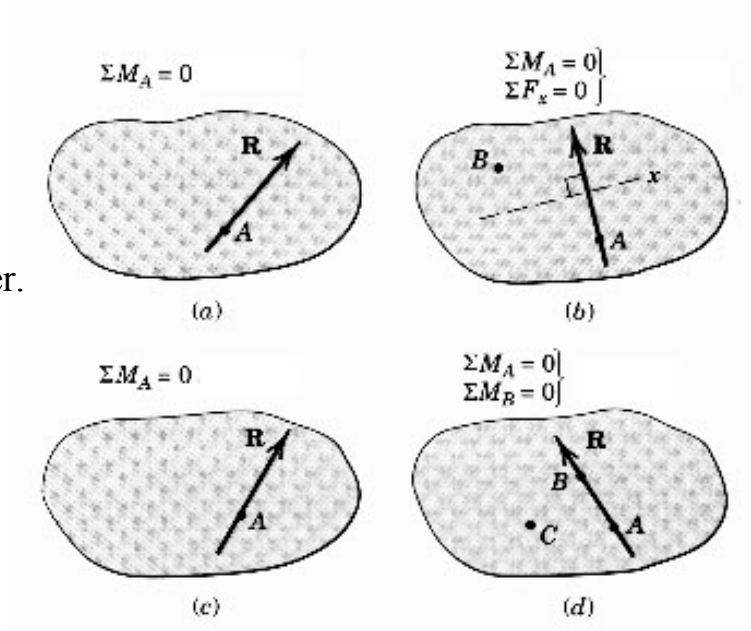
Kuvvet Üçgeni

Alternatif Denge Denklemleri

$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma M_O = 0$ (GENEL)

$\Sigma F_x = 0$ $\Sigma M_A = 0$ $\Sigma M_B = 0$
(A ve B *x*'e dik olmayan bir doğru üzerinde olmalı)
$\Sigma M_A = 0$ $\Sigma M_B = 0$ $\Sigma M_C = 0$
(A, B ve C noktaları aynı doğrultuda olmamak şartı ile)

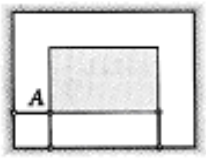
$\Sigma \mathbf{M}_A = 0$ ve
$\Sigma \mathbf{F} = \mathbf{R} \neq 0$
ise $\mathbf{R}$, A'dan geçer.



A ve B x'e dik doğru üzerinde değil

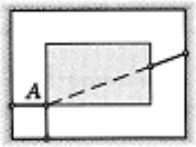
Statikçe Belirlilik (İzo Statik Sistemler: (Tüm bilinmeyenler hesaplanabilir)
Statikçe Belirsizlik (Hiperstatik Sistemler) : (Bilinmeyen sayısı denklemden fazla)

DÜZLEMSEL HAL :



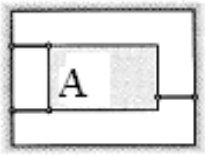
(a)

Bağları uygun (A için) STATİK OLARAK ÇÖZÜLEBİLİR.



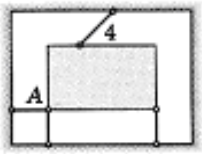
(b)

EKSİK BAĞLI, yüklendiği zaman düşey hareket eder. (A etrafında döner)



(c)

EKSİK (BAĞLARI UYGUN DEĞİL) BAĞLI.
Yüklendiği zaman düşey hareket eder.



(d)

GEREKSİZ BAĞLI (4)

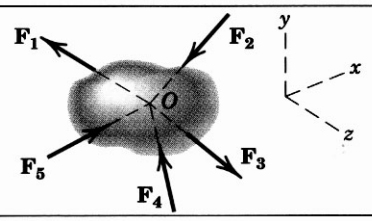
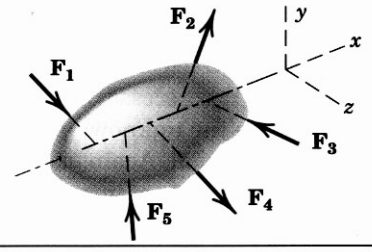
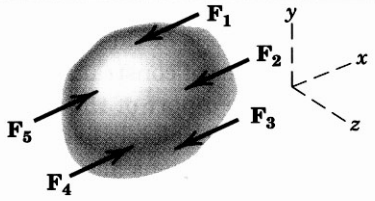
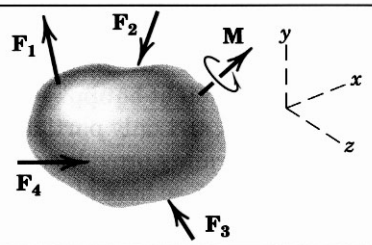
UZAYSAL KUVVET SİSTEMLERİNİN DENGESİ

