



O'ZBEKISTON RESPUBLIKASI
OLIY VA O'RTA MAXSUS TA'LIM VAZIRLIGI
«TOSHKENT IRRIGATSIYA VA QISHLOQ XO'JALIGINI
MEXANIZATSIYALASH MUHANDISLARI INSTITUTI»
MILLIY TADQIQOT UNIVERSITETI

«NAZARIY VA QURILISH MEXANIKASI» KAFEDRASI



FAN: NAZARIY MEXANIKA

MA"RUZACHI:

TEXNIKA FANLARI NOMZODI, DOTSENT

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TOSHKENT-2022

5-ma'ruza.

KINEMATIKA. NUQTA HARAKATINING BERILISH USULLARI.

REJA:

1. Harakat qonuni vektor usulida berilganda tezlik va tezlanish.
2. Harakat qonuni koordinatalar usulida berilganda tezlik va tezlanish.
3. Harakat qonuni tabiiy usulda berilganda tezlik va tezlanish.



Kinematika – nuqta va qattiq jism harakatini shu harakatni vujudga keltiruvchi sabablarni hisobga olmagan holda urganadi.

Harakat turlari:

- ✓ – Ilgarilanma
- ✓ – Aylanma
- ✓ – Tekis-parallel
- ✓ – Sferik
- ✓ – Murakkab

**Kinematik
xarakteristikalar:**

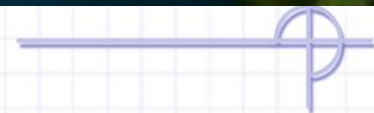
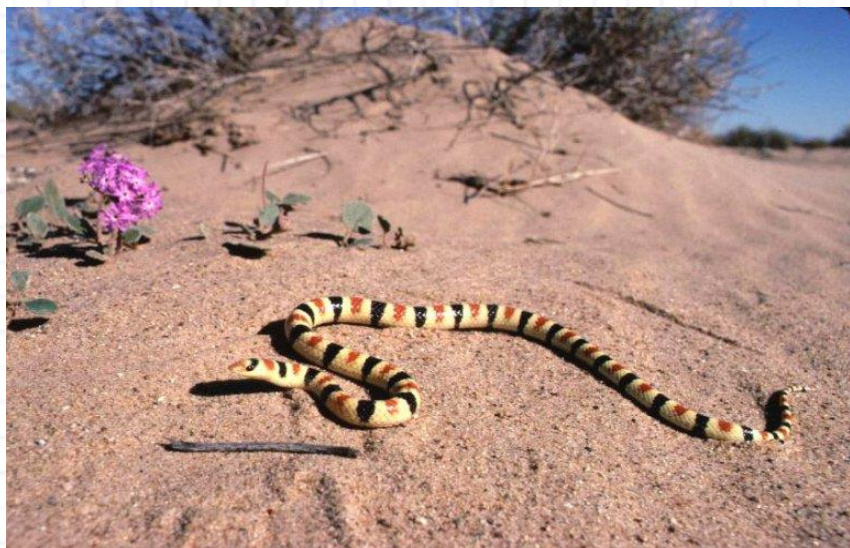
- ✓ – Harakat qonuni
- ✓ – Traektoriya
- ✓ – Tezlik
- ✓ – Tezlanish

**Kinematikaning asosiy
masalalari:**

- ✓ – Jismning harakat qonunlarining matematik berilish usullarini ishlab chiqish
- ✓ – Jismning harakat qonunini bilgan holda shu harakatni asoslovchi asosiy kinematik kattaliklarni aniqlash

HARAKAT – BU HAYOTDIR!

TABIATDA HARAKAT



HARAKAT – BU HAYOTDIR!

HARAKATDAGI MASHINA-MEXANIZMLAR



HARAKAT – BU HAYOTDIR!

