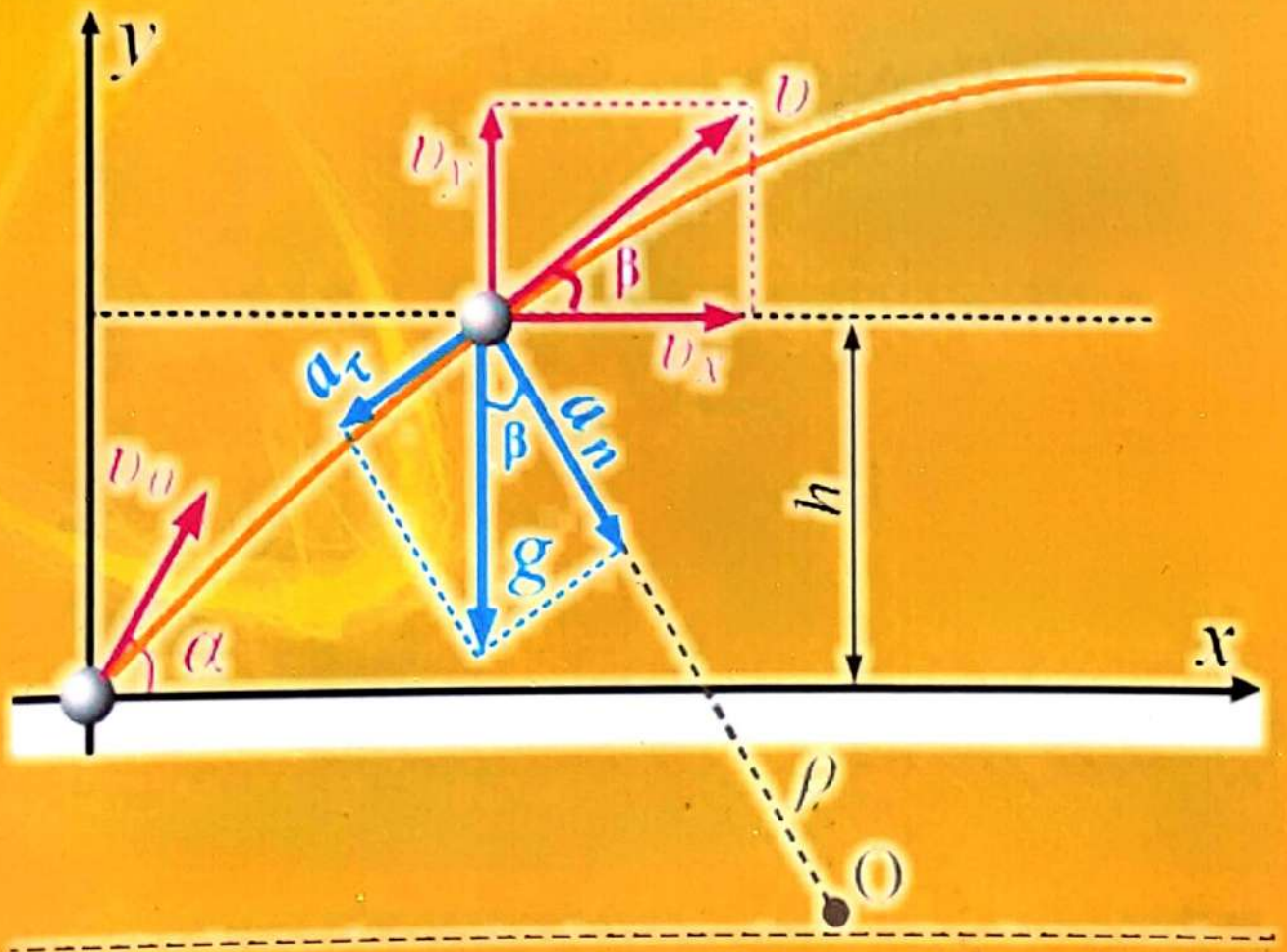
B.X.ESHCHANOV,
M.B.DUSMURATOV, U.R.RUSTAMOV

UMUMIY FIZIKA

(MEXANIKA VA MOLEKULYAR FIZIKADAN MASALALAR YECHISH)



O‘ZBEKISTON RESPUBLIKASI
OLIY VA O‘RTA MAXSUS TA’LIM VAZIRLIGI

TOSHKENT VILOYATI
CHIRCHIQ DAVLAT PEDAGOGIKA INSTITUTI

B.X.Eshchanov, M.B.Dusmuratov, U.R.Rustamov

UMUMIY FIZIKA

(Mexanika va molekulyar fizikadan masalalar yechish)

- *Kinematika*
- *Dinamika*
- *Saqlanish qonunlari*
- *Qattiq jismlar mexanikasi*
- *Noinersial sanoq sistemalaridagi jismlar*
- *Maxsus nisbiylik nazariyasi*
- *Mexanik tebranishlar va to‘lqinlar*
- *Suyuqliklar mexanikasi*
- *Molekulyar kinetik nazariya*
- *Ko‘chki hodisalari*
- *Termodinamika qonunlari, entropiya*
- *Real gazlar, fazaviy o‘tishlar*
- *Moddalarning ichki xossalari*

«ZEBO PRINT»
TOSHKENT – 2023

UDK: 551.51
KBK: 721.33

B.X.Eshchanov, M.B.Dusmuratov, U.R.Rustamov.
UMUMIY FIZIKA (Mexanika va molekulyar fizikadan masalalar yechish). – Toshkent: «ZEBO PRINT» nashriyoti. 2023. – 300 b.

Toshkent viloyati Chirchiq davlat pedagogika instituti, fizika kafedrasi professori, fizika-matematika fanlari doktori, professor K.R.Nasriddinov tahriri ostida

Taqrizchilar:
K.T.Suyarov – TVChDPI fizika kafedrasi dotsenti, pedagogika fanlari bo'yicha falsafa doktori, dotsent
D.A.Begmatova – O'zbekiston Milliy universiteti umumiy fizika kafedrasi mudiri, p.f.d, prof.

O'zbekiston Respublikasi Oliy va o'rta maxsus ta'lim vazirligining 2022-yil 9-sentabrdagi 302-sonli buyrug'i bilan nashrga ruxsat berilgan.

ISBN 978-9943-7478-5-2

1-BO'LIM
MEXANIKA

Nuqta yoki jismning harakati bilan bog‘liq bo‘lgan har qanday tabiat hodisalari va ularning sabablarini o‘rganadigan fizikaning dastlabki qismidir. Mexanika fizikaning boshqa bo‘limlaridan oldin rivojlangan. Mexanika jismlarning harakati va muvozonati haqidagi fandir. Keng ma’noda materiya harakati deb, uning har qanday o‘zgarishi tushuniladi. Lekin, mexanikada harakat deb, uning faqat eng oddiy shakli, ya’ni jismlarning boshqa jismlarga nisbatan ko‘chishi tushuniladi.

Makur o‘rganilayotgan mexanika bo‘limi Isaak Nyutonning klassik mexanikasi hisoblanib, undagi harakatlar yorug‘lik tezligidan ancha kichik bo‘lgan tezliklarda sodir bo‘ladi. Ushbu mexanika yorug‘lik tezligiga yaqin tezliklardagi hodisalar sabablarini tushuntiruvchi “Relyativistik mexanika” ning xususiy holidir. Klassik mexanikada fazoni izotrop va bir jinsli deb, vaqtni esa bir jinsli deb qaraladi. Klassik mexanika qonunlari faqat makroob’ektlar uchun o‘rinli bo‘lib, mikrodunyo hodisa sabablarini tushuntiruvchi “Kvant mexanikasi”dan tubdan farq qiladi.

Biz o‘rganishni maqsad qilgan ushbu qo‘llanmada mexanikani quyidagi qismlarga bo‘lib o‘rganamiz:

- *Kinematika*
- *Dinmika*
- *Saqlanish qonunlari*
- *Jismning noinersial sanoq sistemalaridagi harakati*
- *Qattiq jismlar mexanikasi*
- *Mexanik tebranishlar va to‘lqinlar*
- *Suyuqliklar va gazlar mexanikasi*

1-MAVZU: Asosiy mexanik kattaliklar. Mexanik harakat, trayektoriya, yo'l tushunchalari. Vektorlar ustida amallar

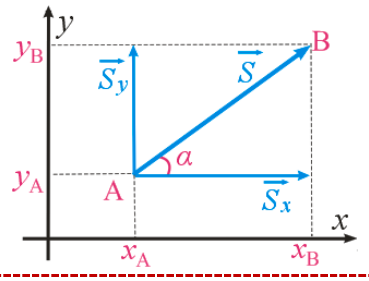
Mavzuga oid muhim formulalar

$1\ km = 10^3\ m = 10^4\ dm = 10^5\ sm = 10^6\ mm = 10^9\ \mu m$ $1\ m = 10^{-3}\ km = 10\ dm = 10^2\ sm = 10^3\ mm = 10^6\ \mu m$ $1\ dm = 10^{-4}\ km = 10^{-1}\ m = 10\ sm = 10^2\ mm = 10^5\ \mu m$ $1\ sm = 10^{-5}\ km = 10^{-2}\ m = 10^{-1}\ dm = 10\ mm = 10^4\ \mu m$ $1\ mm = 10^{-6}\ km = 10^{-3}\ m = 10^{-2}\ dm = 10^{-1}\ sm = 10^3\ \mu m$ $1\ \mu m = 10^{-9}\ km = 10^{-6}\ m = 10^{-5}\ dm = 10^{-4}\ sm = 10^{-3}\ mm$ $1 dyum = 25,4\ mm,\ 1\ fut = 12\ dyum = 30,48\ sm$ $1\ milya = 5280\ fut = 1609,3\ m$	*Uzunlik o'lchovlari*
$1\ km^2 = 10^6\ m^2 = 10^8\ dm^2 = 10^{10}\ sm^2 = 10^{12}\ mm^2 = 10^{18}\ \mu m^2$ $1\ m^2 = 10^{-6}\ km^2 = 10^2\ dm^2 = 10^4\ sm^2 = 10^6\ mm^2 = 10^{12}\ \mu m^2$ $1\ dm^2 = 10^{-8}\ km^2 = 10^{-2}\ m^2 = 10^2\ sm^2 = 10^4\ mm^2 = 10^{10}\ \mu m^2$ $1\ sm^2 = 10^{-10}\ km^2 = 10^{-4}\ m^2 = 10^{-2}\ dm^2 = 10^2\ mm^2 = 10^8\ \mu m^2$ $1\ mm^2 = 10^{-12}\ km^2 = 10^{-6}\ m^2 = 10^{-4}\ dm^2 = 10^{-2}\ sm^2 = 10^6\ \mu m^2$ $1\ \mu m^2 = 10^{-18}\ km^2 = 10^{-12}\ m^2 = 10^{-10}\ dm^2 = 10^{-8}\ sm^2 = 10^{-6}\ mm^2$	*Yuza o'lchovlari*
$1\ km^3 = 10^9\ m^3 = 10^{12}\ dm^3 = 10^{15}\ sm^3 = 10^{18}\ mm^3 = 10^{27}\ \mu m^3$ $1\ m^3 = 10^{-9}\ km^3 = 10^3\ dm^3 = 10^6\ sm^3 = 10^9\ mm^3 = 10^{18}\ \mu m^3$ $1\ dm^3 = 10^{-12}\ km^3 = 10^{-3}\ m^3 = 10^3\ sm^3 = 10^6\ mm^3 = 10^{15}\ \mu m^3$ $1\ sm^3 = 10^{-15}\ km^3 = 10^{-6}\ m^3 = 10^{-3}\ dm^3 = 10^3\ mm^3 = 10^{12}\ \mu m^3$ $1\ mm^3 = 10^{-18}\ km^3 = 10^{-9}\ m^3 = 10^{-6}\ dm^3 = 10^{-3}\ sm^3 = 10^9\ \mu m^3$ $1\ \mu m^3 = 10^{-27}\ km^3 = 10^{-18}\ m^3 = 10^{-15}\ dm^3 = 10^{-12}\ sm^3 = 10^{-9}\ mm^3$	*Hajm o'lchovlari*
$1\ t = 10\ st = 10^3\ kg = 10^6\ g = 10^9\ mg = 10^{12}\ \mu g$ $1\ st = 10^{-1}\ t = 10^2\ kg = 10^5\ g = 10^8\ mg = 10^{11}\ \mu g$ $1\ kg = 10^3\ t = 10^2\ st = 10^3\ g = 10^6\ mg = 10^9\ \mu g$ $1\ g = 10^{-6}\ t = 10^{-5}\ st = 10^{-3}\ kg = 10^3\ mg = 10^6\ \mu g$ $1 mg = 10^{-9}\ t = 10^{-8}\ st = 10^{-6} kg = 10^{-3}\ g = 10^3\ \mu g$ $1\ \mu g = 10^{-12} t = 10^{-11}\ st = 10^{-9}\ kg = 10^{-6}\ g = 10^{-3}\ mg$	*Massa o'lchovlari*
$1 sutka = 24\ soat = 1440\ \min = 86400\ s$ $1 soat = 60\ \min = 3600\ s$ $1 \min = 60\ s$	*Vaqt o'lchovlari*
$\vec{c} = \vec{a} + \vec{b}\ ,\quad \lvert\vec{c}\rvert = \sqrt{\lvert\vec{a}\rvert^2 + \lvert\vec{b}\rvert^2 + 2\lvert\vec{a}\rvert\lvert\vec{b}\rvert\cos\gamma}$	*Ikki vektorning yig'indisi*
$\vec{c} = \vec{a} - \vec{b}\ ,\quad \lvert\vec{c}\rvert = \sqrt{\lvert\vec{a}\rvert^2 + \lvert\vec{b}\rvert^2 - 2\lvert\vec{a}\rvert\lvert\vec{b}\rvert\cos\gamma}$	*Ikki vektorning ayirmasi*