$$\Sigma \mathbf{F} = \mathbf{0} \quad \text{or} \quad \begin{cases} \Sigma F_x = 0 \\ \Sigma F_y = 0 \\ \Sigma F_z = 0 \end{cases}$$

$$\Sigma \mathbf{M} = \mathbf{0} \quad \text{or} \quad \begin{cases} \Sigma M_x = 0 \\ \Sigma M_y = 0 \\ \Sigma M_z = 0 \end{cases}$$

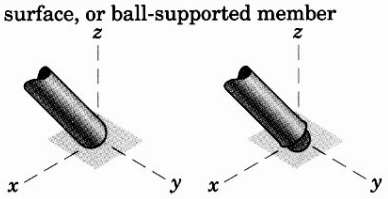
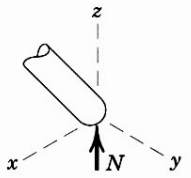
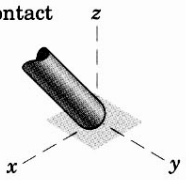
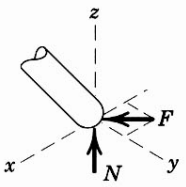
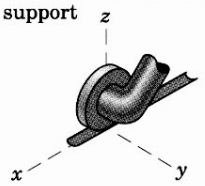
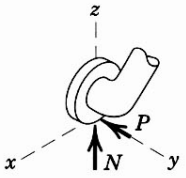
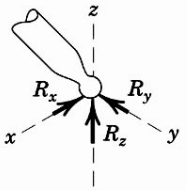
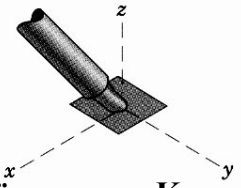
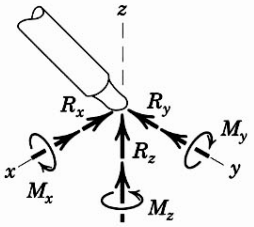
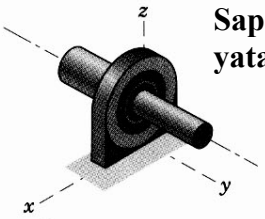
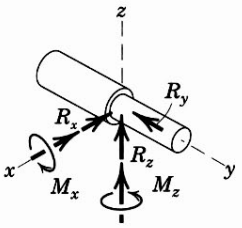
Değişik Uzaysal Kuvvet Sistemlerinin Dengesi

- Bir Noktada Kesişen Kuvvet Sisteminin Dengesi
- Bir Ekseni Kesen Kuvvet Sisteminin Dengesi
- Paralel Kuvvet Sisteminin Dengesi
- Genel Halde Kuvvet Sisteminin Dengesi

CATEGORIES OF EQUILIBRIUM IN THREE DIMENSIONS		
Force System	**Free-Body Diagram**	**Independent Equations**
1. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$
2. Concurrent with a line		$\Sigma F_x = 0$ $\Sigma M_y = 0$ $\Sigma F_y = 0$ $\Sigma M_z = 0$ $\Sigma F_z = 0$
3. Parallel		$\Sigma F_x = 0$ $\Sigma M_y = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma M_x = 0$ $\Sigma F_y = 0$ $\Sigma M_y = 0$ $\Sigma F_z = 0$ $\Sigma M_z = 0$

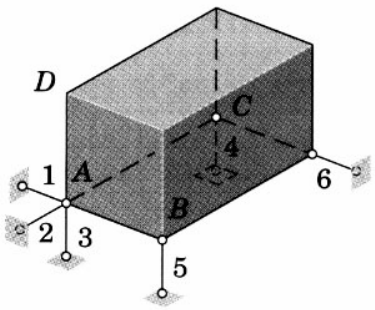
Değişik Bağ Şekillerinde Cismin İzole Edilmesi