HARAKATDAGI MASHINA-MEXANIZMLAR



Kinematikaning asosiy tushunchalari

1. Harakat – jismning bir holatdan ikkinchi holatga ma'lum bir qonuniyat asosida o'tishi!
2. Ko'chish – jismning boshlang'ich va oxirgi holatlarini tutashtiruvchi to'g'ri chiziqli kesma!
3. Tezlik - jismning vaqt birligi ichida bosib o'tgan yo'li!
4. Tezlanish – jism tezligining vaqt birligi ichida o'zgarishi!
5. Fazo – uch o'lchovli Evklid fazosi!
6. Sanoq sistemasi – harakati urganilayotgan jism bilan uzviy bog'langan koordinatalar sistemasi va jism!
7. Vaqt - uzluksiz o'zgaruvchan mustaqil argument!
8. Harakat qonuni – jismning fazoda egallagan holatini sanoq sistemasi bilan bog'lovchi matematik tenglama!
9. Traektoriya – jismning harakat davomida fazoda qoldirgan izi (geometrik nuqtalarining o'rni)!

NUQTA HARAKATINING BERILISH USULLARI



Vektor usuli

$$\vec{r} = \vec{r}(t)$$



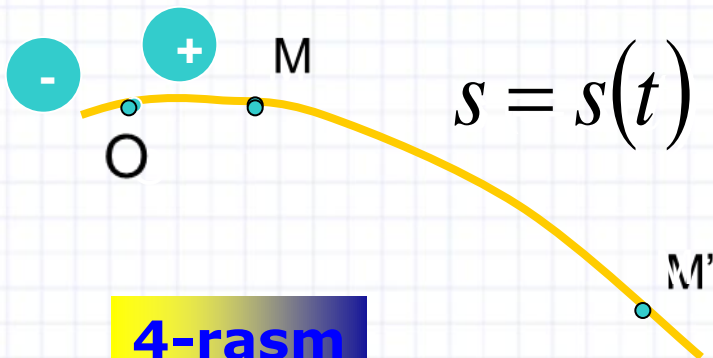
Koordinatalar usuli

$$\begin{cases} x = x(t) \\ y = y(t) \\ z = z(t) \end{cases}$$



Tabiiy usul

$$s = s(t)$$



4-rasm

- ✓ Traektoriya tenglamasi
- ✓ Sanoq boshi
- ✓ Harakat yo'nalishi
- ✓ Harakat qonuni $s = s(t)$

NUQTA TEZLIK VEKTORI

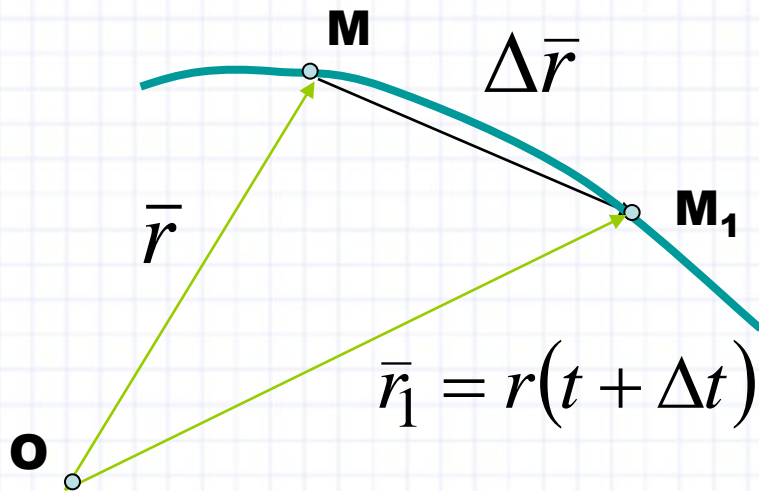
- ✓ *Nuqta tezlik vektori - $\overline{\mathbf{V}}$ jism harakatining eng asosiy kinematik xarakteristikasidir.*
- ✓ *Nuqtaning o'rtacha tezligi deb nuqtaning biror vaqt oralig'idagi ko'chishining shu vaqt oralig'iga nisbatiga aytiladi:*

$$\overline{\mathbf{V}}_{\check{y}p} = \frac{\overline{MM}_1}{\Delta t}$$

Nuqtaning berilgan ondagi tezligi deb vaqt oralig'i nolga intilgandagi o'rtacha tezlik limitiga aytiladi:

$$\overline{\mathbf{V}} = \lim_{\Delta t \rightarrow 0} \frac{\overline{MM}_1}{\Delta t}$$