$\vec{a} = a_x \cdot \vec{i} + a_y \cdot \vec{j} + a_z \cdot \vec{k}$, $\quad |a|^2 = a_x^2 + a_y^2 + a_z^2$	*Vektor va uning moduli koordinatalari orqali*

Ko'chish

$$\begin{cases} \vec{S} = A\vec{B} \\ S_x = x_B - x_A \\ S_y = y_B - y_A \end{cases} \qquad \begin{cases} |\vec{S}| = \sqrt{S_x^2 + S_y^2} \\ S_x = S \cdot \cos\alpha \\ S_y = S \cdot \sin\alpha \end{cases}$$



1-Amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Velosipedchi to'g'ri yo'l bo'ylab g'arbga tomon *7 km* yurdi, so'ngra qaytib sharqqa tomon yana *3 km* yo'l yurdi. Velosipedchining yurgan yo'li *L (km)* va ko'chish moduli *S (km)* nimaga teng?

Berilgan:
S_1=7 km
S_2=3 km
L=? S=?

Yechilishi:

Bundan keyingi shunga o'xshash masalalarni tasavvur qilish qiyin bo'lmasligi uchun dunyo tomonlariga belgilash kiritamiz.

$$|\vec{S}| = S_1 - S_2 = 7 - 3 = 4\ km$$

$$L = S_1 + S_2 = 7 + 3 = 10\ km$$

Javob: A) L=10 km; S=4 km

Masala № 2. Jism *Oxy* koordinata tckisligida $x = -3 + 2t$ (m), $y = 6 - 4t$ (m) tenglamalarga muvofiq harakatlanmoqda. Jism *Ox* o'qini koordinata boshidan qanday masofada (m) kesib o'tadi?

Berilgan:
$x = -3 + 2t$
$y = 6 - 4t$
x=?

Yechilishi:

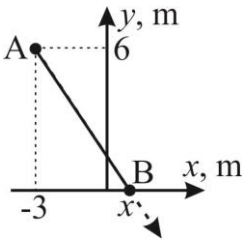
Dastlab jism A nuqtada edi. Biror vaqtdan so'ng u *Ox* o'qini koordinata boshidan *x* masofada joylashgan B nuqtada kesib o'tsin. Kesishish nuqtasida $y = 0$ bo'ladi.

$$6 - 4t = 0$$

$$t = 1{,}5\ s$$

$$x = -3 + 2 \cdot 1{,}5 = 0$$

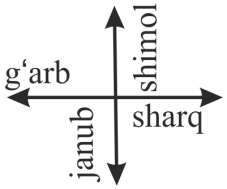
Demak, koordinata boshida kesib o'tadi, *x* = 0

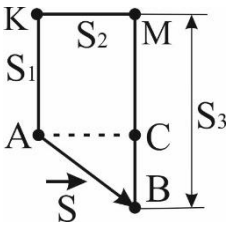


Javob: *x= 0*

Masala № 3. Sportchi shimol tomon harakatianib *5 km* masofani bosib o'tgach, sharq tomonga burilib *4 km* yurdi. So'ngra janub tomonga burilib yana *8 km* masofani o'tdi. Sportchining o'tgan yo'lini (*km*) va ko'chish modulini (*km*) toping.

Berilgan:	*Yechilishi:*
S_1=5 km=5000 m S_2=4 km=4000 m S_3=8 km=8000 m L=? S=?	Dunyo tomonlarini rasmda ko‘rsatilgandek belgilab chizma chizamiz. Bunda yo‘l quyidagicha topiladi:





$L=S_1+S_2+S_3=5+4+8=17$ km.

Ko‘chish esa *AB* oraliqdagi S masofaga teng. *AC* oraliq S_2 ga teng bo‘lsa, *BC* oraliq $(S_3 - S_1)$ ga teng. Demak S ni Pifogor teoremasiga asosan quyidagicha topamiz:

$$S = \sqrt{S_2^2 + (S_3 - S_1)^2} = \sqrt{4^2 + (8-5)^2} = 5 \text{ m}.$$

Javob: 17; 5.

Masala № 4. Qo‘l soati sekund milining uzunligi *1 sm* ga teng. Bir soat davomida sekund mili uchidagi nuqtaning o‘tgan yo‘li qanchaga (m) teng bo‘ladi?

Berilgan:	*Yechilishi:*
R=1 sm =0,01 m *t=1 soat =3600 s* *S=?*	Sekund milining uzunligi u chizayotgan aylananing radiusini ifodalaydi. Endi sekund mili *1 soat* davomida necha marta aylanishini topishimiz kerak bo‘ladi. Bizga ma’lumki sekund

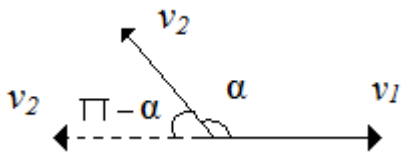
mili 1 minutda bir marta to‘liq aylanadi va bunda $l=2\pi R$ masofani bosib o‘tadi. *1 soat*da *60 minut* bor. Demak sekund mili 1 soat davomida to‘liq 60 marta aylanadi va uning bosib o‘tgan yo‘li

$S=60\cdot l=60\cdot 2\pi R=120\pi R$ $\quad S=120\cdot\pi\cdot 0{,}01=1{,}2\pi$ m

Javob: $1{,}2\cdot\pi$

Masala № 5. Tezliklarining modullari bir xil *72 km/soat* ga teng bo‘lgan ikki jismning harakat yo‘nalishlari orasidagi burchak *120°* ga teng. Ikkinchi jismning birinchi jismga nisbatan tezligining modulini toping (*m/s*).

Berilgan:	*Yechilishi:*
$\alpha = 120^\circ$ $v_1=v_2=v$=20 m/s v=?	1-jismni tinch deb olib, tezlikni ikkinchi jismga beramiz. Endi tezliklarni qo‘shamiz:



$$v = \sqrt{v^2 + v^2 + 2\cdot v\cdot v\cdot\cos\alpha}$$

$$v = \sqrt{2v^2 + 2v^2 cos\alpha} = \sqrt{2\cdot 400 + 2\cdot 400\cdot\frac{1}{2}} = 20\sqrt{3}\, m/s.$$

Javob: $20\sqrt{3}$ m/s

1-Amaliy mashg‘ulot topshirig‘i

1.1. Yer kurrasini $6,37\cdot10^6\,m$ radiusli sharga qiyoslash mumkin. Yerning radiusi va aylana uzunligi necha kilomerga teng. **Javob:** *6370 km; 40 000 km.*

1.2. Uzunlik o‘chov birligi mikrometr (μm) ni ba’zan *mikron* deb ham ataladi. Necha mikron *1 km* ni tashkil etadi. *1 sm* ning qanday qismi *1 mikron*ni tashkil etadi. **Javob:** $1km=10^9\,\mu m;\ 1\mu m=10^{-4}\,sm$

1.3. Antarktida muzligi taxminan *2000 km* radiusli yarim doira shaklida bo‘lib, uning o‘rtacha qalinligi 3000 m ni tashkil etadi. Antarktida muzligi qirg‘oq uzunligini *km* va *m* larda ifodalang. Uning hajmini km^3, m^3, sm^3 larda ifodalang.

Javob: $L=10\,280\,km=10\,280\,000\,m;\ V=1,844\cdot10^7\,km^3=1,844\cdot10^{16}\,m^3=1,844\cdot10^{22}\,sm^3$

1.4. Agar inson organizmidagi xujayralar hajmi 10^4-10^6 kub mikronga teng bo‘lsa, uning chiziqli o‘lchami necha mikron oralig‘ida bo‘ladi? *1* sm^3 hajmda nechta xujayra bo‘lishi mumkin? **Javob:** $\ell=21,5-100\ \mu m;\ N=10^6-10^8\,ta$

1.5. Surxondaryo viloyati Afg‘oniston Islom Respublikasi bilan *137 km* lik umumiy chegaraga ega. Bu uzunlikni *m* va *sm* larda ifodalang. **Javob:** $1,37\cdot10^5\,m;\ 1,37\cdot10^7\,sm$

1.6. AQSh dagi Ozodlik haykalining balandligi *305 fut*. Agar *1 fut* uzunlik *304,8 mm* ga teng bo‘lsa, haykalning balandligi necha metrga teng? *1245 fut* balandlikdagi “Empire State building” binosining balandligi necha metr? *375 m* balandlikdagi “Toshkent teleminorasi” ning balandligi necha futga teng? **Javob:** *92,964 m; 379,476 m; 1230,3 fut*.

1.7. Samarqand viloyatining umumiy yer maydoni $16800\,km^2$ ni tashkil etadi. Buni m^2 va sm^2 larda ifodalang. **Javob:** $1,68\cdot10^{10}\,m^2;\ 1,68\cdot10^{14}\,sm^2$

1.8. *1 litr* hajm *1000* sm^3 ga teng ekanligini bilgan holda $1m^3$ hajm necha litr va necha sm^3 ga teng ekanligini hisoblang. **Javob:** $1m^3=1000l;\ 1m^3=10^6\,sm^3$

1.9. Inson DNK molekulasining ko‘ndalang diametri *d=20* $\overset{0}{A}$ (Anstrem) atrofida. Agar $1\overset{0}{A}=10^{-10}\,m$ ga teng bo‘lsa, DNK o‘lchamini $nm, \mu m, mm$ va *sm* larda ifodalang. **Javob:** $2\,nm;\ 2\cdot10^{-3}\,\mu m;\ 2\cdot10^{-6}\,mm;\ 2\cdot10^{-7}\,sm$

1.10. Yer sutka davomiyligini minut va sekundlarda ifodalang. J: *1440 min*; *86400 s*.

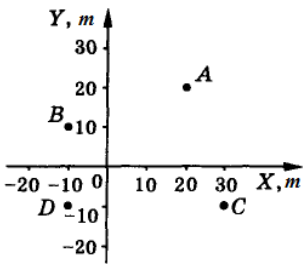
1.11. Yil uzunligini 365,25 sutka deb hisoblab, uni soat, minut va sekundlarda ifodalang. **Javob:** *8 766 soat*; *525 960 min*; *31 557 600 s*

1.12. Inson yuragi – a’lo darajadagi dvigateldir. U o‘rta hisobda minutiga 72 marta uradi. 70 yillik umri davomida inson yuragi necha marta uradi? J: $2,649\cdot10^9$ marta uradi.

