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

Xudaynazarov Sherzod Ochilovich

TOSHKENT-2022

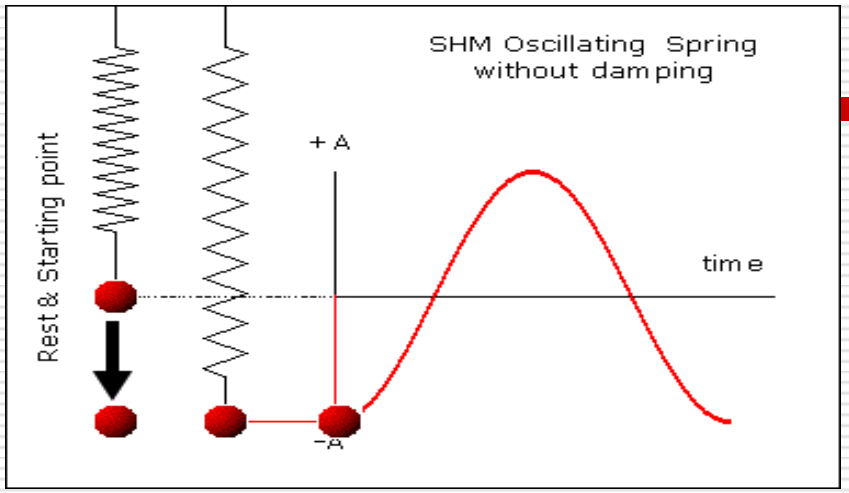
8-ma’ruza.

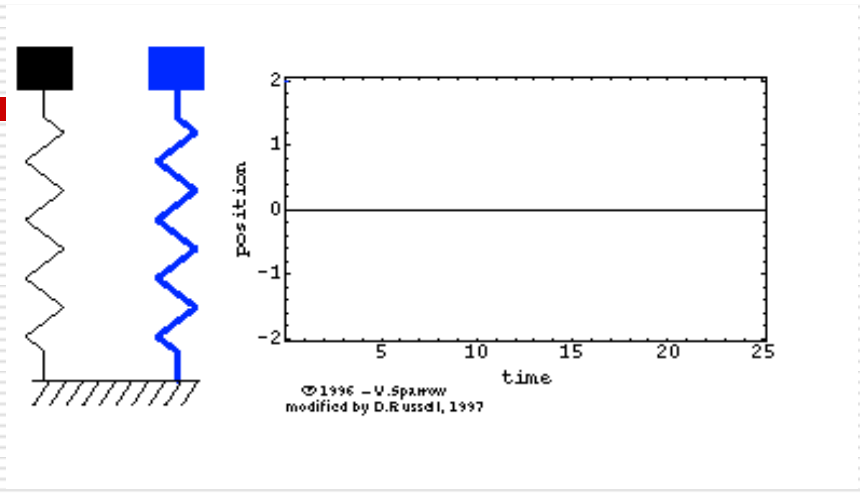
Nuqtaning to’g’ri chiziqli erkin va majburiy tebranma harakati.

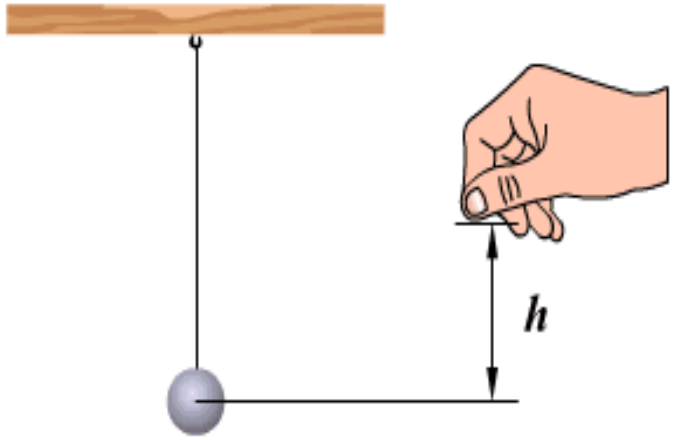
REJA:

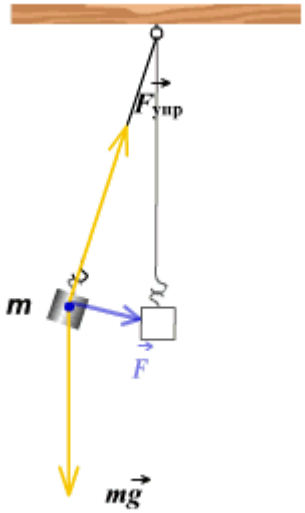
1. Tebranma harakat va uning turlari. Asosiy tushuncha va qoidalar.
2. Moddiy nuqtaning erkin tebranma harakati.
3. Moddiy nuqtaning majburiy tebranma harakati.

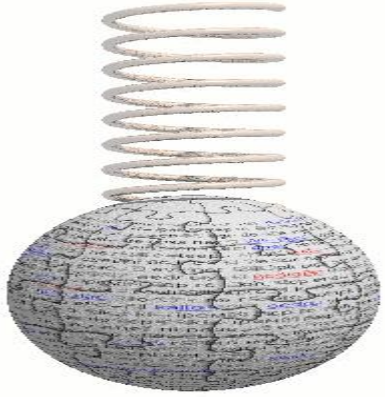
Tebranma harakat va uning turlari. Asosiy tushuncha va qoidalar.











Tebranma harakat va uning turlari. Asosiy tushuncha va qoidalar.

Moddiy nuqtaning muvozanat holatiga qaytarishga intiluvchi kuchga qaytaruvchi kuch deyiladi:

$$\vec{F}_x = -cx$$

Moddiy nuqta harakatlanayotgan muhitning ta’sir kuchlari muhitning qarshilik kuchlari deyiladi:

$$\vec{R} = -\mu\vec{v}$$

Moddiy nuqtaga davriy yoki nodavruy ta’sir etuvchi tashqi kuchlar uyg’otuvchi kuchlar deyiladi:

$$Q_x = H\sin(pt+\delta),$$

Tebranma harakat va uning turlari. Asosiy tushuncha va qoidalar.