HARAKAT VEKTOR USULIDA BERILGANDA NUQTA TEZLIK VEKTORI



5-rasm

✓ Nuqtaning harakat qonuni

$$t_1 = t + \Delta t \quad \bar{r} = \bar{r}(t)$$

$$\bar{r}_1 = \bar{r}(t + \Delta t)$$

$$\bar{r}_1 = \bar{r}(t + \Delta t) = \bar{r} + \overline{MM}_1$$

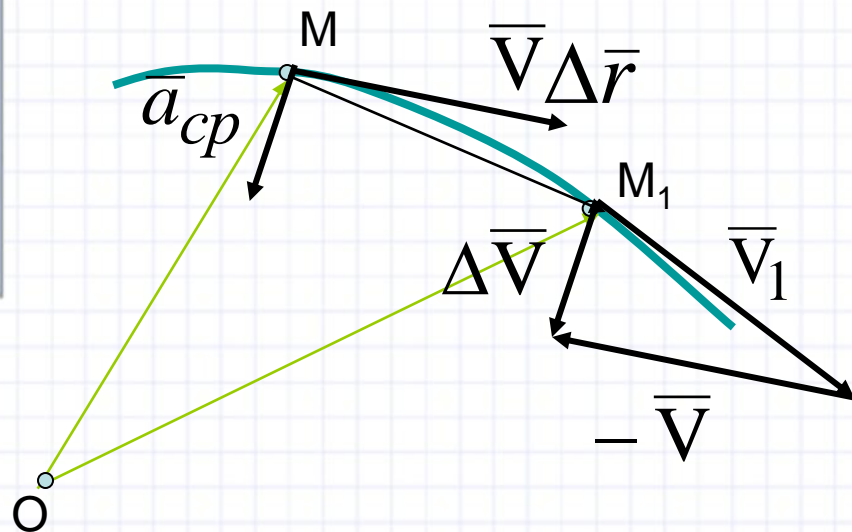
$$\overline{MM}_1 = \bar{r}_1 - \bar{r} = \Delta \bar{r}$$

$$\bar{V}_{\check{y}p} = \frac{\overline{MM}_1}{\Delta t} = \frac{\Delta \bar{r}}{\Delta t};$$

$$\bar{V} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \bar{r}}{\Delta t} = \frac{d\bar{r}}{dt} = \dot{\bar{r}}$$

$$[\bar{V}] = \left[\frac{\text{masofa}}{\text{vaqt}} \right] = \frac{m}{s}; \frac{km}{soat}$$