1.13. Havo shari qandaydir balandlikka vertikal ko‘tarilgach, shamol uni gorizontal yo‘nalishda 1*200 m* masofaga uchirib ketdi. Agar havo sharining ko‘chishi 2 *km* bo‘lsa, havo sharining o‘tgan yo‘lini aniqlang. **Javob:** *2800 m*

1.14. Jism radiusi *5 m* bo‘lgan aylana trayektoriya bo‘ylab o‘zgarmas *6 m/s* tezlik bilan harakatlanmoqta. Jismning o‘tgan yo‘li *628 m* ga teng bo‘lishi uchun u aylanani necha marta o‘tishi kerak ? **Javob:** *20*

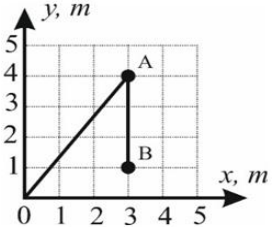
1.15. Jism rasmda ko‘rsatilgan nuqtalardan *A* nuqtadan *B* nuqtaga, *B* nuqtadan *D* nuqtaga va *D* nuqtadan *C* nuqtaga to‘g‘ri chiziq bo‘yicha ko‘chdi. Bunda har bir qism uchun ko‘chish vektorining koordinatalari S_x va S_y ni hamda ko‘chish moduli *S* ni aniqlang.



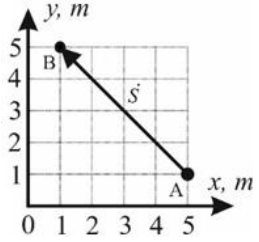
1.16. Jism koordinatlari *(4; 2) (m)* bo‘lgan nuqtadan koordinatlari *(0; –1) (m)* nuqtaga ko‘chgan bo‘lsa, jism ko‘chishining moduiini toping (m). **Javob:** *S=5 m*

1.17. Jism *Oxy* koordinata tekisligida $x = 3 + 2t$ (m), $y = 6 - 3t$ *(m)* tenglamalarga muvofiq harakatlanmoqda. Jism *Ox* o‘qini koordinata boshidan qanday masofada (m) kesib o‘tadi? **Javob:** *7 m*

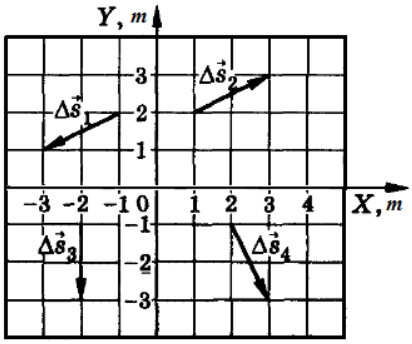
1.18. Jism *Oxy* koordinata tekisligida (rasmga qarang) O nuqtadan *B* nuqtaga *OAB* trayektoriya bo‘yicha ko‘chdi. Jismning bosib o‘tgan yo‘li *L* va natijaviy ko‘chishining moduli *S* ni toping. **Javob:** $L = 8\,m;\ S = \sqrt{10}\,m$



1.19. Jism *Oxy* koordinata tekisligida *A* nuqtadan *B* nuqtaga ko‘chdi. Jism ko‘chishining *Ox* va *Oy* o‘qlaridagi proeksiyalarini toping. **Javob:** $S_x = -4\ m;\ S_y = 4\ m$



1.20. Rasmda to‘rtta nuqtaning ko‘chishi tasvirlangan. Har bir nuqtaning boshlang‘ich va oxirgi holatini, ko‘chishnig korrdinata o‘qlariga proyeksiyasini hamda ko‘chish modulini aniqlang. **Javob:** *1-nuqta uchun* $(-1;2);(-3;1);S_x = -2;S_y = -1;S = \sqrt{5}$; *2-nuqta uchun* $(1;2);(3;3);S_x = 2;S_y = 1;S = \sqrt{5}$; *3-nuqta uchun* $(-2;-1);(-2;-3);S_x = 0;S_y = -2;S = 2$; *4-nuqta uchun* $(2;-1);(3;-3);S_x = 1;S_y = -2;S = \sqrt{5}$



1.21. Moddiy nuqta to‘g‘ri yo‘l bo‘ylab harakatlanib *1 m* masofani bosib o‘tdi, so‘ngra harakat yo‘nalishini 30° ga o‘zgartirib, yana to‘g‘ri chiziqli trayektoriya bo‘ylab *2 m* masofani o‘tdi. Moddiy nuqtaning natijaviy ko‘chishining modulini toping. **Javob:** *2,91m*

1.22. Moddiy nuqta to‘g‘ri yo‘l bo‘ylab harakatlanib *2 m* masofani bosib o‘tdi, so‘ngra harakat yo‘nalishini *120°* ga o‘zgartirib, yana to‘g‘ri chiziqli trayektoriya bo‘ylab *1 m* masofani o‘tdi. Moddiy nuqtaning natijaviy ko‘chishining modulini toping. **Javob:** *1,73 m*

2-Mavzu: To‘g‘ri chiziqli tekis harakat. O’rtacha va oniy tezlik. Harakatning nisbiyligi. Tezliklarni qo‘shish.

Mavzuga oid muhim formulalar

$\vec{\vartheta}_{o'rt}=\frac{\Delta\vec{r}}{\Delta t}, \qquad \vec{\vartheta}=\lim\limits_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t}=\frac{d\vec{r}}{dt}=\dot{\vec{r}}$	*O‘rtacha va oniy tezlikning vektor usulda berilishi*
$\vec{\vartheta}=\frac{dx}{dt}\vec{i}+\frac{dy}{dt}\vec{j}+\frac{dz}{dt}\vec{k}$ $\vartheta_x=\frac{dx}{dt}=\dot{x}, \quad \vartheta_y=\frac{dy}{dt}=\dot{y}, \quad \vartheta_z=\frac{dz}{dt}=\dot{z}$	*Tezlikning koordinata usulda berilishi*
$\vartheta=\sqrt{\vartheta_x^2+\vartheta_y^2+\vartheta_z^2}=\sqrt{\dot{x}^2+\dot{y}^2+\dot{z}^2}$ $\cos\left(\vec{\vartheta}\wedge\vec{i}\right)=\frac{\vartheta_x}{\vartheta}, \quad \cos\left(\vec{\vartheta}\wedge\vec{j}\right)=\frac{\vartheta_y}{\vartheta}, \quad \cos\left(\vec{\vartheta}\wedge\vec{k}\right)=\frac{\vartheta_z}{\vartheta}$	*Tezlikning miqdor va yo‘nalishini aniqlash*
$x=x_0+\vartheta_x t, \qquad y=y_0+\vartheta_y t$	*Oxy tekisligida to‘g‘ri chiziqli tekis harakat tenglamasi*
$\vec{\vartheta}_{1.2}=\vec{\vartheta}_1-\vec{\vartheta}_2$ $\vartheta_{1.2}=\sqrt{\vartheta_1^2+\vartheta_2^2-2\vartheta_1\vartheta_2\cos\gamma}$	*Bir jismning ikkinchi jismga nisbatan nisbiy tezligining miqdor va yo‘nalishini aniqlash*
$\vec{\vartheta}_{na}=\vec{\vartheta}_1+\vec{\vartheta}_2$ $\vartheta_{1.2}=\sqrt{\vartheta_1^2+\vartheta_2^2+2\vartheta_1\vartheta_2\cos\gamma}$	*Tezliklarni qo‘shish – natijaviy tezlikning miqdor va yo‘nalishini aniqlash*
$\vartheta_{o'rt}=\frac{s_{um}}{t_{um}}, \qquad \vartheta_{oniy}=\lim\limits_{\Delta t\to 0}\frac{\Delta s}{\Delta t}=\frac{ds}{dt}=\dot{s}$	*O‘rtacha va oniy tezlik formulalari*

2-Amaliy mashg‘ulot uchun dars ishlanmasi

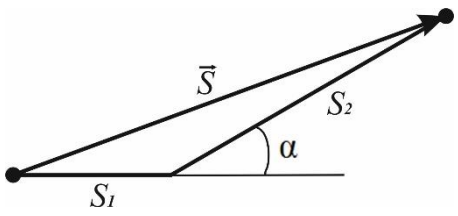
Masala № 1. Moddiy nuqta to‘g‘ri yo‘l bo‘ylab harakatlanib *1 m* masofani bosib o‘tdi, so‘ngra harakat yo‘nalishini *30°* ga o‘zgartirib, yana to‘g‘ri chiziqli traektoriya bo‘ylab *2 m* masofani o‘tdi. Moddiy nuqtaning natijaviy ko‘chishining modulini (*m*) toping.

Berilgan:
S_1=1 m
α=30°
S_2=2 m
S=?

Yechilishi: Masalani ishlashda kosinuslar teoremasidan foydalanamiz. $S=\sqrt{S_1^2+S_1^2+2S_1S_2\cos(180^o-\alpha)}$

$$S=\sqrt{1+4+2\cdot 1\cdot 2\cdot\frac{\sqrt{3}}{2}}=$$

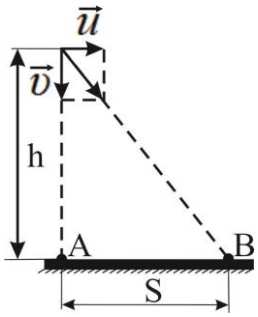
$$=\sqrt{5+2\sqrt{3}}=2{,}91\ m$$



Javob: S= 2,91

Masala № 2. Parashyutchi shamol bo‘lmaganda *5 m/s* tezlik bilan erga vertikal yo‘nalishda tushadi. Lekin esayotgan shamol uning mo‘ljalidan *160 m* farq qiluvchi masofaga tushirdi. Agar parashyutchi *200 m* balandlikdan sakragan bo‘lsa, u gorizontal yo‘nalishda qanday tezlik (*m/s*) bilan harakatlangan bo‘ladi?

Berilgan:	*Yechilishi:*
S=160 m	Parashutchi aslida A nuqtaga tushishi kerak edi.
h=200 m	Lekin esayotgan shamol tufayli u B nuqtaga
υ=5 m/s	tushadi. U vertikal yo‘nalishda υ tezlik bilan h
u=?	masofani, gorizontal yo‘nalishda esa *u* tezlik bilan
	S masofani bir xil vaqtda bosib o‘tadi.



$$h = \upsilon t; \quad S = ut$$

$$\frac{S}{h} = \frac{u}{\upsilon} \quad \Rightarrow \quad u = \frac{S}{h} \cdot \upsilon.$$

$$u = \frac{160}{200} \cdot 5 = 4\ m/s.$$

Javob: *u=4 m/s*.

Masala № 3. Daryodagi qayiqning oqim bo‘ylab va oqimga qarshi tezliklarining o‘rtacha qiymati *3 km/soat*, harakat vaqtlari esa bir-biridan ikki marta farq qiladi. Qayiqning turg‘un suvdagi tezligi necha km/soat ga teng?