Bitta to‘liq tebranish uchun ketadigan vaqt – tebranish davri deyiladi va quyidagi formula orqali topiladi:

$$T = \frac{2\pi}{k} = \frac{1}{\nu}$$

Yukning muvozanat holatidan chetga chiqishi (og‘ishi) ning eng katta qiymati tebranish amplitudasi deyiladi va quyidagi formula orqali topiladi:

$$a = \sqrt{x_0^2 + \frac{\upsilon_0^2}{\kappa^2}}$$

Ma’lum bir vaqt mobaynidagi tebranishlar soni - tebranish chastotasi va quyidagi formula orqali topiladi:

$$\nu = \frac{k}{2\pi} = \frac{1}{T}$$

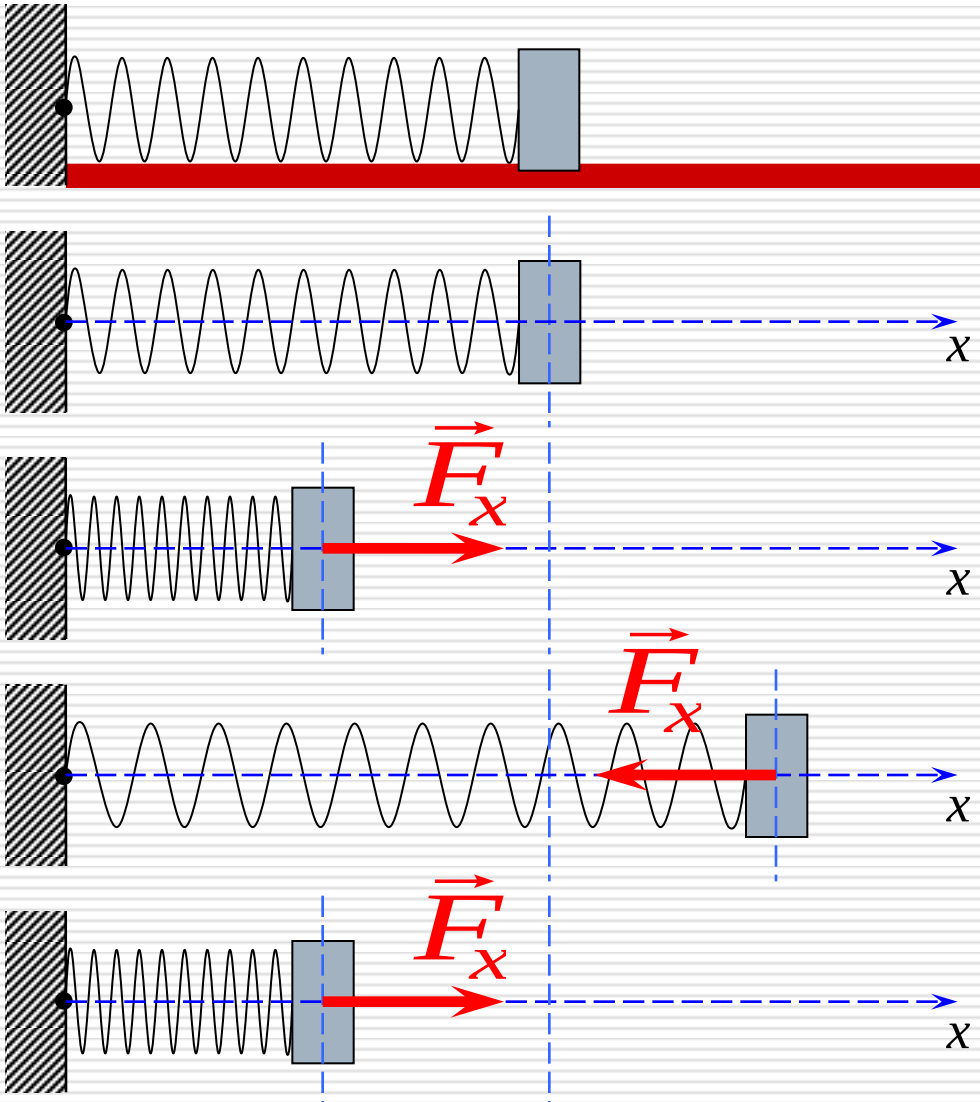
Tebranma harakat va uning turlari. Asosiy tushuncha va qoidalar.

Moddiy nuqtaning davriy ravishda takrorlanadigan harakatiga tebranma harakat deyiladi.

Moddiy nuqtaning tebranma harakati asosan besh turga bo'linadi:

1. Muhit qarshiligi hisobga olinmagandagi erkin tebranma harakat;
2. Muhit qarshiligi hisobga olingandagi erkin tebranma harakat (so'nuvchi tebranma harakat).
3. Muhit qarshiligi hisobga olinmagandagi majburiy tebranma harakat;
4. Muhit qarshiligi hisobga olingandagi majburiy tebranma harakat;
5. Juda kichik tebranma harakat.

Muhit qarshiligi hisobga olinmagandagi erkin tebranma harakat

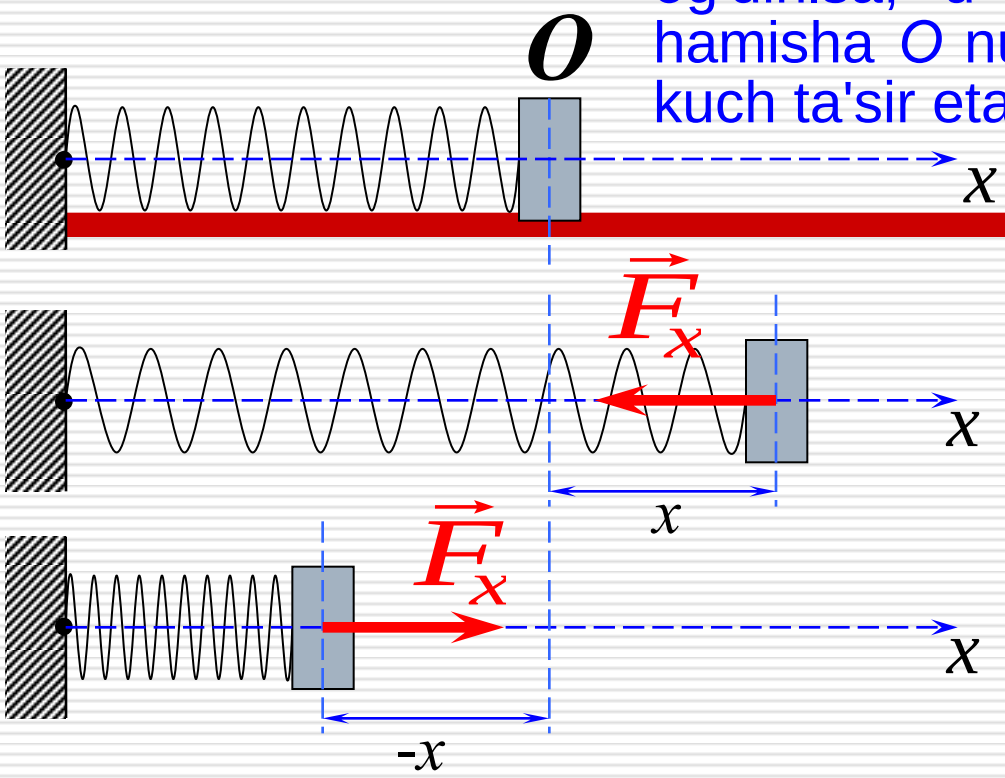


Moddiy nuqta tinch muvozanat holatidan chetlatilganda moddiy nuqtaning tebranma harakati vujudga keladi.