HARAKAT VEKTOR USULIDA BERILGANDA NUQTA TEZLANISH VEKTORI



✓ Nuqta tezligi $\bar{V} = \bar{V}(t)$

✓ $t_1 = t + \Delta t$

✓ M_1

$$\bar{V}_1 = \bar{V}_1(t_1) = \bar{V}(t + \Delta t)$$

$$\Delta \bar{V} = \bar{V}_1 - \bar{V} = \bar{V}(t + \Delta t) - \bar{V}(t)$$

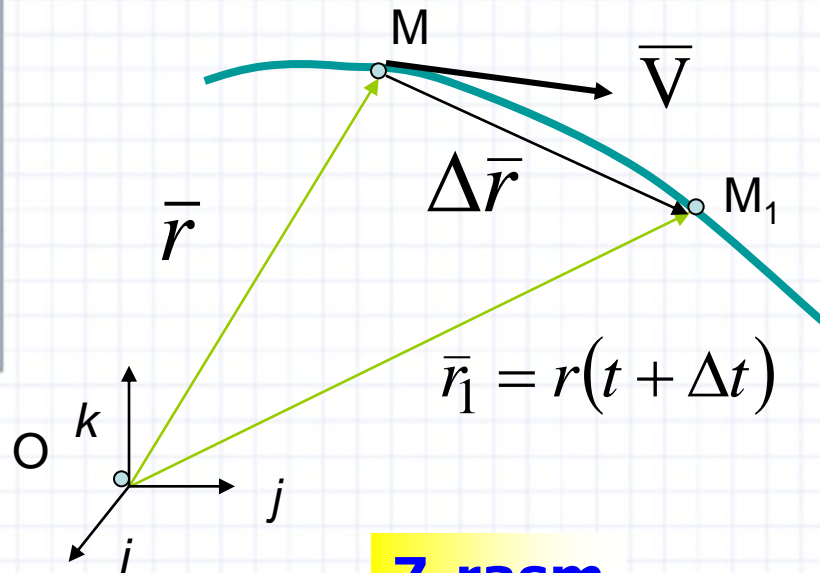
6-rasm

$$\bar{a} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \bar{V}}{\Delta t} = \frac{d\bar{V}}{dt} = \frac{d^2 \bar{r}}{dt^2} = \dot{\bar{V}} = \ddot{\bar{r}}$$

$$\bar{a}_{yp} = \frac{\Delta \bar{V}}{\Delta t};$$

$$[\bar{a}] = \left[\frac{\text{masofa}}{\text{vaqt}^2} \right] = \frac{m}{\text{sek}^2}$$

NUQTA HARAKATI KOORDINATALAR USULIDA BERILGANDA TEZLIK



$$\bar{r} = x \bar{i} + y \bar{j} + z \bar{k}$$

$$\Delta \bar{r} = \bar{r}_1 - \bar{r} = \overline{MM_1}$$

$$\bar{V} = \frac{d\bar{r}}{dt} = \frac{dx}{dt} \bar{i} + \frac{dy}{dt} \bar{j} + \frac{dz}{dt} \bar{k}$$

7-rasm

$$\bar{V} = \dot{x} \bar{i} + \dot{y} \bar{j} + \dot{z} \bar{k}$$

$$\bar{V} = V_x \bar{i} + V_y \bar{j} + V_z \bar{k}$$

NUQTA HARAKATI KOORDINATALAR USULIDA BERILGANDA TEZLIK

$$v_x = \dot{x} \equiv \frac{dx}{dt} \quad v_y = \dot{y} \equiv \frac{dy}{dt} \quad v_z = \dot{z} \equiv \frac{dz}{dt}$$

$$|\bar{\mathbf{V}}| = V = \sqrt{V_x^2 + V_y^2 + V_z^2}$$

$$\left. \begin{aligned} \cos(\bar{\mathbf{V}}, \bar{x}) &= \frac{V_x}{V} \\ \cos(\bar{\mathbf{V}}, \bar{y}) &= \frac{V_y}{V} \\ \cos(\bar{\mathbf{V}}, \bar{z}) &= \frac{V_z}{V} \end{aligned} \right\}$$

Yo'naltiruvchi
kosinuslar

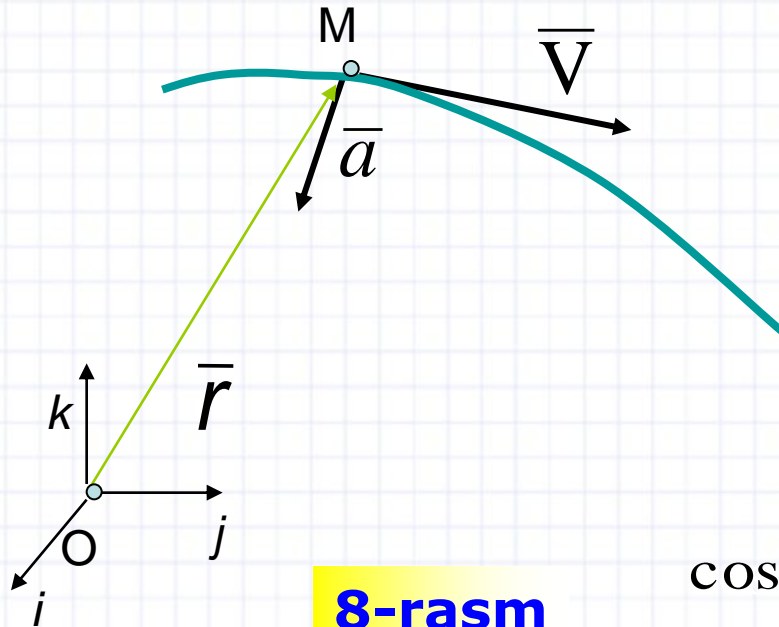
NUQTA HARAKATI KOORDINATALAR USULIDA BERILGANDA TEZLANISH

$$\bar{a} = \frac{d\bar{V}}{dt} = \frac{d^2\bar{r}}{dt^2} = \dot{\bar{V}} = \ddot{\bar{r}}$$