Berilgan:	*Yechilishi:* υ_0 – daryo oqimining tezligi;
$\upsilon_{o'rt}$=3km/soat	υ – qayiqning turg‘un suvdagi tezligi;
$t_1=2t_2$	Qayiqning manzilga borishdagi tezligi: $\upsilon_1 = \upsilon - \upsilon_0$
υ=?	Qayiqning manzildan qaytishdagi tezligi: $\upsilon_2 = \upsilon + \upsilon_0$

Qayiq manzilga borishda S_1 masofani, qaytishda esa S_2 masofani bosib o‘tgan va bu masofalar bir biriga teng.

Qayiq bosib o‘tgan umumiy masofa: $S = S_1 + S_2$

Shu masofani bosib o‘tish uchun ketgan umumiy vaqt: $t = t_1 + t_2$

$$\begin{cases} S_1 = \upsilon_1 t_1 = (\upsilon - \upsilon_0)t_1 \\ S_2 = \upsilon_2 t_2 = (\upsilon + \upsilon_0)t_2 \end{cases}$$

O‘rtacha tezlik jism bosib o‘tgan umumiy masofani shu masofani bosib o‘tish uchun ketgan umumiy vaqtga nisbati bilan topiladi.

$$\upsilon_{o'rt} = \frac{S_{um}}{t_{um}} = \frac{S_1+S_2}{t_1+t_2} = \frac{(\upsilon-\upsilon_0)t_1+(\upsilon+\upsilon_0)t_2}{2t_2+t_2} = \frac{(\upsilon-\upsilon_0)2t_2+(\upsilon+\upsilon_0)t_2}{3t_2}$$

$$\upsilon_{o'rt} = \frac{3\upsilon-\upsilon_0}{3}$$

Ushbu ifodani yodda saqlaymiz.

$S_1=S_2$ ekanidan foydalanamiz. $(\upsilon - \upsilon_0)t_1 = (\upsilon + \upsilon_0)t_2$

$$(\upsilon - \upsilon_0)2t_2 = (\upsilon + \upsilon_0)t_2 \quad \Longrightarrow \quad \upsilon_0 = \frac{\upsilon}{3}$$

$v_0 = \frac{v}{3}$ ekanini bilgan holda $v_{o'rt} = \frac{3v - v_0}{3}$ ifodani quyidagicha yozamiz:

$v_{o'rt} = \frac{3v - \frac{v}{3}}{3} = \frac{8v}{9} \quad \Rightarrow \quad v = \frac{9}{8} v_{o'rt} \quad \Rightarrow v = \frac{9}{8} \cdot 3 = \frac{27}{8}\ km/soat.$

Javob: v =27/8 $km/soat$.

Masala № 4. Moddiy nuqta yo'lning *1/6* qismida *4 m/s* teslik bilan qolgan qismida *10 m/s* tezkik bilan harakatlandi. Uning harakat vaqti davomidagi o'rtacha tezligini toping (*m/s*).

Berilgan:

$S_1 = S/6$

$v_1 = 4$ m/s

$S_2 = 5S/6$

$v_2 = 10$ m/s

$v_{o'rt} = ?$

Yechilishi:

O'rtacha tezlik jism bosib o'tgan umumiy masofani shu masofani bosib o'tish uchun ketgan umumiy vaqtga nisbati bilan topiladi:

$$v_{o'rt} = \frac{S_{um}}{t_{um}}$$

Jism bosib o'tgan umumiy masofa:

$$S_{um} = S_1 + S_2 = \frac{S}{6} + \frac{5S}{6} = S$$

Shu masofani bosib o'tish uchun ketgan umumiy vaqt:

$t_{um} = t_1 + t_2 = \frac{S_1}{v_1} + \frac{S_2}{v_2} = \frac{S}{6v_1} + \frac{5S}{6v_2}$; $\quad v_{o'rt} = \frac{S_{um}}{t_{um}} = \frac{S}{\frac{S}{6v_1} + \frac{5S}{6v_2}} = \frac{6v_1 v_2}{v_2 + 5v_1}$

Demak, jism yo'lning beshdandan bir qismini v_1 qolgan qismini v_2 tezlik bilan bosib o'tsa, jismning o'rtacha tezligi quyidagicha topilarkan:

$v_{o'rt} = \frac{6v_1 v_2}{v_2 + 5v_1}$; $\quad v_{o'rt} = \frac{6 \cdot 4 \cdot 10}{10 + 5 \cdot 4} = 8\ m/s.$

Javob: $v_{o'rt} = 8\ m/s.$

Masala № 5. Jismning tezligi $\vartheta = 6 + 6t - t^2$ qonuniyat bilan o'zgaradi. Bu yerda t sekundlarda, ϑ esa sm/s larda ifodalanadi. Jismning tezligi $t_1 = 2s$ va $t_2 = 5s$ vaqt onlaridagi oniy tezliklarni toping. Bu vaqt oralig'ida tezlik o'zgarishi nimaga teng?

Berilgan:

$\vartheta = 6 + 6t - t^2$

$t_1 = 2$ s

$t_2 = 5$ s

$v_1 = ?$, $v_2 = ?$, $\Delta v = ?$

Yechilishi:

Oniy vaqtlarni tezlik formulasiga qo'yamiz.

$\vartheta_1 = \vartheta(t_1) = 6 + 6 \cdot 2 - 2^2 = 14\ sm/s$

$\vartheta_2 = \vartheta(t_2) = 6 + 6 \cdot 5 - 5^2 = 11\ sm/s$

$\Delta\vartheta = \vartheta_2 - \vartheta_1 = -3\ sm/s$

Javob: $\vartheta_1 = 14\ sm/s;\ \vartheta_2 = 11\ sm/s;\ \Delta\vartheta = -3\ sm/s$

2-Amaliy mashg‘ulot topshirig‘i

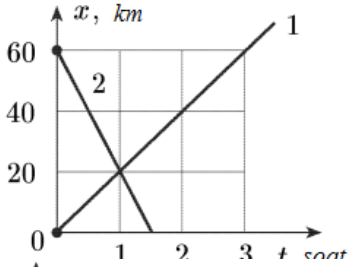
2.1. Reaktiv samolyot Toshkentdan Moskvagacha bo‘lgan *3850 km* masofani *4 soat*da bosib o‘tgan bo‘lsa, u Yerdan Oygacha qancha vaqtda yetib boradi? Oy va Yer orasidagi masofa *385000 km* ga teng. **Javob:** *16 sutkayu 16 soat*

2.2. Yashin chaqnashini ko‘rgandan *5 s* vaqt o‘tgach kuzatuvchi momaqaldiroq ovozini eshitdi. Agar tovushning havoda tarqalish tezligi *340 m/s* ga teng bo‘lsa, chaqmoqqacha masofa necha km ga teng? **Javob:** *1,7 km.*

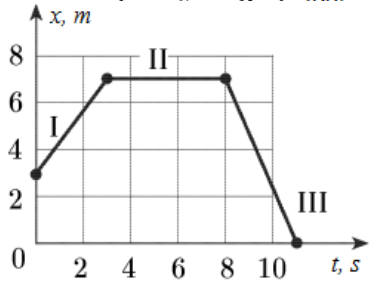
2.3. Oy va Yer orasidagi masofa *384000 km* ga teng. Agar kosmik kemaning Oyga yetib borishiga 3 kun ketsa uning tezligi qanday? **Javob:** *5333,3 km/soat* yoki *1481 m/s*

2.4. Qattiq kiprik qoqish *0,5 s* gacha bo‘lishi mumkin. *90 km/soat* tezlikda ketayotgan haydovchi shunday kiprik qoqqanda qancha masofa bosib o‘tadi? **Javob:** *12,5 m*

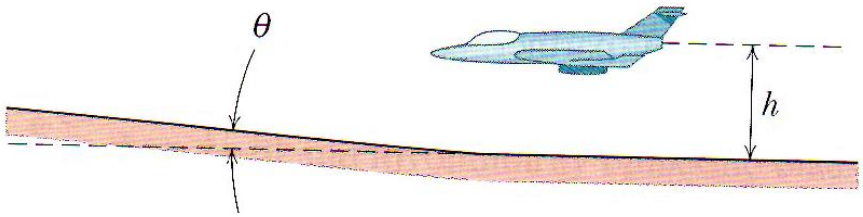
2.5. Chizmadagi grafiklar uchun tezlikning miqdori va yo‘nalishlari nimaga teng? Grafiklar uchun harakat tenglamalarini yozing. Grafiklar kesishgan nuqta nimani anglatadi? **Javob:** $\vartheta_1 = 20\ km/soat;\ \vartheta_2 = -40\ km/soat;$ $x_1 = 20t;\ x_2 = 60 - 40t;$ *jismlar uchrashgan vaqt va joyni bildiradi*



2.6. Rasmda to‘g‘i chiziqli harakat berilgan Grafikning I, II, III qismlar harakati haqida nima deyish mumkin? Umumiy yo‘lni hamda har bir qismdagi ko‘chishni va umumiy ko‘chishni aniqlang? **Javob:** $x_1 = 3 + \frac{4}{3}t;\ x_2 = 7;\ x_3 = 27 - \frac{5}{2}t;$ $\ell_{um} = 12m;\ s_1 = 4m;\ s_2 = 0;\ s_3 = -7\,m; s_{um} = -3m$



2.7. Uchuvchi samolyotda $\vartheta = 1440\ km/soat$ tezlikda $h = 40\,m$ balandlikda uchmoqda. Biror $t = 0$ vaqtdan boshlab gorizontga nisbatan $\theta = 2,29^0$ qiyalangan sirt ustida ucha boshlaydi. Agar uchuvchi boshqaruv yo‘nalishini o‘zgartirmasa, qancha vaqtdan keyin qiya sirtga borib uriladi? **Javob:** *2,5 s*



2.8. Jismning tezligi $\vartheta = 6 + 6t - t^2$ qonuniyat bilan o‘zgaradi. Bu yerda *t* sekundlarda, ϑ esa sm/s larda ifodalanadi. Jismning tezligi $t_1 = 2s$ va $t_2 = 5s$ vaqt onlaridagi oniy tezliklarni toping. Bu vaqt oralig‘ida tezlik o‘zgarishi nimaga teng? **Javob:** $\vartheta_1 = 14\ sm/s;\ \vartheta_2 = 11\ sm/s;\ \Delta\vartheta = -3\ sm/s$

2.9. Jismning tezligi $\vartheta = 20\sin(0,1\pi t)$ qonuniyat bilan o‘zgaradi. Bu yerda *t* sekundlarda, ϑ esa sm/s larda ifodalanadi. Eng kamida qancha vaqt o‘tganda tezlik eng katta

qiymatga erishadi? Jism *10 sm/s* tezlikka erishguncha qancha vaqt o‘tadi? **Javob:** $t = 5\ s;\ t = 5/3\ s$

2.10. Jismning tezligi $\vartheta = 2 - 3t + t^2$ qonuniyat bilan o‘zgaradi. Bu yerda t sekundlarda, ϑ esa m/s larda ifodalanadi. Jismning tezligi nolga aylanadigan vaqt onlarini aniqlang. J: $t_1 = 1s;\ t_2 = 2s;$

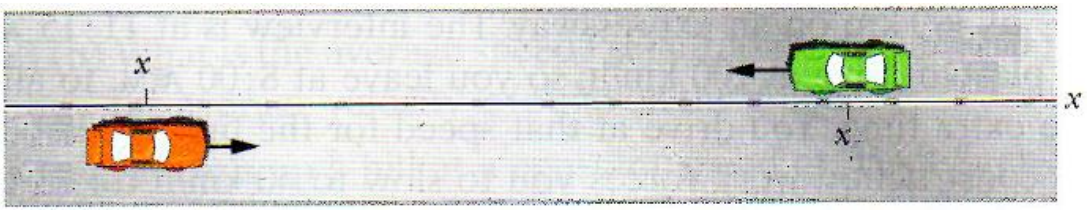
2.11. Velosipedchi dastlabki *5 s* da *40 m*, keyingi *10 s* da *100 m* va oxirgi *5 s* da *20 m* yurgan. Yo'lning har qaysi qismidagi va butun yo'ldagi o'rtacha tezliklarni toping. **Javob:** *8 m/s; 10 m/s; 4 m/s; 8 m/s*