Moddiy nuqtaning muvozanat holatiga qaytarishga intiluvchi kuchga qaytaruvchi kuch deyiladi.

Muhit qarshiligi hisobga olinmagandagi erkin tebranma harakat

Nuqta muvozanat holatidan *x* masofaga og'dirilsa, u holda unga *x* o'qi bo'ylab hamisha *O* nuqtaga yo'nalgan qaytaruvchi kuch ta'sir etadi.



Bu kuchning *Ox* o'qdagi proektsiyasi quyidagicha aniqlanadi:

$$\vec{F}_x = -cx$$

Bunda: *c* - proportsionallik koeffitsienti (prujinaning bikrligi).

Moddiy nuqtaning erkin tebranma harakatining differentsial tenglamasi:

$$m\ddot{x} = -cx$$

$$\frac{c}{m} = k^2$$ desak,

$$\ddot{x} + k^2 x = 0$$

Muhit qarshiligi hisobga olinmagandagi erkin tebranma harakat

$$\ddot{x} + k^2 x = 0$$

Moddiy nuqtaning erkin tebranma harakat differentsial tenglamasi deyiladi.

$t = 0$ **da** $x = x_0,\ \upsilon = \dot{x} = \upsilon_0$

$$x = C_1 \cos kt + C_2 \sin kt$$

$$\dot{x} = -C_1 k \sin kt + C_2 k \cos kt$$

$$C_1 = x_0,\ C_2 = \upsilon_0 / k$$

$$x = x_0 \cos kt + \frac{\upsilon_0}{k} \sin kt$$

$$x = a \sin(kt + \alpha)$$

$$\dot{x} = a k \cos(kt + \alpha)$$

$$x_0 = a \sin\alpha,\ \upsilon_0 = a k \cos\alpha$$

$$a = \sqrt{x_0^2 + \upsilon_0^2 / k^2}$$

Tebranish amplitudasi – nuqtaning tebranish markazidan (O dan) eng katta og'ishi.

$kt + \alpha$ - tebranish fazasi;

α -tebranishlarning boshlang'ich fazasi;

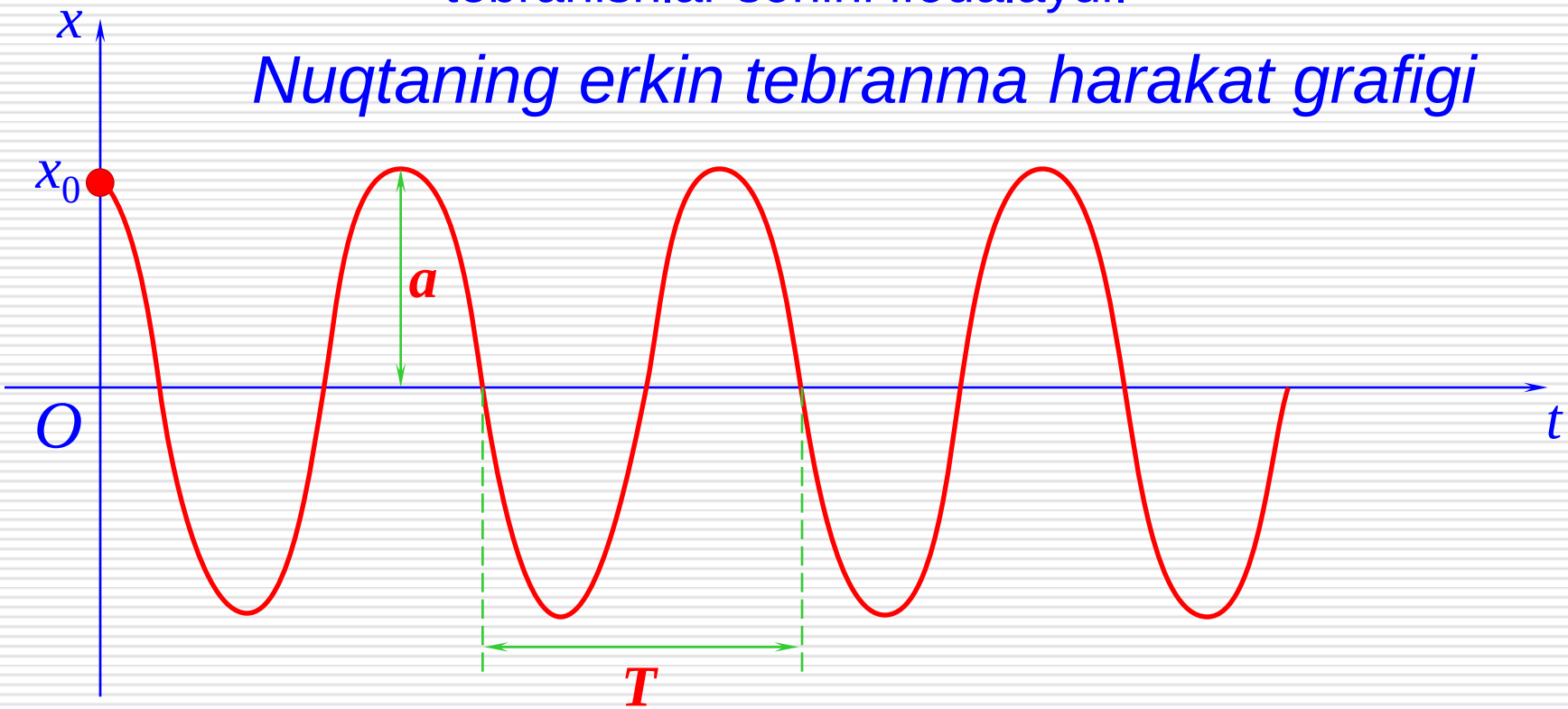
Muhit qarshiligi hisobga olinmagandagi erkin tebranma harakat

$x_0 = a \sin \alpha$ - nuqtaning boshlang'ich paytdagi og'ishi;