$$\bar{a} = a_x \bar{i} + a_y \bar{j} + a_z \bar{k}$$

$$\bar{a} = \dot{V}_x \bar{i} + \dot{V}_y \bar{j} + \dot{V}_z \bar{k}$$

$$\bar{a} = \ddot{x} \bar{i} + \ddot{y} \bar{j} + \ddot{z} \bar{k}$$



8-rasm

$$|\bar{a}| = a = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

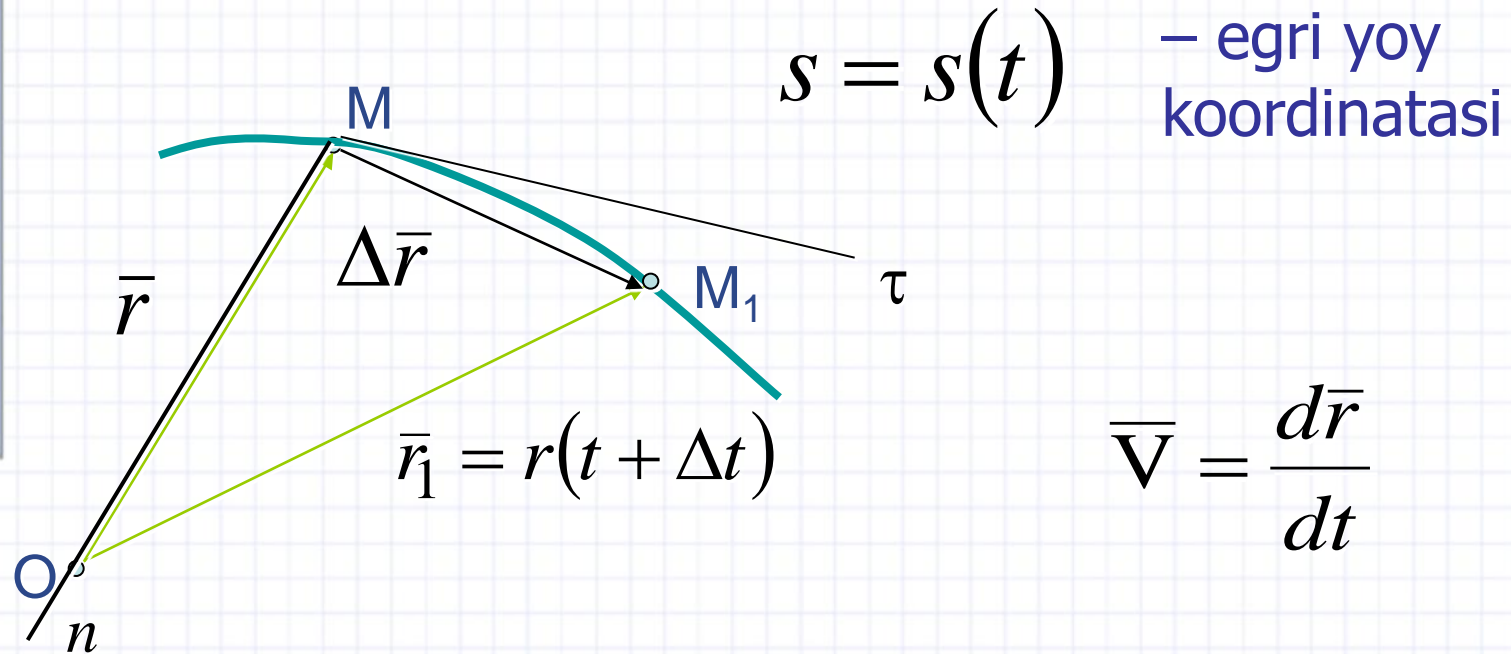
$$\cos(\hat{\bar{a}}, \hat{\bar{x}}) = \frac{a_x}{a}$$