MODELING THE ACTION OF FORCES IN THREE-DIMENSIONAL ANALYSIS

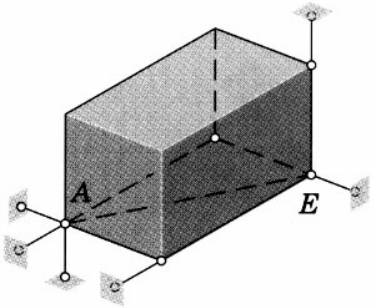
Type of Contact and Force Origin	Action on Body to be Isolated	
1. Member in contact with smooth surface, or ball-supported member 		Force must be normal to the surface and directed toward the member.
2. Member in contact with rough surface 		The possibility exists for a force F tangent to the surface (friction force) to act on the member, as well as a normal force N.
3. Roller or wheel support with lateral constraint 		A lateral force P exerted by the guide on the wheel can exist, in addition to the normal force N. **Ray üzerinde tekerlek**
4. Ball-and-socket joint **Küresel Mafsal**		A ball-and-socket joint free to pivot about the center of the ball can support a force $\boldsymbol{R}$ with all three components. **Küresel Mafsal**
5. Fixed connection (embedded or welded)  **Gömme veya Kaynak**		In addition to three components of force, a fixed connection can support a couple M represented by its three components.
6. Thrust-bearing support  **Saplama yatak**		Thrust bearing is capable of supporting axial force R_y as well as radial forces R_x and R_z. Couples M_x and M_z must, in some cases, be assumed zero in order to provide statical determinacy.

Statikçe Belirlilik (İzo Statik Sistemler)
Statikçe Belirsizlik (Hiperstatik Sistemler)

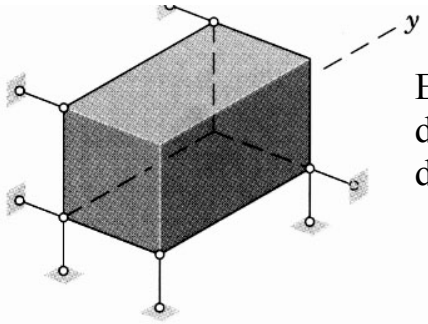
1, 2, 3 A daki bağlarla sabitlenir. 4 Bağı 1 etrafında dönmeyi önler. 5 Bağı 2 etrafındaki dönmeyi önler. 6 Bağı cismin 3 etrafında dönmesini önler.



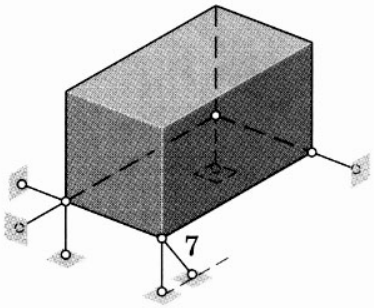
Tam sabitleme bağlar yeterli.



Eksik bağlı AE etrafında dönebilir.