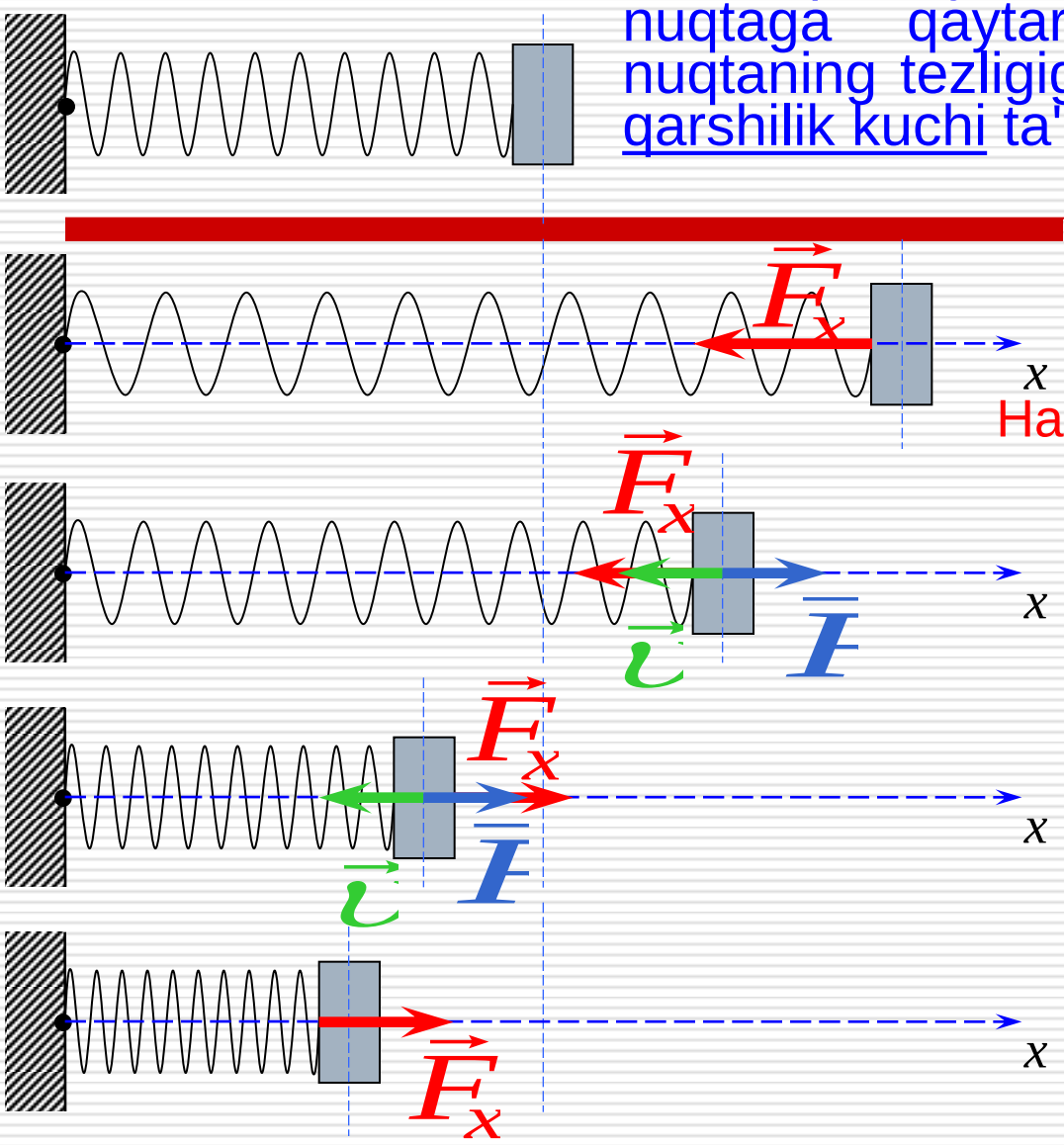
$T = 2\pi / k$ - tebranishlar davri, ya’ni nuqta bir marta to'liq tebranishi uchun ketgan vaqt;

$\nu = 1/T = k/2\pi$ - tebranishlar chastotasi: bir sekunddagi tebranishlar sonini ifodalaydi.

Nuqtaning erkin tebranma harakat grafigi



Muhit qarshiligi hisobga olingandagi erkin tebranma harakat (so'nuvchi tebranma harakat).



Ox o'q bo'yicha harakatlanuvchi moddiy nuqtaga qaytaruvchi kuchdan tashqari nuqtaning tezligiga qarama-qarshi yo'nalgan qarshilik kuchi ta'sir etadi:

$$\vec{R} = -\mu\vec{\upsilon}$$

μ - qarshilik koeffitsienti.

Harakat differentsial tenglamasi:

$$m\,\vec{a} = \vec{F}_x + \vec{R}$$

Qaytaruvchi va qarshilik kuchlarining *Ox* o'qdagi proektsiyalari:

$$F_x = -cx\ ;$$

$$R = -\mu\upsilon = -\mu\dot{x}$$

Harakat differentsial tenglamasi:

$m\vec{a} = \vec{F}_x + \vec{R}$

$m\ddot{x} = -cx - \mu\dot{x}$ yoki $\ddot{x} + 2n\dot{x} + k^2 x = 0$

$k^2 = c/m$

$2n = \mu/m$

Qaytaruvchi kuch va nuqta tezligiga proportsional bo'lgan qarshilik kuchi ta'siridagi moddiy nuqtaning harakat differentsial tenglamasini ifodalaydi:

$t = 0$ **da** $x = x_0,\ v = \dot{x} = v_0$

Xarakteristik tenglamasi: $\lambda^2 + 2n\lambda + k^2 = 0$ bo'lib, u

$\lambda_{1,2} = -n \pm \sqrt{n^2 - k^2}$ ildizlarga ega.

a) Muhitning qarshiligi uncha katta bo'lmagan hol.

$n < k$ - xarakteristik tenglamaning ildizlari qo'shma kompleks sonlardan iborat bo'ladi;

b) muhitning qarshiligi katta bo'lgan hol.

$n > k$ - xarakteristik tenglamaning ildizlari xaqiqiy va turlicha bo'ladi.