$$\cos(\hat{\bar{a}}, \hat{\bar{y}}) = \frac{a_y}{a}$$

$$\cos(\hat{\bar{a}}, \hat{\bar{z}}) = \frac{a_z}{a}$$

Yo'naltiruvchi
kosinuslar

NUQTA HARAKATI TABIIY USULDA BERILGANDA TEZLIK



9-rasm

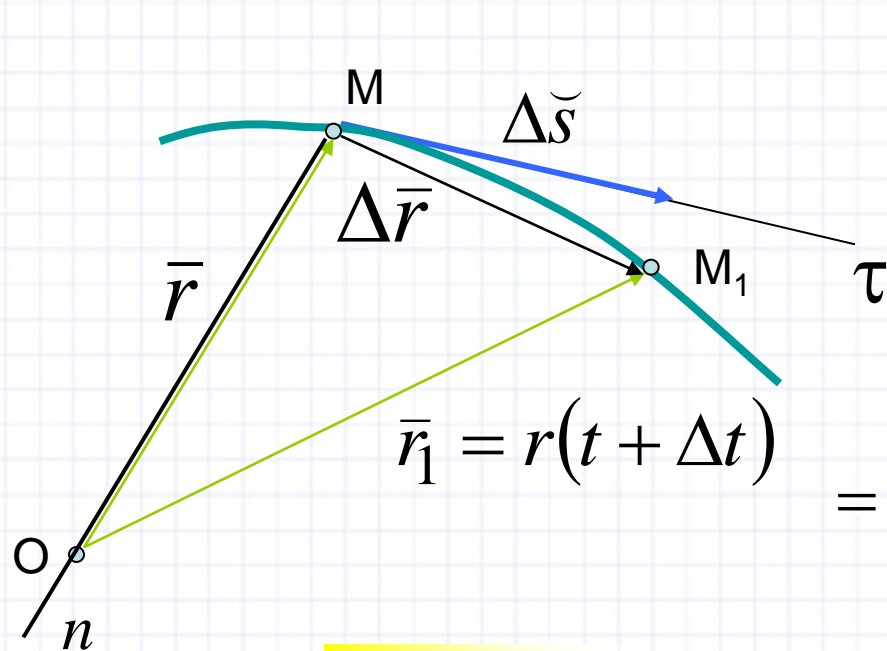
$$\bar{V} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \bar{r}}{\Delta t}$$

$M\tau$ - Urinma

Mn - Normal

Mb - Binormal

NUQTA HARAKATI TABIIY USULDA BERILGANDA TEZLIK



$$\bar{\mathbf{V}} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \bar{r}}{\Delta t}$$

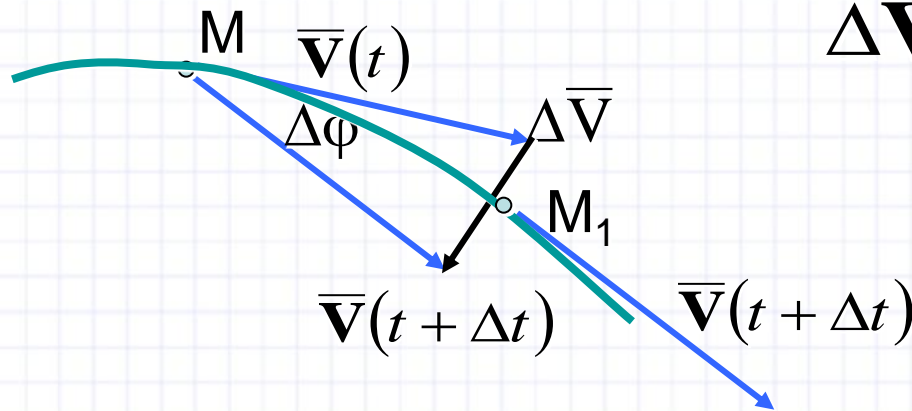
$$\bar{\mathbf{V}} = \lim_{\Delta t \rightarrow 0} \left[\frac{\Delta \bar{r}}{\Delta t} \cdot \frac{\Delta s}{\Delta s} \right] =$$

$$= \lim_{\Delta t \rightarrow 0} \frac{\Delta \bar{r}}{\Delta s} \cdot \lim_{\Delta t \rightarrow 0} \frac{\Delta s}{\Delta t} = \bar{\tau} \cdot \frac{ds}{dt}$$