2.12. Moddiy nuqta yo‘lning *1/6* qismida *4 m/s* teslik bilan qolgan qismida *10 m/s* tezkik bilan harakatlandi. Uning harakat vaqti davomidagi o‘rtacha tezligini toping. **Javob:** *8 m/s*

2.13. *A* punktdan *B* punktga tomon avtomashina $\vartheta_1 = 80\,km/soat$ tezlik bilan yo‘lga chiqdi. Oradan $\Delta t = 15\,min$ vaqt o‘tgach *B* punktdan *A* punktga tomon velosipedchi $\vartheta_2 = 20\,km/soat$ tezlik bilan yo‘lga chiqdi. Punktlar orasidagi masofa $\ell = 55\,km$. Quyidagilarni aniqlang: *a)* koordinata boshi *A* punktda joylashgan va vaqt hisobi avtomahina yo‘lga chiqqan paytdan boshlangan deb hisoblab, avtomashina va velosipedchining harakat tenglamasini yozing; b) ularning uchrashish vaqti va joyini analitik va grafik usulda aniqlang. **Javob:** $x_1 = 80t\ \ [km];\ x_2 = 60 - 20t\ \ [km];\ t_{uch} = 0,6\,soat;\ x_{uch} = 48\,km$

2.14. Qirg‘oqdagi jarlik tepasidan turib bola arqon bilan suvdagi qayiqni tortmoqda. Arqon va suv sirti orasidagi burchak α ga teng. Bola arqonni ϑ_1 tezlik bilan tortayotgan bo‘lsa, qayiq suvda qanday ϑ_2 tezlik bilan suzadi? **Javob:** $\vartheta_2 = \vartheta_1 / sos\alpha$

2.15. Ikkita avtomobil yo‘lning ikki parallel yo‘laklarida bir-biriga tomon *90 km/soat* tezlik bilan bir-biriga tomon harakatlanmoqda. Dastlab ular orasidagi masofa *8,5 km* bo‘lgan bo‘lsa, qancha vaqtdan so‘ng ular bir-birining yonidan o‘tib ketishadi? J: *170 s*.



2.16. Ikki to‘g‘ri chiziq yo‘l o‘zaro $\alpha = 60^0$ burchak ostida kesishadi. Chorrahadan bir vaqtda ikki mashina biri $\vartheta_1 = 60\,km/soat$, ikkinchisi $\vartheta_2 = 80\,km/soat$ tezlikda o‘tgan bo‘lsa, bu mashinalar bir-biriga nisbatan qanday tezlikda uzoqlashadilar? **Javob:** $\vartheta_{nisb} = 72,1\ km/soat$

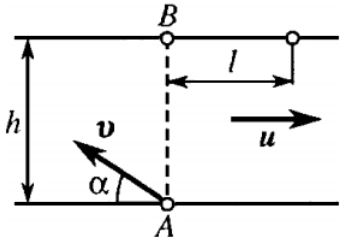
2.17. Vertolyot shamolsiz kunda aniq shimolga qarab *90 km/soat* tezlik bilan harakatlanmoqda. Agar meridianga *45°* burchak ostida shimoli-g'arb tomondan shamol esadigan bo'lsa, vertolyotning tezligi va kursi qanday bo'lishini toping. Shamolning tezligi *10 m/s*. **Javob:** *19,3 m/s; meridiandan 21,5° sharqqa*

2.18. Velosipedchi va yo‘lovchi bir joydan bir tomonga harakat boshlaganda bir minutdan keyin ular orasidagi masofa *240 m* ni tashkil qildi. Ular qarama-qarshi tomonga harakat boshlaganda esa, ikki minutdan keyin masofa *720 m* ga teng bo‘ldi. Yo‘lovchining tezligi velosipedchinikidan necha marta kichik? **Javob:** *5*

2.19. Velosiped g‘arb tomonga qarab *8 m/s* teslik bilan harakatlanmoqda. Shimol tomondan esayotgan shamolning tezligi *2 m/s* ga teng bo‘lsa, velosipedning shamolga nisbatan tezligi qanchaga teng bo‘ladi? **Javob:** $2\sqrt{17}\ m/s$

2.20. Ikki moddiy nuqta bitta tekislikda $\vartheta_1 = 4\,m/s$ va $\vartheta_2 = 7\,m/s$ tezliklar bilan o‘zaro $\alpha = 60^0$ burchak hosil qilib harakatlanmoqdalar. Birinchi nuqta ikkinchisiga nisbatan qanday ϑ tezlik bilan uzoqlashadi. $\vec{\vartheta}$ tezlik vektori $\vec{\vartheta}_2$ tezlik vektori bilan qanday φ burchak tashkil etadi? **Javob:** $\vartheta = \sqrt{37}\ m/s;\ \varphi = 145,3^0$

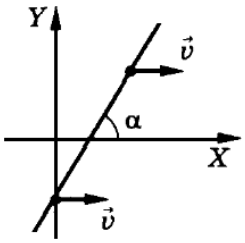
2.21. Qayiqchi eni h ga teng bo‘lgan daryodan A punktdan B punktga suzib o‘tmoqchi. Uning tezligi hamma vaqt qirg‘oqqa nisbatan rasmdagidek α burchak tashkil etadi. Agar daryoning oqim tezligi u ga teng bo‘lib, oqim qayiqni B punktdan ℓ masofaga surib ketgan bo‘lsa, u holda qayiqning suvga nisbatan tezligi ϑ nimaga teng? **Javob:**



$$\vartheta = \frac{\ell}{h\sin\alpha + \ell\cos\alpha}u$$

2.22. Ikkita kesishuvchi to‘g‘ri chiziq ϑ_1 va ϑ_2 tezliklar bilan o‘z chiziqlariga tik holda turli tomonlarga harakatlanmoqdalar. To‘g‘ri chiziqlar orasidagi o‘tkir burchak α ga teng. Bu to‘g‘ri chiziqlar kesishgan nuqta qanday tezlik bilan harakar qiladi? **Javob:** $\vartheta = \frac{1}{\sin\alpha}\sqrt{\vartheta_1^2 + \vartheta_2^2 + 2\vartheta_1\vartheta_2\cos\alpha}$

2.23. Dekart koordinatalar tekisligida Ox o‘qi bilan $\alpha = 30^0$ burchak hosil qiluvchi to‘g‘ri chiziq Ox o‘qi bo‘ylab ϑ tezlik bilan harakatlanmoqda. Bu to‘g‘ri chiziqning Oy o‘qi bilan kesishadigan nuqtasi qanday tezlik bilan harakat qiladi? **Javob:** $\vartheta tg\alpha$



3-MAVZU: To‘g‘ri chiziqli tekis o’zgaruvchan harakat. Tezlanish tushunchasi. To‘g‘ri chiziqli notekis harakat.

Mavzuga oid muhim formulalar

$\vec{a}_{o'rt}=\frac{\Delta\vec{\vartheta}}{\Delta t}, \qquad \vec{a}=\lim\limits_{\Delta t\to 0}\frac{\Delta\vec{\vartheta}}{\Delta t}=\frac{d\vec{\vartheta}}{dt}=\frac{d^2\vec{r}}{dt^2}$	*O‘rtacha va oniy tezlanishning vektor usulda berilishi*
$\vec{a}=\frac{d\vartheta_x}{dt}\vec{i}+\frac{d\vartheta_y}{dt}\vec{j}+\frac{d\vartheta_z}{dt}\vec{k}$ $a_x=\frac{d\vartheta_x}{dt}=\dot{\vartheta}_x, \quad a_y=\frac{d\vartheta_y}{dt}=\dot{\vartheta}_y, \quad a_z=\frac{d\vartheta_z}{dt}=\dot{\vartheta}_z$ $a_x=\frac{d^2x}{dt^2}=\ddot{x}, \quad a_y=\frac{d^2y}{dt^2}=\ddot{y}, \quad a_z=\frac{d^2z}{dt^2}=\ddot{z}$	*Tezlanishning koordinata usulda berilishi*
$a=\sqrt{a_x^2+a_y^2+a_z^2}=\sqrt{\ddot{x}^2+\ddot{y}^2+\ddot{z}^2}$ $\cos\left(\vec{a}\wedge\vec{i}\right)=\frac{a_x}{a}, \quad \cos\left(\vec{a}\wedge\vec{j}\right)=\frac{a_y}{a}, \quad \cos\left(\vec{a}\wedge\vec{k}\right)=\frac{a_z}{a}$	*Tezlanishning miqdor va yo‘nalishini aniqlash*
$x=x_0+\vartheta_x t+\frac{a_x t^2}{2}, \quad y=y_0+\vartheta_y t+\frac{a_y t^2}{2}$	*Oxy tekisligida to‘g‘ri chiziqli tekis o‘zgaruvchan harakat tenglamasi*
$a=\frac{\Delta\vartheta}{\Delta t}=\frac{\vartheta-\vartheta_0}{\Delta t}=tg\alpha$	*Tezlanish formulasi*
$\vartheta=\vartheta_0+at$ $\begin{cases}\vartheta=\vartheta_0+\lvert a\rvert t & -\ tezlanuvchan\\ \vartheta=\vartheta_0-\lvert a\rvert t & -\ sekinlanuvchan\end{cases}$	*To‘g‘ri chiziqli tekis o‘zgaruvchan harakat uchun oniy tezlik formulasi*
$S=\frac{\vartheta+\vartheta_0}{2}t \quad (1), \qquad S=\frac{\vartheta^2-\vartheta_0^2}{2a} \quad (2),$ $S=\vartheta_0 t+\frac{at^2}{2} \quad (3)$	*To‘g‘ri chiziqli tekis o‘zgaruvchan harakatda ko‘chishni topishning 3 ta formulasi*
$S=\frac{\vartheta}{2}t \quad (1), \qquad S=\frac{\vartheta^2}{2a} \quad (2), \qquad S=\frac{at^2}{2} \quad (3)$	*Tinch holatdan tekis tezlanuvchan harakat boshlagan jism uchun ko‘chishni topishning 3 ta formulasi*

3-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Jismning boshlang‘ich tezligi *10 m/s*, tezlanishi esa *2 m/s²* bo‘lsa, jism tezligini ikki marta orttirishi uchun qancha masofani bosib o‘tishi kerak bo‘ladi (*m*)?

Berilgan:	*Yechilishi:*
υ_0=10 m/s *a*=2s υ=2υ_0=20 m/s S=?	Tekis o‘zgaruvchan harakatda jismning bosib o‘tgan yo‘li quyidagicha topiladi: $$S = \upsilon_{o‘rt} \cdot t \qquad (1)$$ Tekiso‘zgaruvchan harakatda o‘rtacha tezlikni topish uchun quyidagi ifoda har doim o‘rinli: $$\upsilon_{o‘rt} = \frac{\upsilon + \upsilon_0}{2} \qquad (2)$$

$a = \frac{\upsilon - \upsilon_0}{t}$ ushbu formuladan t ni topsak quyidagicha bo‘ladi:

$$t = \frac{\upsilon - \upsilon_0}{a} \qquad (3)$$

(2) va (3) ifodani (1) ifodaga qo‘ysak quyidahi ko‘rinish hosil bo‘ladi va biz undan jism a tezlanish bilan harakatlaniv tezligini 2 barobar oshirishi uchun qancha masofa bosib o‘tganini topamiz:

$$S = \upsilon_{o‘rt} \cdot t = \frac{\upsilon + \upsilon_0}{2} \cdot \frac{\upsilon - \upsilon_0}{a} = \frac{\upsilon^2 - \upsilon_0^2}{2a} = \frac{20^2 - 10^2}{2 \cdot 2} = 75 \text{ m}.$$

Javob: S=75 m

Masala № 2. Sportchi *0,2 m/s²* tezianish bilan harakatlanib, uzunligi *60 m* bo‘lgan qiyalikni *10 s* da o‘tdi. Uning qiyalik boshidagi tezligi qanday bo‘lgan?