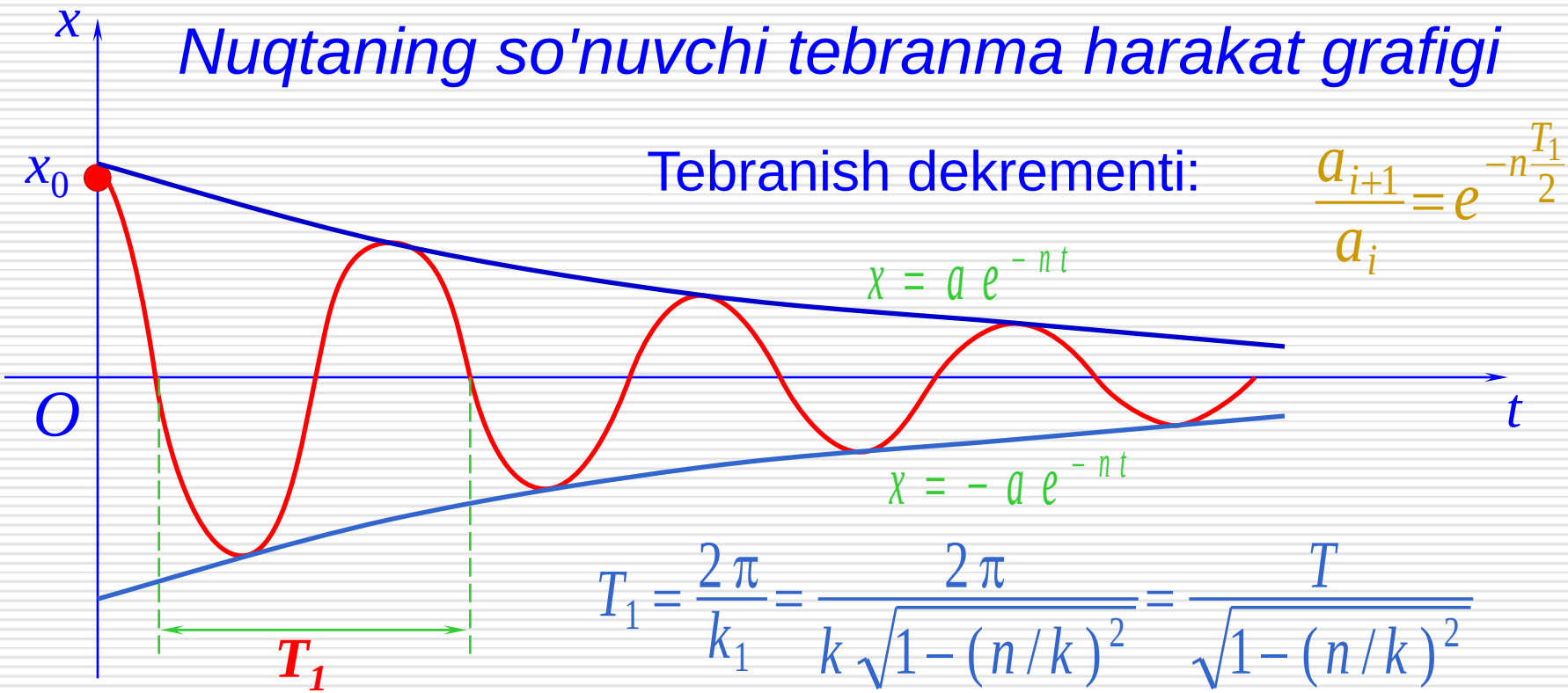
$n = k$ - xarakteristik tenglamaning ildizlari xaqiqiy va o'zaro teng bo'ladi.

a) Muhitning qarshiligi uncha katta bo'lmagan hol.

$n < k$ - xarakteristik tenglamaning ildizlari qo'shma kompleks sonlardan iborat bo'ladi.

$k^2 - n^2 = k_1^2$ belgilash kiritilsa, $\lambda_{1,2} = -n \pm ik_1$ bo'ladi va

$x = e^{-nt}(C_1 \cos k_1 t + C_2 \sin k_1 t)$ yoki $x = a e^{-nt} \sin(k_1 t + \alpha)$



Nuqtaning so'nuvchi tebranma harakat grafigi

Tebranish dekrementi: $\frac{a_{i+1}}{a_i} = e^{-n\frac{T_1}{2}}$

$$T_1 = \frac{2\pi}{k_1} = \frac{2\pi}{k\sqrt{1-(n/k)^2}} = \frac{T}{\sqrt{1-(n/k)^2}}$$

b) muhitning qarshiligi katta bo'lgan hol.

$n > k$ - xarakteristik tenglamaning ildizlari xaqiqiy va turlicha bo'ladi.

$n^2 - k^2 = h^2$ belgilash kiritilsa, $\lambda_{1,2} = -n \pm h$ bo'ladi va

$x = e^{-nt}(C_1 e^{ht} + C_2 e^{-ht})$ yoki $x = e^{-nt}\left(A \cdot \frac{e^{ht} + e^{-ht}}{2} + B \cdot \frac{e^{ht} - e^{-ht}}{2}\right)$

yoki $x = a\, e^{-nt} \operatorname{sh}(k_1 t + \alpha)$

$n = k$ - xarakteristik tenglamaning ildizlari xaqiqiy va o'zaro teng bo'ladi.

$\lambda_1 = \lambda_2 = -n$ va $x = e^{-nt}(C_1 t + C_2)$

$$\dot{x} = -n\, e^{-nt}(C_1 t + C_2) + e^{-nt} C_1$$

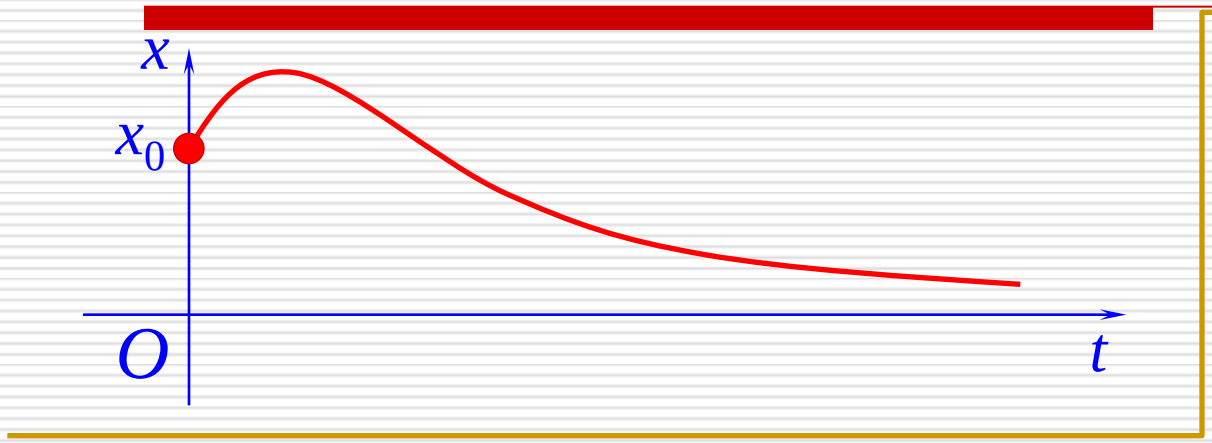
boshlang'ich shartlardan $C_2 = x_0$, $C_1 = \upsilon_0 + n x_0$

$$x = e^{-nt}[x_0 + (\upsilon_0 + n x_0) \cdot t]$$

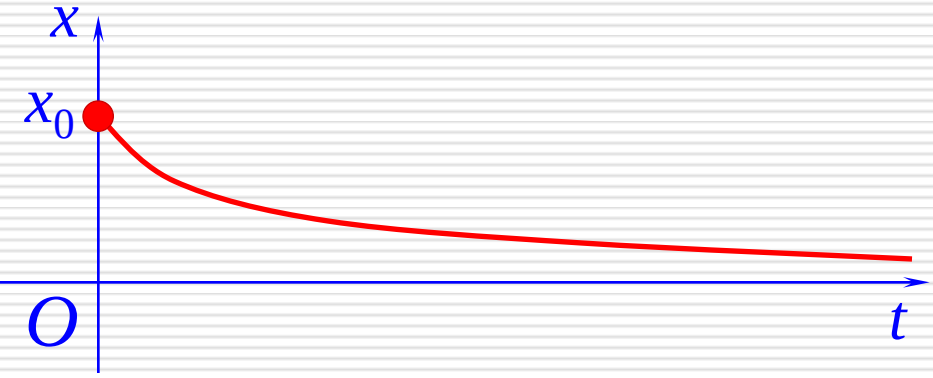
b) muhitning qarshiligi katta bo'lgan hol.