10-rasm

$$\bar{\mathbf{V}} = \frac{ds}{dt} \bar{\tau} = \dot{s} \bar{\tau}; \quad \mathbf{V}_{\tau} = \frac{ds}{dt}; \quad |\bar{\mathbf{V}}| = |\mathbf{V}_{\tau}|;$$

NUQTA HARAKATI TABIIY USULDA BERILGANDA TEZLANISH



11-rasm

$\Delta\varphi$ – siljish
burchagi

$$\Delta\bar{\mathbf{V}} = \bar{\mathbf{V}}(t + \Delta t) - \bar{\mathbf{V}}(t)$$

$$\bar{a}_{\check{y}p} = \frac{\Delta\bar{\mathbf{V}}}{\Delta t};$$

$$\bar{a}_{\check{y}p} \parallel \Delta\bar{\mathbf{V}}$$

$$\bar{a} = \lim_{\Delta t \rightarrow 0} \frac{\Delta\bar{\mathbf{V}}}{\Delta t} = \frac{d\bar{\mathbf{V}}}{dt} = a_n \bar{n} + a_\tau \bar{\tau} + a_b \bar{b};$$

$$a_{\tau} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \mathbf{V}_{\tau}}{\Delta t} = \lim_{\substack{\Delta t \rightarrow 0 \\ \Delta \varphi \rightarrow 0}} \frac{\mathbf{V}_1 \cos \Delta \varphi - \mathbf{V}}{\Delta t} = \lim_{\Delta t \rightarrow 0} \frac{\mathbf{V}_1 - \mathbf{V}}{\Delta t} = \frac{d\mathbf{V}}{dt};$$

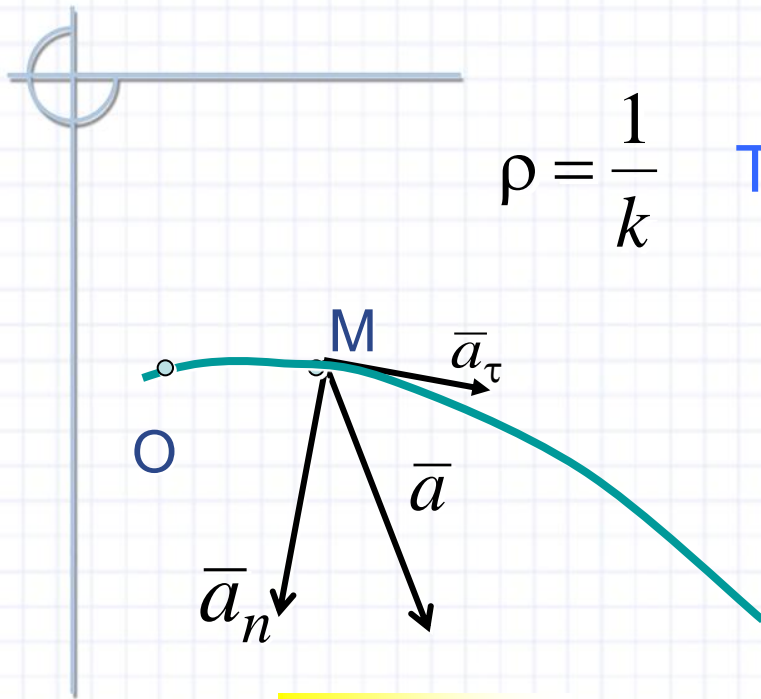
$$a_n = \lim_{\Delta t \rightarrow 0} \frac{\Delta \mathbf{V}_n}{\Delta t} = \lim_{\substack{\Delta t \rightarrow 0 \\ \Delta \varphi \rightarrow 0}} \frac{\mathbf{V}_1 \sin \Delta \varphi}{\Delta t} = \lim_{\substack{\Delta t \rightarrow 0 \\ \Delta \varphi \rightarrow 0}} \left[\frac{\mathbf{V}_1 \sin \Delta \varphi}{\Delta t} \cdot \frac{\Delta s}{\Delta s} \cdot \frac{\Delta \varphi}{\Delta \varphi} \right] =$$