Berilgan:	*Yechilishi:*
S=60 m *a=0,2 m/s²* *t=10 s* υ_0=?	Bu masalada sportchi tekis tezlanuvchan harakat qilmoqda. Bunda sportchi harakatni qanday υ_0 tezlik bilan boshlaganini topish uchun sportchining bosib o‘tgan masofasini boshlang‘ich tezligi, tezlanishi va harakatlanish vaqtiga bog‘lanish formulasini keltirib chiqaramiz. $$S = \frac{\upsilon_0 + at + \upsilon_0}{2} \cdot t = \frac{2\upsilon_0 t + at^2}{2} = \upsilon_0 t + \frac{at^2}{2}$$ $$S = \upsilon_0 t + \frac{at^2}{2}$$

(5) ifodadan υ_0 ni topamiz.

$$\upsilon_0 = \frac{2S - at^2}{2t} = \frac{2 \cdot 60 - 0{,}2 \cdot 10^2}{2 \cdot 10} = 5\ m/s.$$

Javob: $\upsilon_0 = 5\ m/s$

Masala № 3. Agar samolyotning qo‘nish tezligi *180 km/soat* va qo‘nish masofasi *750 m* bo‘lsa, u qancha vaqtda qo‘nadi (*s*)?

Berilgan:	*Yechilishi:*
υ_0=50 m/s S=750 m t=?	Samalot qonishni boshlagan paytda tezligi υ_0 edi va butunlay qo‘nib bo‘lgunicha tekis sekinlanuvchan harakat qiladi va harakat oxirida samalotning tezligi υ=0 bo‘ladi.

Tekis o‘zgaruvchan harakatda jismning bosib o‘tgan yo‘li quyidagicha topiladi:

$$S = \upsilon_{o'rt} \cdot t \qquad (1)$$

Tekiso‘zgaruvchan harakatda o‘rtacha tezlikni topish uchun quyidagi ifoda har doim o‘rinli:

$$\upsilon_{o'rt} = \frac{\upsilon + \upsilon_0}{2} \qquad (2)$$

Bu ifodadan foydalanib (1) ifodani quyidagicha yozishimiz mumkin:

$$S = \frac{\upsilon + \upsilon_0}{2} \cdot t \qquad (3)$$

Biz qarayotgan masala tekis sekinlanuvchan harakat va harakat oxiridagi telik υ=0 bo‘lgani uchun (3) ifodani quyidagicha ifodalaymiz:

$$S = \frac{\upsilon_0}{2} \cdot t \qquad (4)$$

(4) ifodadan samalotning qo‘nish vaqti t ni topamiz:

$$t = \frac{2S}{\upsilon_0} = \frac{2 \cdot 750}{50} = 30 \text{ s}.$$

Javob: *30 s*.

Masala № 4. Qiya nov bo‘yicha ishqalanishsiz dumalayotgan sharcha harakatining birinchi sekundida *3,6 m* yo‘l o‘tdi. U harakatining uchinchi sekundida qancha yo‘l o‘tishini toping.

Berilgan:	*Yechilishi:*
t=1 s *S=3,6 m* *n=3* S_n=?	Jismning *3 sekund*da bosib o‘tgan yo‘i bilan 3-sekundda bosib o‘tgan yo‘lini farqi bor. Jismning 3 sekundda bosib o‘tgan yo‘li bu: jismning 1, 2 va uchinchi sekunlarda bosib o‘tgan yo‘llar yig‘indisi yoki harakat boshlanganidan to 3 sekund o‘tganisha bosib o‘tgan masofasidir.

Jismning 3-sekundda bosib o‘tgan yo‘li esa jismning aynan 3- sekundda bosib o‘tgan masofasi holos! Buni biz n-sekundda bosib o‘tilgan yo‘l deymiz va quyidagi formula orqali topamiz:

$$S_n = \upsilon_0 + \frac{a}{2}(2n - 1) \qquad (1)$$

Jism boshlang‘ich tezliksiz harakatlanayotgani uchun (1) ifodani quyidagicha yozishimiz mumkin:

$$S_n = \frac{a}{2}(2n - 1) \qquad (2)$$

Bizga jismning tezlanishi nomalum shuning uchun quyigagi ifodadan jismning tezlanishini topib uni (2) ifodaga keltirib qo'yamiz:

$$S = \frac{at^2}{2} \Rightarrow a = \frac{2S}{t^2}$$

$$S_n = \frac{S}{t^2}(2n-1) = \frac{3{,}6}{1^2}(2\cdot 3 - 1) = 18\ m.$$

Javob: *18 m.*

Masala № 5. Gorizontal sirtdagi jismga *5 m/s* boshlang'ich tezlik berildi. U – *1 m/s²* tezianish bilan harakat qilgan bo'lsa *5 s* da qancha masofani o'tadi (*m*)?

Berilgan:	*Yechilishi:*
v_0=5 m/s *a*=-1 m/s² t=5 s S=?	Bu masalada jism tekis sekinlanuvchan harakat qilayotganini tezlanishning manfiy qiymati ko'rsatib turibdi! Bunda jismni qancha masofani bosib o'tganini topish uchun jismning bosib o'tgan masofasini jismning boshlang'ich tezligi, tezlanishi va harakatlanish vaqtiga bog'lanish formulasini keltirib chiqaramiz!

Tekis o'zgaruvchan harakatda jismning bosib o'tgan yo'li quyidagicha topiladi:

$$S = v_{o'rt} \cdot t \qquad (1)$$

Tekiso'zgaruvchan harakatda o'rtacha tezlikni topish uchun quyidagi ifoda har doim o'rinli:

$$v_{o'rt} = \frac{v + v_0}{2} \qquad (2)$$

Bu ifodadan foydalanib (1) ifodani quyidagicha yozishimiz mumkin:

$$S = \frac{v + v_0}{2} \cdot t \qquad (3)$$

$a = \frac{v - v_0}{t}$ ushbu formuladan v ni topsak quyidagicha bo'ladi:

$$v = v_0 + at \qquad (4)$$

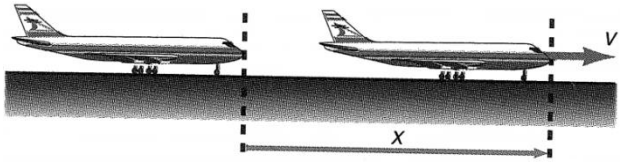
(4) ifodani (3) ifodaga qo'ysak quyidagi ifoda hosil bo'ladi va biz undan jismni qancha masofani bosib o'tganini topamiz:

$$S = \frac{v_0 + at + v_0}{2} \cdot t = \frac{2v_0 t + at^2}{2} = v_0 t + \frac{at^2}{2} = 5\cdot 5 + \frac{(-1)\cdot 5^2}{2} = 12{,}5\ m.$$

Javob: 12,5.

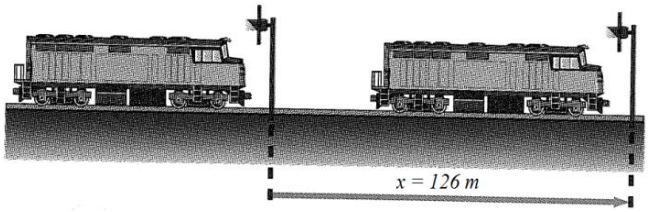
3-amaliy mashg'ulot topshirig'i

3.1. Harbiy samolyot yerdan ko'tarilish uchun *75 m/s* tezlik kerak bo'ladi. U tinch holatdan kerakli tezlikka *125 m* yo'lda erisha oladi. Bunda samolyotning tezlanishi qanday (*m/s²*)? **Javob:** 22,5



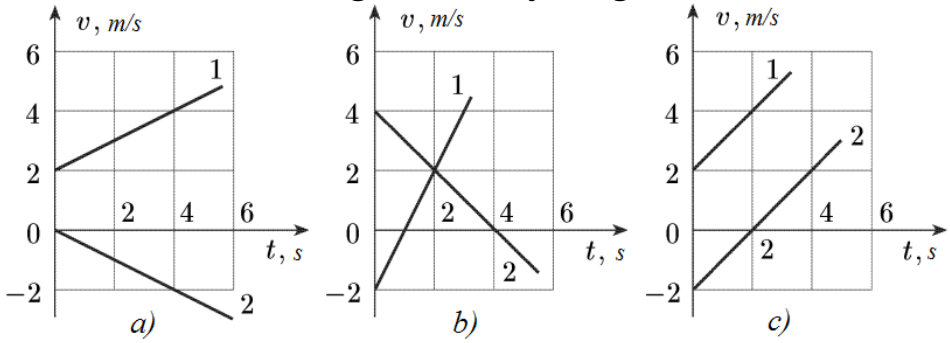
3.2. Elektron *0,25 sm* uzunlikdagi vakkum trubkada $5{,}3\cdot10^6\ m/s$ tezlikkacha erishadi. Uning tezlanishi nimaga teng (m/s^2)? **Javob:** $5{,}618\cdot10^{15}$

3.3. Tekis tezlanayotgan poyezd svetoforning yashil chirog‘i yonidan *27 km/soat* tezlikda o‘tib ketadi. Bundan *126 m* uzoqlikdagi ikkinchi sfetofordan *12 s* vaqtdan keyin o‘tadi. Poyezdning telzlanishi nimaga teng (m/s^2)? Ikkinchi svetofor yonidan o‘tishdagi tezligi qanday (m/s)? **Javob:** $0{,}5\ m/s^2$; $13{,}5\ m/s$



3.4. Motosikl tinch holatdan $4\ m/s^2$ tezlanish bilan qo‘zg‘alib *5 s* davomida tezligini oshiradi. Keyingi *25 s* davomida tekis harakat qiladi. So‘ngra tormozni bosib $2\ m/s^2$ sekinlanish (manfiy tezlanish) bilan to‘xtaydi. Motosiklning to‘liq yurgan yo‘lini va butun yo‘ldagi o‘rtacha tezligini aniqlang. **Javob:** *650 m; 16,25 m/s²*

3.5. Qyidagi rasmlarda I va II jismlarning tezlik grafiklari berilgan. Grafikdan foydalanib, jismlarning boshlang‘ich tezlik va tezlanish qiymatlarini ayting. I va II jismlar uchun tezlik va harakat tenglamalarini yozing.