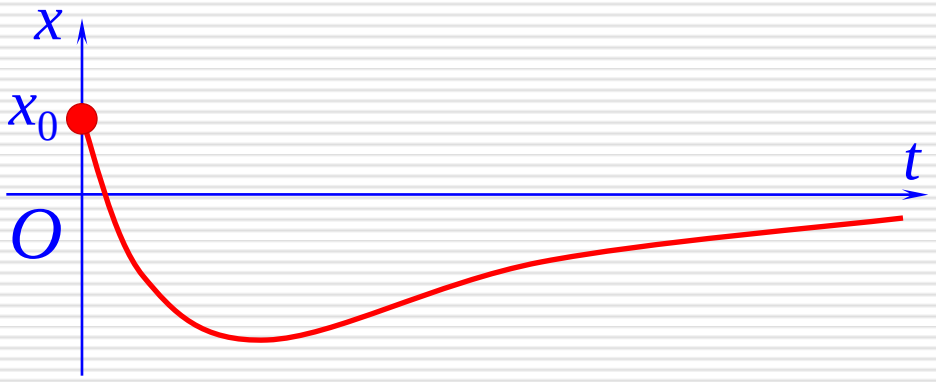
Nuqtaning so'nuvchi tebranma harakat grafigi

a) agar nuqta boshlang'ich vaqtda *Ox* o'qning musbat yo'nalishi bo'yicha yo'nalgan boshlang'ich tezlikka ega bo'lsa



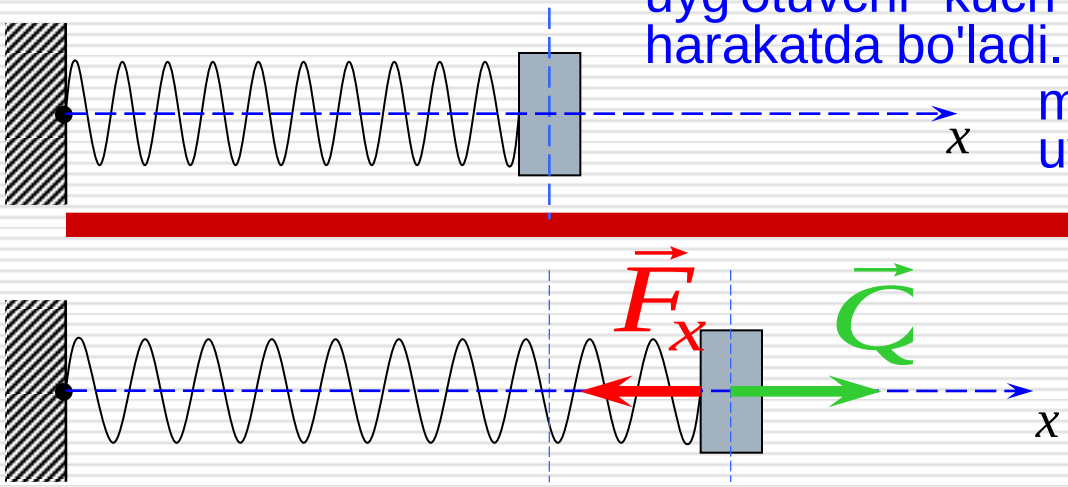
b) agar nuqta boshlang'ich vaqtda *Ox* o'qqa qarama-qarshi yo'nalgan boshlang'ich tezlikka ega bo'lsa





Moddiy nuqtaning majburiy tebranma harakati

Moddiy nuqtaga qaytaruvchi kuchdan tashqari vaqtning davriy funktsiyasidan iborat bo'lgan uyg'otuvchi kuch ham ta'sir etsa, u majburiy harakatda bo'ladi.



moddiy nuqtaga ta'sir etuvchi uyg'otuvchi kuch: $\vec{Q}$ bo'lsa,

harakat differentsial tenglamasi:

$$m\vec{a} = \vec{F}_x + \vec{Q}$$

Qaytaruvchi va uyg'otuvchi kuchlarining *Ox* o'qdagi proektsiyalari:

$$F_x = -cx; \quad Q_x = H\sin(pt+\delta),$$

n – uyg'otuvchi kuchning amplitudasi;
r – uning doiraviy chastotasi;
δ – boshlang'ich faza.

Qaytaruvchi va uyg'otuvchi kuchlar ta'siridagi moddiy nuqtaning harakat differentsial tenglamasi:

$$m\ddot{x} = -cx + H\sin(pt+\delta)$$ yoki

$$\ddot{x} + k^2 x = H_0 \sin(pt+\delta)$$

$$k^2 = c/m \qquad H_0 = H/m$$

Moddiy nuqtaning majburiy tebranma harakati

$$\ddot{x} + k^2 x = H_0 \sin(pt + \delta) \longrightarrow x = x_1 + x_2$$

$m\ddot{x} + k^2 x = 0$ ning umumiy echimi

$\ddot{x} + k^2 x = H_0 \sin(pt + \delta)$ ning xususiy echimi

$$x_1 = a \sin(kt + \alpha)$$

$$x_2 = A \sin(pt + \delta)$$

$$\ddot{x}_2 = -Ap^2 \sin(pt + \delta)$$

$$A(k^2 - p^2)\sin(pt + \delta) = H_0 \sin(pt + \delta)$$

$$A(k^2 - p^2) = H_0 \longrightarrow A = H_0/(k^2 - p^2)$$

$$x_2 = \frac{H_0}{k^2 - p^2}\sin(pt + \delta)$$

$$\ddot{x} + k^2 x = H_0 \sin(pt + \delta)$$

$$x = a \sin(kt + \alpha) + \frac{H_0}{k^2 - p^2}\sin(pt + \delta)$$

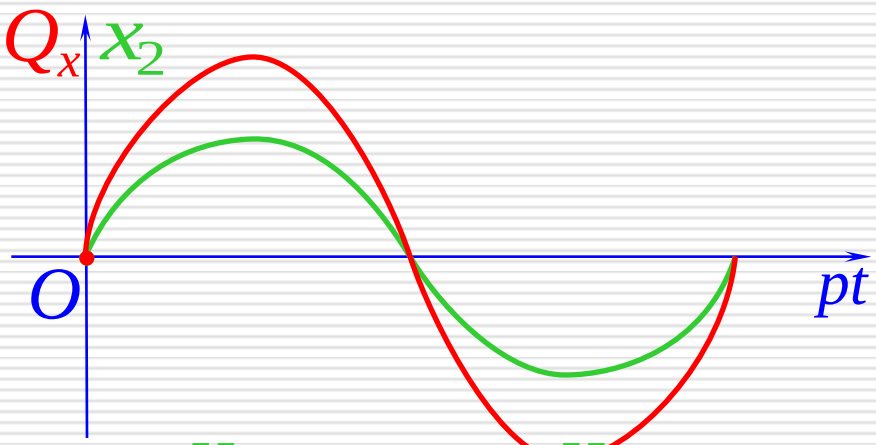
Moddiy nuqtaga bir vaqtning o'zida qaytaruvchi va uyg'otuvchi kuchlar ta'sir etsa, mazkur nuqta ***k*** chastota bilan sodir bo'ladigan *erkin tebranma harakat*, xamda uyg'otuvchi kuch chastotasi ***r*** bilan sodir bo'ladigan *majburiy tebranma harakatlaridan* tashkil topgan murakkab harakatda ishtirok etadi.