$$= \lim_{\substack{\Delta t \rightarrow 0 \\ \Delta \varphi \rightarrow 0}} \left[\mathbf{V}_1 \cdot \frac{\Delta s}{\Delta t} \right] \cdot \lim_{\substack{\Delta t \rightarrow 0 \\ \Delta \varphi \rightarrow 0}} \frac{\Delta \varphi}{\Delta s} \cdot \lim_{\substack{\Delta \varphi \rightarrow 0 \\ \Delta t \rightarrow 0}} \frac{\sin \Delta \varphi}{\Delta \varphi} = \mathbf{V}^2 \cdot k = \frac{\mathbf{V}^2}{\rho};$$

$$\lim_{\Delta s \rightarrow 0} \frac{\Delta \varphi}{|\Delta s|} = \frac{d\varphi}{ds} \equiv k$$

$$\lim_{\Delta \varphi \rightarrow 0} \frac{\sin \Delta \varphi}{\Delta \varphi} = 1$$

$$a_b \equiv 0$$



$$\rho = \frac{1}{k}$$

Traektoriyaning egrilik radiusi

$$\bar{a} = \frac{d\mathbf{V}}{dt} \bar{\tau} + \frac{\mathbf{V}^2}{\rho} \bar{n}$$

$$a = \sqrt{a_{\tau}^2 + a_n^2}$$

12-rasm

a_n - Har doim musbat, chunki u har doim traektoriyaning botiq tomoniga qarab yo'naladi.

a_{τ} - Har doim musbat, chunki u har doim traektoriya bo'ylab harakat yo'nalishi tomoniga qarab yo'naladi.

a_{τ} - Nuqta tezligi modulining o'zgarishini ko'rsatadi.

a_n - Nuqta tezligi yo'nalishining o'zgarishini ko'rsatadi.

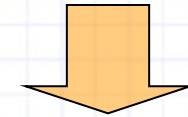
INSERT JADVALI

V	+	-	?

Insert jadvali:

- ma'lumotlarni sistemalashtirishni (mustaqil o'qish/ ma'ruza eshitish jarayonida olingan), ularni tasdiqlash, aniklashtirish yoki rad etish; qabul qilinayotgan ma'lumotning tushunarligini nazorat qilish, avval egallangan ma'lumotni yangisi bilan bog'lash qobiliyatlarini shakllantirishni ta'minlaydi;*
- o'quv ma'lumotini mustaqil o'rganilganidan so'ng qo'llanadi.*

Insert jadvalining tuzilishi va uni to'ldirish qoidasi bilan tanishadilar.



O'qish jarayonida olingan ma'lumotlarni individual holda sistemalashtiradilar;

Matnda qo'yilgan belgilar asosida jadval ustunlarini to'ldiradilar:

V - xaqidagi bilimlarimga javob beradi;

«-» - xaqidagi bilimlarimga zid;

+ - yangi ma'lumotlar

? – tushunarsiz (aniqlashtirish, to'ldirishni talab qiladi) ma'lumot.



NAZORAT SAVOLLARI:

1. Kinematika deb nimaga aytiladi?
2. Fazo nima?
3. Vaqt qanday kattalik?
4. Ko'chish deb nimaga aytiladi?
5. Harakat deb nimaga aytiladi?
6. Kinematikaning asosiy masalasi nima?
7. Harakat vektor usulda qanday ifodalanadi?
8. Harakat koordinata usulda qanday ifodalanadi?
9. Harakat tabiiy usulda qanday ifodalanadi?
10. Harakat vektor usulda berilganda nuqtaning tezligi formulasi qanday ifodalanadi?
11. Harakat vektor usulda berilganda nuqtaning tezlanishi formulasi qanday ifodalanadi?

**E'TIBORLARINGIZ UCHUN
RAHMAT!**