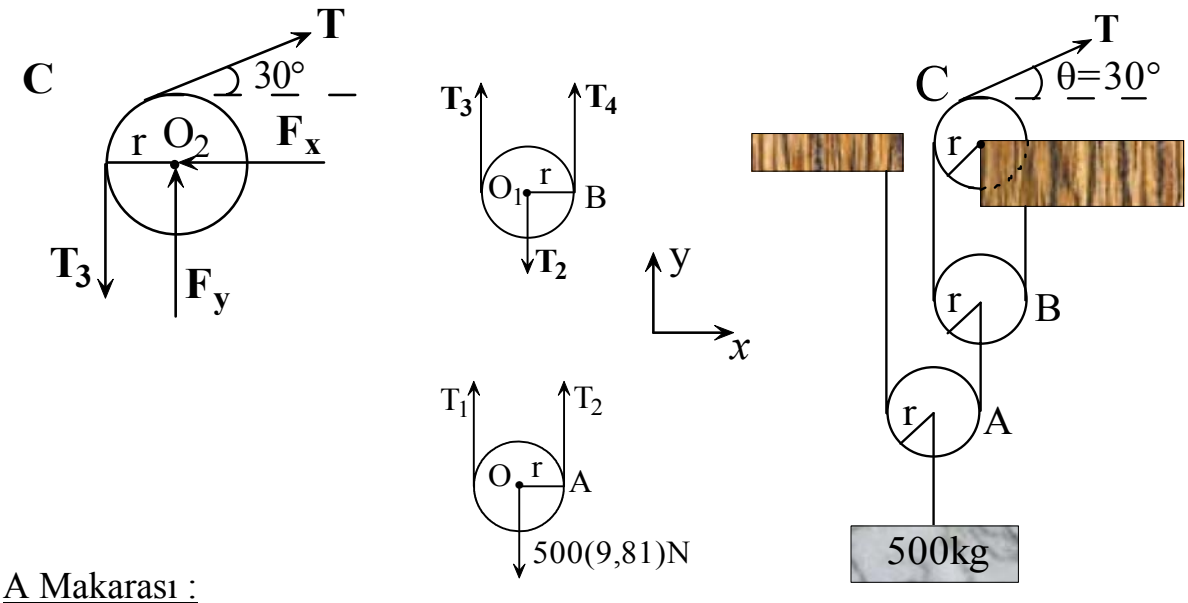


Eksik Bağlı y doğrultusunda harekete dayanıklı değil.



7. ci bağ gereksiz. Statik olarak çözülemez.

Örnek Problem 3-1 : Şekildeki makara sisteminde C makarasına etkiyen toplam kuvveti bulunuz. Makaraların ağırlıkları ihmal ediliyor. Sürtünme yok.



A Makarası :

$$\Sigma \mathbf{M}_0 = 0 \;\Rightarrow\; (-T_1 \mathrm{r} + T_2 \mathrm{r}) = 0 \;\Rightarrow\; T_1 = T_2$$

$$\Sigma \mathbf{F}_\mathbf{y} = 0 \;\Rightarrow\; T_1 + T_2 - 500(9{,}81) = 0 \Rightarrow\; 2T_1 = 500(9{,}81)\,\mathrm{N}$$

$$T_1 = T_2 = 2450\,\mathrm{N}$$

B Makarası:

$$\Sigma \mathbf{M}_{O_1} = 0 \;\Rightarrow\; (-T_3 \mathrm{r} + T_4 \mathrm{r}) = 0 \;\Rightarrow\; T_3 = T_4$$

$$\Sigma \mathbf{F}_\mathbf{y} = 0 \;\Rightarrow\; T_3 + T_4 - T_2 = 0 \Rightarrow\; 2T_3 = T_2 = 2450\,\mathrm{N}$$

$$T_3 = T_4 = \frac{2450}{2} = 1225\,\mathrm{N}$$

C Makarası:

$$\Sigma \mathbf{M}_{O_2} = 0 \;\Rightarrow\; T_3 = T = 1225\,\mathrm{N}$$

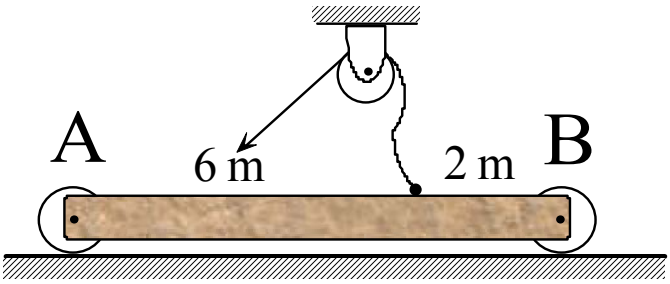
$$\Sigma \mathbf{F}_\mathrm{x} = 0 \;\Rightarrow\; T\cos 30 - F_\mathrm{x} = 0 \;\Rightarrow\; F_\mathrm{x} = 1225.\cos 30 = 1062\,\mathrm{N}$$

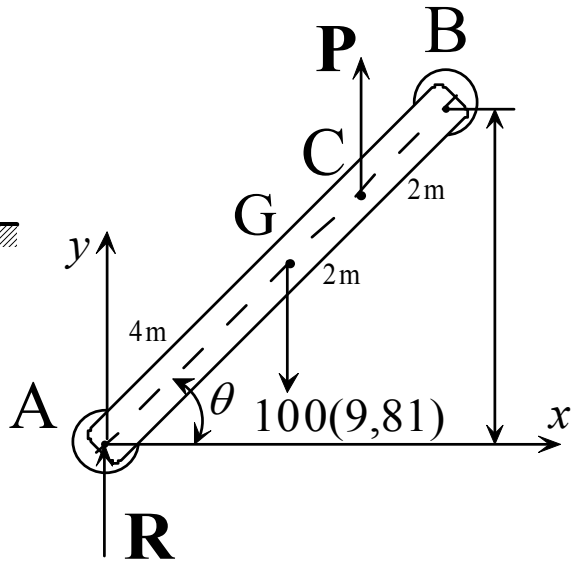
$$\Sigma \mathbf{F}_\mathrm{y} = 0 \;\Rightarrow\; T\sin 30 + F_\mathrm{y} - T_3 = 0 \;\Rightarrow\; F_\mathrm{y} = T.\sin 30 + T_3$$