3.6. Ikkita avtomobilning harakat tenglamalari $x_1 = 2t^2 + 4t$ va $x_2 = 8t + 6$ ko‘rinishga ega. Ular qaerda va qachon uchrashadilar? **Javob:** *x = 30 m, t = 3s*

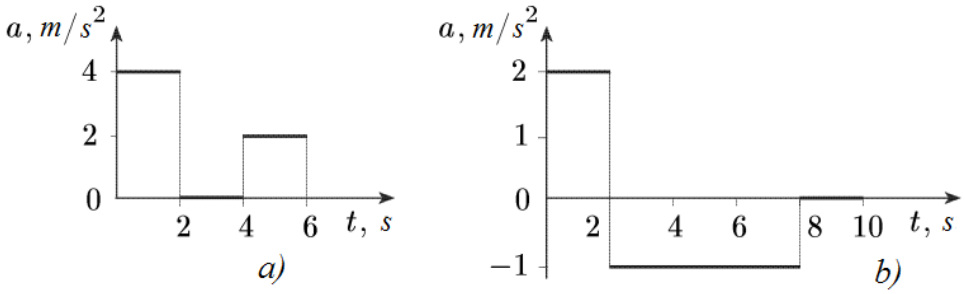
3.7. 90 m uzunlikdagi tinch turgan poyezd tekis tezlanuvchan harakat boshlaydi. Lokomotiv harakat boshlanish nuqtasidan *160 m* masofada turgan shlagbaum yonidan *12 m/s* tezlikda o‘tadi. Oxirgi vagon shlagbaum yonidan qanday tezlikda o‘tadi? **Javob:** *15 m/s*

3.8. Qo‘liga kitob tutgan bola *a* tezlanish bilan harakat boshlagan liftda turibdi. Bolaning qo‘lidagi kitob to‘satdan tushib ketdi. Kitobning polga nisbatan tezlanishi nimaga teng? Polga bog‘langan sanoq sistemasida kitobning harakat tenglamasini yozing. Poldan bolaning qo‘ligacha masofa y_0 ga teng. Masalani lift harakati: *a)* tepaga; *b)* pastga yo‘nalgan hollar uchun ko‘ring. **Javob:** *a)* $g+a;\ y = y_0 - \dfrac{(g+a)t^2}{2}$;

b) $g-a;\ y = y_0 - \dfrac{(g-a)t^2}{2}$

3.9. Kosmik kemaning tezligi *t=0* vaqt onida $\vartheta_0 = 55 m/s$ tezlikka ega. *t=10 s* vaqt onigacha u $\vartheta = 162 m/s$ tezlikkacha tezlashadi. Bu kosmik kema *t=2* s dan *t=6 s* gacha vat davomida qancha masofaga uchib boradi? **Javob:** *391 m*

3.10. Quyidagi rasmda jism tezlaishining vaqtga bog‘lanish grafiklari berilgan. Tezlikning vaqtga bog‘lanish grafiklarini chizing. Boshlang‘ich tezlikni nolga teng deb oling.



3.11. Orasidagi masofa ℓ bo‘lgan ikki jism bir vaqtda bir-biriga tomon harakat boshlaydi. Birinchi jism doimiy ϑ tezlik bilan tekis harakat qiladi, ikkinchisi esa a tezlanish bilan joyidan qo‘zg‘aladi. Qancha vaqtda ular uchrashadilar?

Javob: $t = \dfrac{\sqrt{\vartheta_0^2 + 2a\ell} - \vartheta_0}{a}$

3.12. Ikkita jismning harakat tenglamasi $x_1 = -3 + 2t + t^2$ va $x_2 = 7 - 8t + t^2$ qonunga bo‘ysunadi. Jismlarning ular uchrashgan paytdagi nisbiy tezligi ϑ_{nis} ni aniqlang. Bu yerda x metrlarda, t sekundlarda berilgan. **Javob:** $\vartheta_{nis} = 10\ m/s$

3.13. A nuqtaning B nuqtaga nisbatan harakat tenglamasi $x_{nis} = 1 - 2t + t^2$ ko‘rinishida va A nuqtaning harakat tenglamasi $x_A = 1 - t^2$ ko‘rinishida ekanligi ma’lum. B nuqtaning harakat tenglmasini yozing. Nuqtalarning tezlanishlari a_A va a_B ni hamda $t = 1s$ vaqt onidagi tezliklari ϑ_A va ϑ_B ni aniqlang. Bu yerda x metrlarda, t sekundlarda berilgan. **Javob:** $x_B = 2t - 2t^2$; $a_A = -2\,m/s^2$; $a_B = -4\,m/s^2$; $\vartheta_A = -2\,m/s$; $\vartheta_B = -2\,m/s$

3.14. Elementar zarra – myuon elektr maydoniga $\vartheta_0 = 6 \cdot 10^6\ m/s$ tezlik bilan uchib kiradi va $a = 1{,}25 \cdot 10^{14}\ m/s^2$ sekinlanish bilan tormozlanadi. Myuon qancha masofada va qancha vaqtda to‘xtaydi? **Javob:** $\ell = 14{,}4\ sm$; $t = 4{,}8 \cdot 10^{-8} s$

3.15. Jismning bosib o’tgan yo’li s ning t vaqtga bog’liqligi $s = At - Bt^2 + Ct^3$ tenglama orqali berilgan; bunda $A = 2\,m/s$, $B = 3\,m/s^2$ va $C = 4\,m/s^3$. 1) Tezlik ϑ ning hamda tezlanish a ning vaqt t ga bog’lanishini aniqlang; 2) harakat boshlangandan 2 s vaqt o’tgandan so’ng jismning bosib o’tgan yo’li, erishgan tezligi va tezlanishini aniqlang. **Javob:** 1) $\vartheta = 2 - 6t + 12t^2$; $a = -6 + 24t$; 2) $s = 24m$; $\vartheta = 38\,m/s$; $a = 42\,m/s^2$

3.16. Jismning bosib o’tgan yo’li s ning t vaqtga bog’liqligi $s = A + Bt + Ct^2$ tenglama orqali berilgan; bunda $A = 3m$, $B = 2\,m/s$ va $C = 1\,m/s^2$. Jism harakatining birinchi, ikkinchi va uchinchi sekund oralig’idagi o’rtacha tezligi va o’rtacha tezlanishinni aniqlang. **Javob:** $\vartheta_{o'rt.1} = 3\,m/s$; $\vartheta_{o'rt.2} = 5\,m/s$; $\vartheta_{o'rt.3} = 7\,m/s$; $a = 2\,m/s^2 = const$

3.17. Jismning bosib o’tgan yo’li s ning t vaqtga bog’liqligi $s = A + Bt + Ct^2 + Dt^3$ tenglama orqali berilgan; bunda $C = 0{,}14\,m/s^2$ va $D = 0{,}01\,m/s^3$. 1) Harakat boshlangandan qancha vaqt o’tgach jismning tezlanishi $1\,m/s^2$ ga teng bo’ladi? 2) Shu vaqt oralig’ida jismning o’rtacha tezlanishi nimaga teng? **Javob:** *1) 12s; 2) 0,64 m/s²*

4-MAVZU: Jismlarning erkin tushishi. Erkin tushish tezlanishi. Yuqoriga tik otilgan jismning harakati.

Mavzuga oid muhim formulalar

$\begin{cases}\vartheta=\vartheta_0-\lvert g\rvert t \ - \ tepaga\\ \vartheta=\vartheta_0+\lvert g\rvert t \ - \ pastga\end{cases}$	*O'g'irlik kuchi ta'sirida vertikal harakat qiladigan jism uchun oniy tezlik formulasi*
$y=y_0+\vartheta_0 t-\frac{gt^2}{2}$	*O'g'irlik kuchi ta'sirida vertikal harakat qiladigan jism harakat tenglamasi*
$y=y_0+\lvert\vartheta_0\rvert t-\frac{gt^2}{2}$ – *yuqoriga* $y=y_0-\lvert\vartheta_0\rvert t-\frac{gt^2}{2}$ – *pastga*	*Biror balandlikdan turib boshlang'ich tezlik bilan tik holda yuqoriga yoki pastga otilgan jismning harakat tenglamalari*
$S=\frac{\vartheta+\vartheta_0}{2}t$ (1), $S=\left\lvert\frac{\vartheta^2-\vartheta_0^2}{2g}\right\rvert$ (2), $\begin{cases}S=\vartheta_0 t-\frac{gt^2}{2} \ - \ tepaga\\ S=\vartheta_0 t+\frac{gt^2}{2} \ - \ pastga\end{cases}$ (3)	*O'g'irlik kuchi ta'sirida vertikal harakat qiladigan jism uchun ko'chishni topishning 3 ta formulasi*
$t_{tush}=\frac{\vartheta_0}{g}, \quad \vartheta_{tush}=\sqrt{2gh}$	*Biror h balandlikdan erkin tashlangan jismning tushish vaqti va tushish tezligi*
$t_1=\frac{\sqrt{\vartheta_0^2+2gh}+\vartheta_0}{g}, \ t_2=\frac{\sqrt{\vartheta_0^2+2gh}-\vartheta_0}{g}$	*Biror h balandlikdan tik holda yuqoriga va pastga otilgan jismlarning tushish vaqtlari*
$\vartheta_{tush}=\sqrt{\vartheta_0^2+2gh}$	*Biror h balandlikdan tik holda otilgan jismlarning tushish tezligi*
$\vartheta_{tush}=\sqrt{\vartheta_0^2-2gh}$	*Yer sirtidan tik holda yuqoriga otilgan jismning ixtiyoriy h balandlikdagi tezligi*
$t_{k.t}=\frac{2\vartheta_0}{g}$	*Yer sirtidan tik holda yuqoriga otilgan jismning yerga qaytib tushish vaqti*

4-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Erkin tushayotgan jismning *2 s* dan keyingi tezligi *30 m/s* bo'lsa, uning boshlang'ich tezligi qanday (*m/s*)?

Berilgan:

υ=30m/s

t=2s

υ_0=?

Yechilishi:

Erkin tushishda jismning tezligi $\upsilon=\upsilon_0+gt$ qonuniyat bo'yicha o'zgarishidan foydalanib erkin tushayotgan jismni boshlang'ich tezligini topamiz.

$$\upsilon_0=\upsilon-gt$$

$$\upsilon_0=30-10\cdot 2=10 \text{ m/s}.$$

Javob: 10 m/s

Masala № 2. Boshlang‘ich tezliksiz erkin tushayotgan jismning boshlang‘ich uch va to‘rt sekundda o‘tgan yo‘llari nisbati qanday bo‘ladi?

Berilgan:
$t_1=3$ s
$t_2=4$ s
$h_1/h_2=?$

Yechilishi:
Erkin tushayotgan jismning tushish balandligini boshlang‘ich tezlik bo‘lmagan holda $h=\frac{gt^2}{2}$ ifoda orqali topar edik. Har ikkala jismning tushish balandliklari nisbatini olsak, quyidagi korinish hosil bo‘ladi:

$\frac{h_1}{h_2}=\frac{t_1^2}{t_2^2}$ bu ifodadan $\frac{h_1}{h_2}=\frac{9}{16}$ ekani ko‘rinib turibdi.

Javob: *9: 16*

Masala № 3. Bir iism *80 m* balandlikdan erkin tushmoqda, u bilan bir vaqtda boshqa jism *160 m* balandlikdan tusha boshladi. Ularning ikkalasi erga bir vaqtda tushishi uchun 2-jismmng boshlang‘ich tezligi qanday (*m/s*) bo‘lishi kerak?

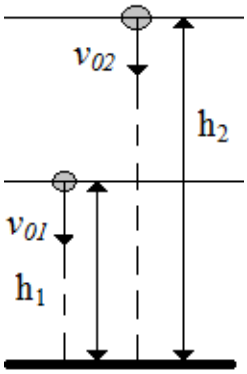
Berilgan:
$t_1=t_2$
$h_1=80$ m
$h_2=160$ m
$\upsilon_{01}=0$
$g=10$ m/s^2
$u_{02}=?$

Yechilishi: g tezlanish bilan tekis tezlanuvchan harakat formulasidan foydalanamiz.