Moddiy nuqtaning majburiy tebranma harakati

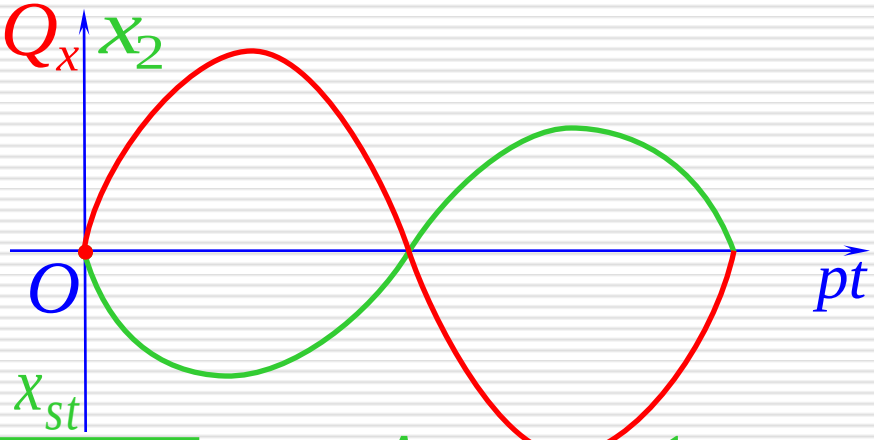
$$x_2 = \frac{H_0}{k^2 - p^2}\sin(pt + \delta)$$ ⟹ Majburiy tebranma harakat nuqta harakatining boshlang'ich shartlariga bog'liq bo'lmaydi.

majburiy tebranma harakat amplitudasi $A_1 = \frac{H_0}{|k^2 - p^2|}$ desak,

$k > p$, $x_2 = A_1 \sin(pt + \delta)$



$k < p$, $x_2 = -A_1 \sin(pt + \delta)$



$$A_1 = \frac{H_0}{|k^2 - p^2|} = \frac{H_0}{k^2|1-(p/k)^2|} = \frac{x_{st}}{|1-(p/k)^2|}$$

$$\eta = \frac{A_1}{x_{st}} = \frac{1}{|1-(p/k)^2|}$$

η – dinamiklik koeffitsienti:

Moddiy nuqtaning majburiy tebranma harakati

$p \approx k$ bo'lganda, $\ddot{x} + k^2 x = H_0 \sin(pt + \delta)$

ning xususiy echimini quyidagicha tanlab olamiz:

$$x_2 = \frac{H_0}{k^2 - p^2}(\sin pt - \sin kt)$$

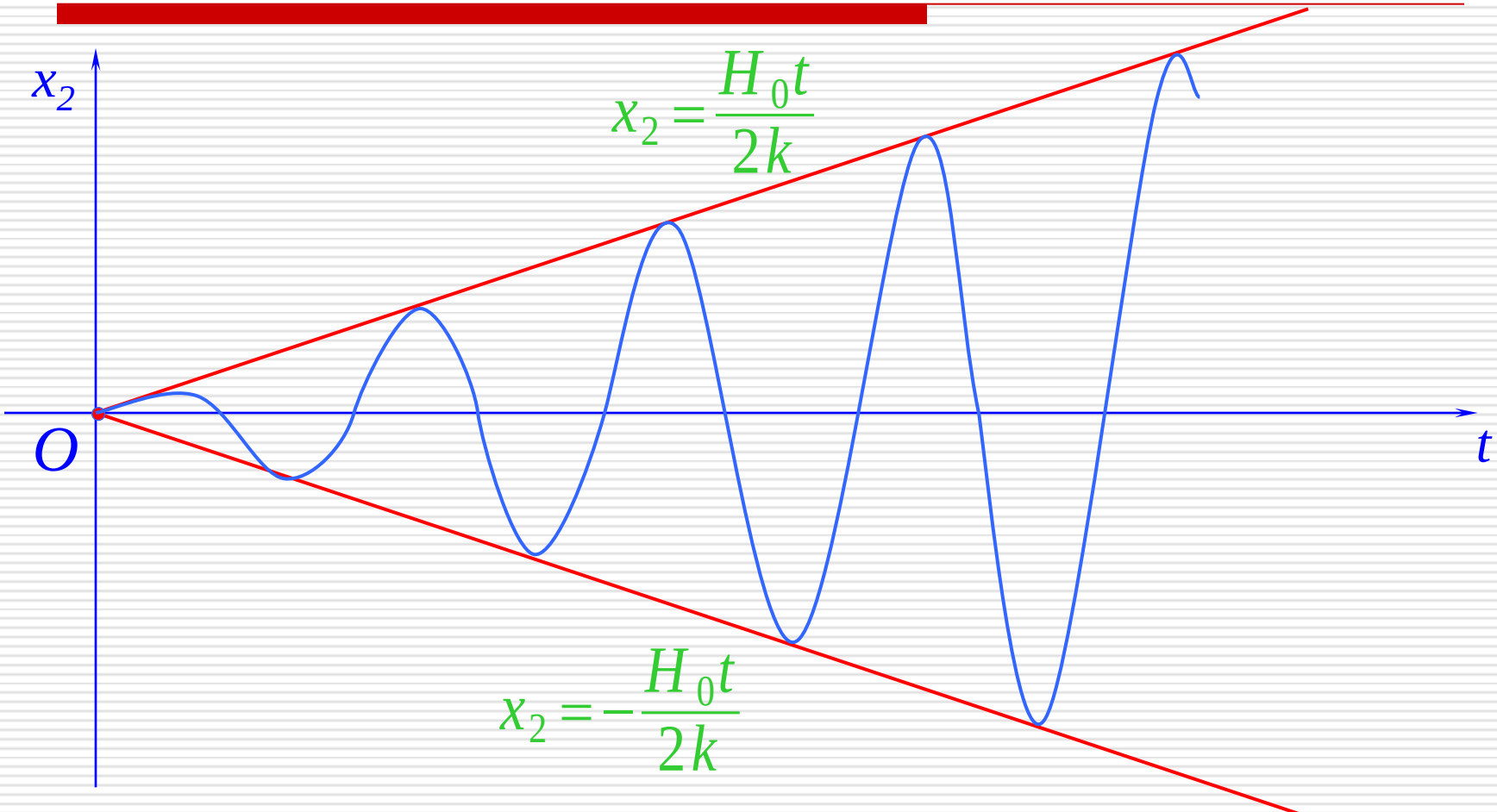
$p = k$ bo'lsa,

$$x_2 = H_0 \left[\frac{\frac{d}{dp}(\sin pt - \sin kt)}{\frac{d}{dp}(k^2 - p^2)} \right]_{p=k} = -\frac{H_0 t}{2k} \cos kt$$