$$F_\mathrm{y} = -1225(0.5) + 1225 = 613\,\mathrm{N}$$

$$\Sigma F = \sqrt{\Sigma F_\mathrm{x}^2 + \Sigma F_\mathrm{y}^2} = \sqrt{1062^2 + 613^2} = 1226\,\mathrm{N}$$

Örnek Problem 3-2: 100 kg'lık düzgün kiriş A ve B uçlarında kayıcı mafsalla mesnetlenmiştir. Şekildeki ip ile B ucunu A etrafında 3 m yukarı kaldırmak istiyoruz. **P** kuvvetini, A daki bağ kuvvetini (reaksiyonu) ve θ açısını hesaplayınız.





$$\Sigma M_A = 0 \Rightarrow$$

$$P(6.\cos\theta) - 100(9,81)(4\cos\theta) = 0 \quad \Rightarrow P = \frac{981(4)}{4}$$

$$P = 654\,\text{N}$$

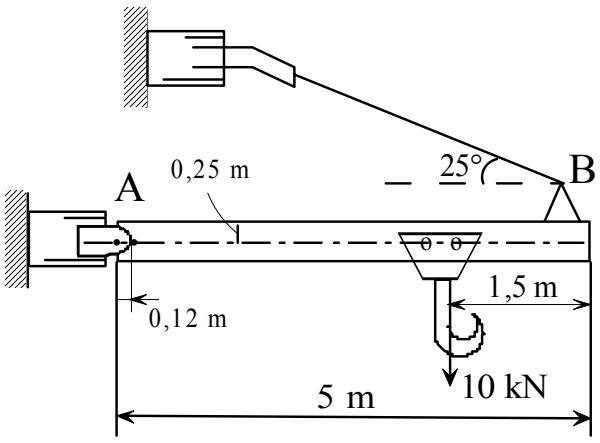
$$\Sigma F_y = 0 \quad \Rightarrow \quad 654 - 981 + R = 0$$

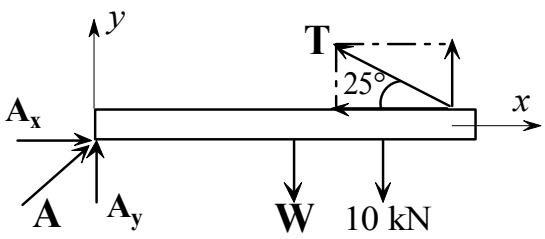
$$R = 327\,\text{N}$$

$$\sin\theta = \frac{3}{8} \quad \Rightarrow \theta = \arcsin\frac{3}{8} = 22°$$

Örnek Problem 3-3 : Şekildeki vinç kolunun A mafsalındaki kuvveti ve kablodaki T gerilmesini bulunuz. Çubuk 0,5 m genişliğinde standart bir kiriş olup kütlesi 95 kg.

$W = 95.(9{,}81).(10^{-3}) = 4{,}66$ kN





$$\Sigma M_A = 0 \;\Rightarrow\; T.\cos 25.(0{,}25) + T.\sin 25.(5-0{,}12)$$
$$-10(5-1{,}5-0{,}12) - 4{,}66(5-0{,}12)$$
$$T = 19{,}61$$
$$\Sigma F_x = 0 \;\Rightarrow\; A_x - 19{,}61.\cos 25 = 0 \quad A_x = 17{,}77\ kN$$
$$\Sigma F_y = 0 \;\Rightarrow\; A_y - 19{,}61.\sin 25 - 4{,}66 - 10 = 0$$
$$A_y = 6{,}37\ kN$$

$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(17{,}77)^2 + (6{,}37)^2}$$

$$A = 18{,}88\ kN \qquad \tan\theta = \frac{A_y}{A_x} \quad \theta = ?$$