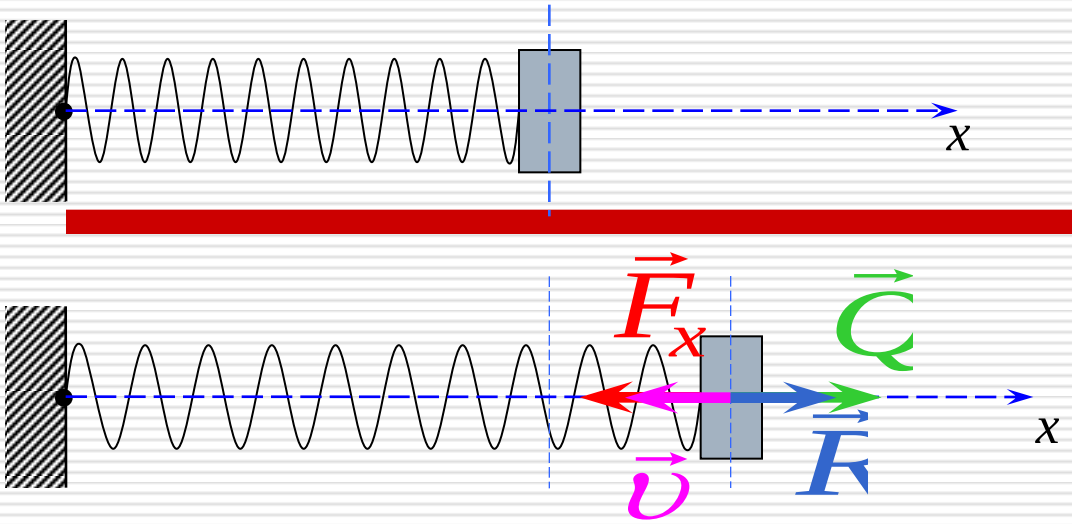
$$\ddot{x} + k^2 x = H_0 \sin(pt + \delta) \Rightarrow x = a \sin(kt + \alpha) + \frac{H_0 t}{2k} \cos kt$$

Moddiy nuqtaning majburiy tebranma harakati

$p = k$ Bo'lganda, x_2 funktsiyaning grafigi vaqtning o'tishi bilan tebranish amplitudasi vaqtning chiziqli funktsiyasi sifatida cheksiz orta boradi. bu xodisaga **rezonans** deyiladi.



Muhit qarshiligi hisobga olingandagi majburiy tebranma harakat



Harakat differentsial tenglamasi:

$$m\,\vec{a} = \vec{F}_x + \vec{Q} + \vec{R}$$

Qaytaruvchi, uyg'otuvchi va qarshilik kuchlarining *Ox* o'qdagi proektsiyalari:

$$F_x = -cx\,; \quad Q_x = H\sin(pt+\delta), \quad R = -\mu\upsilon = -\mu\dot{x}$$

Qaytaruvchi, uyg'otuvchi va qarshilik kuchlari ta'siridagi moddiy nuqtaning harakat differentsial tenglamasi:

$$m\ddot{x} = -cx + H\sin(pt+\delta) - \mu\dot{x} \quad \text{yoki}$$

$$\ddot{x} + 2n\dot{x} + k^2 x = H_0\sin(pt+\delta)$$

$$k^2 = c/m$$
$$2n = \mu/m$$
$$H_0 = H/m$$

Muhit qarshiligi hisobga olingandagi majburiy tebranma harakat

$$\ddot{x} + 2n\dot{x} + k^2 x = H_0 \sin(pt + \delta)$$

$$x = x_1 + x_2$$

$$m\ddot{x} + 2n\dot{x} + k^2 x = 0$$

ning umumiy echimi

$$\ddot{x} + 2n\dot{x} + k^2 x = H_0 \sin(pt + \delta)$$

ning xususiy echimi

$$x_2 = A\sin(pt + \delta - \varepsilon) \rightarrow x_2 = \frac{H_0}{\sqrt{(k^2 - p^2)^2 + 4n^2 p^2}} \sin(pt + \delta - \varepsilon)$$

$n < k$ bo'lsa, $x = e^{-nt}(C_1 \cos k_1 t + C_2 \sin k_1 t) + A\sin(pt + \delta - \varepsilon)$

$$k^2 - n^2 = k_1^2$$

$n > k$ bo'lsa, $x = e^{-nt}(C_1 e^{ht} + C_2 e^{-ht}) + A\sin(pt + \delta - \varepsilon)$

$$n^2 - k^2 = h^2$$

$n = k$ bo'lsa, $x = e^{-nt}(C_1 t + C_2) + A\sin(pt + \delta - \varepsilon)$

INSERT JADVALI

V	+	-	?

Insert jadvali:

- ma'lumotlarni sistemalashtirishni (mustaqil o'qish/ ma'ruza eshitish jarayonida olingan), ularni tasdiklash, aniklashtirish yoki rad etish; qabul qilinayotgan ma'lumotning tushunarliligini 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. Tebranma harakat deb nimaga aytiladi?
2. Qarshilik kuchi bo‘lmagandagi nuqtaning erkin tebranma harakati deb nimaga aytiladi?
3. Qarshilik kuchi bo‘lgandagi nuqtaning erkin tebranma harakati deb nimaga aytiladi?
4. Majburiy tebranish deb nimaga aytiladi?
5. Rezonans deb nimaga aytiladi?
6. Tebranish davri deb nimaga aytiladi?
7. Tebranish chastotasi deb nimaga aytiladi?
8. Tebranish amplitudasi deb nimaga aytiladi?
9. Qachon qarshilik kuchi bo‘lmagandagi erkin tebranma harakat sodir bo’ladi?
10. Qachon qarshilik kuchi bo‘lgandagi erkin tebranma harakat sodir bo’ladi?
11. Qachon qarshilik kuchi bo‘lmagandagi majburiy tebranma harakat sodir bo’ladi?
12. Qachon qarshilik kuchi bo‘lgandagi majburiy tebranma harakat sodir bo’ladi?

E’TIBORLARINGIZ UCHUN RAHMAT!