$h=\upsilon_{01}t_1+\frac{gt_1^2}{2}$

$h=\upsilon_{02}t_2+\frac{gt_2^2}{2}$

$t_1=t_2=t$; $\upsilon_{01}=0$ dan foydalanamiz.



$$h=\frac{gt^2}{2};\ h=\upsilon_{02}t+\frac{gt^2}{2};\ t=\sqrt{\frac{2h_1}{g}} \quad\Rightarrow\quad h_2=\upsilon_{02}\sqrt{\frac{2h_1}{g}}+h_1$$

$$h_2-h_1=\upsilon_{02}\sqrt{\frac{2h_1}{g}} \Rightarrow \upsilon_{02}=(h_2-h_1)\sqrt{\frac{g}{2h_1}}$$

$$\upsilon_{02}=(160-80)\sqrt{\frac{10}{2\cdot 80}}=20\ m/s.$$

Javob: $\upsilon_{02}=20\ m/s$

Masala № 4. *180 m* balandlikdan erkin tushayotgan jism harakatining oxirgi sekundida necha metr yo‘l o‘tadi? *g =10 m/s*^{2}.

Berilgan:
$h=180$m
$h_n=?$

Yechilishi:
Bu masalani erkin tushayotgan jismning *n*-sekundda bosib o‘tgan masofasini topish formulasidan topamiz.

$\Delta h_n=u_0+\frac{g}{2}(2n-1)$

Ammo biz bu jismni qancha vaqtda erga tushgani va uning harakatini oxirgi sekundi nechanchi sekund ekanini bilmaymiz, shuning uchun bu jismni qancha vaqtda erga tushganini $t = \sqrt{\frac{2h}{g}}$ formula orqali topib olamiz.

$t = \sqrt{\frac{2 \cdot 180}{10}} = 6\ s$ demak biz jismni 6- sekundda boib o'tgan balandligini topishimiz kerak ekan.

Boshlang'ich tezlik yo'q ekanidan biz bu formulani

$h_n = \frac{g}{2}(2n-1)$ deb yozsak bo'ladi.

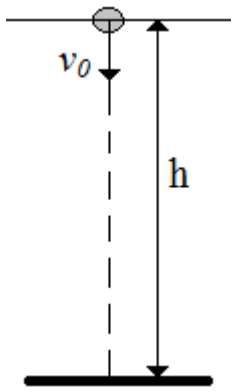
$$h_n = \frac{10}{2}(2 \cdot 6 - 1) = 55\ m.$$

Javob: *55 m*

Masala № 5. *1 s* dan so'ng suvga tegishi uchun toshni balandligi *25 m* bo'lgan ko'prikdan qanday boshlang'ich tezlik bilan tashlash kerak (*m/s*)?

Berilgan:
t=1s
h=25m
g=10m/s²
v_0=?

Yechilishi: Og'irlik kuchi ta'siridagi vertikal tezlanuvchan harakatda balandlikni topish formulasidan foydalanamiz.



$h = v_0 t + \frac{gt^2}{2}$

$$v_0 t = h - \frac{gt^2}{2}$$

$$v_0 = \frac{h}{t} - \frac{gt}{2} = \frac{25}{1} - \frac{10 \cdot 1}{2} = 25 - 5 = 20\ m/s.$$

Javob: *20 m/s*

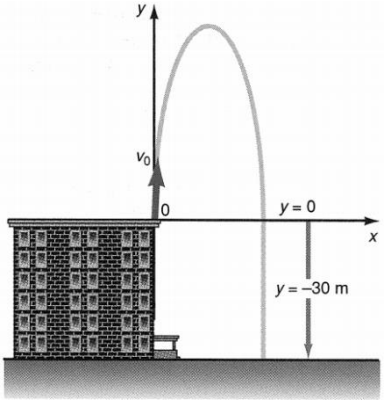
4-Amaliy mashg'ulot topshirig'i

4.1. Erkin tushayotgan jism harakatining *n*-metrini qancha vaqtda bosib o'tadi (*s*)?
Javob: $\Delta t = \frac{\sqrt{n} - \sqrt{n-1}}{\sqrt{5}}$

4.2. Qandaydir sayyorada jism *50 m* balandlikdan *5 s* da tushgan. Bu sayyorada erkin tushish tezlanishi qanday? **Javob:** *4 m/s²*

4.3. Boshlang'ich tezliksiz erkin tushayotgan birinchi jism ikkinchi jismga qaraganda 3 marta ko'p vaqt uchgan. Ularning ko'chishlari necha marta farq qiladi? **Javob:** *9 marta*

4.4. Erkin tushayotgan jismning n-sekunddagi ko'chishi qanday (m)? *(n+1)*-sekunddagi ko'chishi-chi? *g =10 m/s²*. **Javob:** *5(2 n – 1); 5(2 n + 1)*



4.5. Jism *30 m* balandlikdagi binoning ustidan turib *35 m/s* tezlik bilan tik holda yuqoriga otildi. Quyidagilarni aniqlang: *a)* jismi yer sirtidan qancha balandlikkacha ko‘tarilishini; *b)* maksimal balandlikkacha qancha vaqtda ko‘tarilishini; *c)* yerga tushguncha jami qancha vaqt ketishini; *d)* yerga qanday tezlik bilan urilishini. $g = 9{,}8\ m/s^2$. **Javob:** *a) 92,5 m; b) 3,52 s; c) 7,92 s; d) 42,6 m/s*

4.6. Oyda erkin tushish tezlanishining qiymati *1,62 m/s*^{2} ga teng. Oy sirtida turib tik holda yuqoriga *25 m/s* tezlik bilan otilgan tosh qancha vaqtda qaytib tushadi? Bunda tosh qancha balandlikka ko‘tariladi? **Javob:** *30,86 s; 192,9 m*

4.7. Balandlikka sakrash bo‘yicha o‘tkazilgan chempionatda g‘olib *2,2 m* natija ko‘rsatdi. Agar u Oyda bo‘lganda edi bu natija nimaga teng bo‘lar edi? Marsda bo‘lganda-chi? Erkin tushish tezlanishining qiymati Oyda *1,62 m/s*^{2} ga, Marsda esa *3,71 m/s*^{2} ga teng. $g = 9{,}8\ m/s^2$. **Javob:** *13,3 m; 5,81 m*

4.8. Boshlang‘ich tezliksiz tashlangan jism *4 s* da yerga tushdi. Agar jism shu balandlikdan *30 m/s* boshlang‘ich tezlik bilan tashlansa, u qancha vaqtda va qanday tezlik bilan yerga tushadi? **Javob:** *2 s; 50 m/s*

4.9. *30 m* balandlikdan *5 m/s* boshlang‘ich tezlik bilan tik pastga otilgan jismning tezligi yerdan qanday balandlikda *3* marta oshadi? J: *20 m*

4.10. Jism *h* balandlikdan erkin tushmoqda. Uning yo‘lning ikkinchi yarmidagi o‘rtacha tezligi qanday? **Javob:** $\frac{\sqrt{gh}(\sqrt{2}+1)}{4}$

4.11. Shaxtaga tushib ketgan toshning shaxta tubiga urilgandagi tovushi *9 s* dan keyin eshitildi. Shaxtaning chuqurligi qanday? Tovushning tezligi *320 m/s*, g=10 m/s^2. Havoning qarshiligini hisobga olmang. **Javob:** *320 m*

4.12. Jism qanday boshlang‘ich tezlik bilan yuqoriga tik otilganda, u *7 s* o‘tgach, *10 m/s* tezlik bilan pastga harakat qiladi? **Javob:** *60 m/s*

4.13. Tennis to‘pi *10 m/s* boshlang‘ich tezlik bilan yuqoriga tik otildi. Qaysi tenglama to‘p balandligining vaqtga bog‘lanishini ifodalaydi? **Javob:** $h = 10t - 5t^2$

4.14. Erkin tushayotganda birinchi jism ikkinchi jismga qaraganda *2* marta ko'p vaqt uchgan. Jismlarning oxirgi tezliklarini va ularning ko'chishlarini taqqoslang. **Javob:** $\vartheta_1 : \vartheta_2 = 2;\ h_1 : h_2 = 4$

4.15. G. Galiley erkin tushish qonunlarini o'rganayotib 1589-yilda Pize shahridagi og'ma minoradan turli buyumlarni boshlang'ich tezliksiz tashladi. Minoraning balandigi *57,5 m*. Buyumlar bu minoradan qancha vaqtda tushadi va ularning yerga urilishdagi tezliklari qanday? **Javob:** *3,4 s; 33,6 m/s*

4.16. Yuk *63 m* balandlikdan tushmoqda. Shu balandlikni shunday uch qismga bo'lish kerakki, bunda har bir qismni o'tish uchun bir xil vaqt kerak bo'lsin. **Javob:** *7 m, 21 m, 35 m*

4.17. Boshlang'ich tezliksiz erkin tushayotgan jism oxirgi *0,4 s* da *12 m* yo'l o'tgan bo'lsa, jism tushayotgan balandlik nimaga teng? $g=10\ m/s^2$. **Javob:** *51 m*

4.18. Vertolyot tik yuqoriga $2,5\ m/s^2$ tezlanish bilan ko'tarilmoqda. *12 s* dan so'ng vertolyotdan tushib ketgan jism yerga necha m/s tezlik bilan tushadi? **Javob:** *67 m/s*

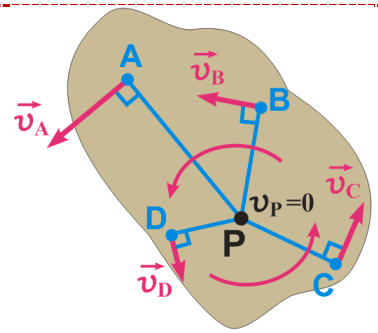
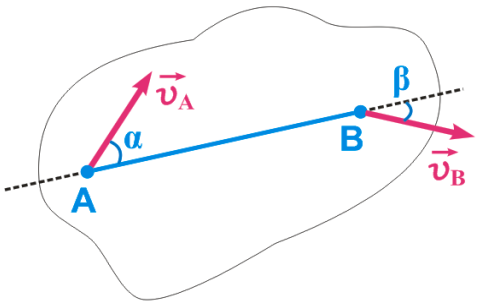
4.19. Jism $h=19,6\ m$ balandlikdan boshlang‘ich tezliksiz tushmoqda. 1) Jism o‘z yo‘lining birinchi *1 metr*ini qancha vaqtda bosib o‘tadi? 2) Yo‘lning oxirgi *1 metr*ini-chi? Havoning qarshiligini hisobga olmang. **Javob:** $1)\,0,452\,s;\ \ 2)\,0,052\,s$

4.20. Jism $h=19,6\ m$ balandlikdan boshlang‘ich tezliksiz tushmoqda. 1) Jism o‘z harakatining birinchi *0,1 sekund*ida qancha yo‘l o‘tadi? 2) Oxirgi *0,1 sekund*ida-chi? Havoning qarshiligini hisobga olmang. $g=9,8m/s^2$. **Javob:** $1)\,0,049\,m;\ \ 2)1,911m$

4.21. *A* jism ϑ_1 boshlang‘ich tezlik bilan tik yuqoriga otilgan paytda, *h* balandlikdan $\vartheta_2=0$ boshlang‘ich tezlik bilan *B* jism pastga tushib kela boshladi. Agar jismlar bir vaqtda harakat boshlagan bo‘lsalar, *A* va *B* jismlar orasidagi *s* masofaning *t* vaqtga bog‘lanish idodasi topilsin. **Javob:** $s=h-\vartheta_1 t$

5-MAVZU: Tekis aylanma harakatda kattaliklarni aniqlash. Burchak tezlik va chiziqli tezlik orasidagi bog‘lanish. Markazga intilma tezlanish. Tezliklarning oniy markazi.

Mavzuga oid muhim formulalar

$\omega = \frac{\varphi - \varphi_0}{t} = \frac{\Delta\varphi}{t} = tg\alpha$	*Burchak tezlik topish formulasi*
$\varphi = \varphi_0 + \omega t$	*Tekis aylanma harakat tenglamasi*
$\Delta\varphi = \frac{\Delta S}{R}$	*Yoy va burilish burchagi orasida bog‘lanish*
$N = \frac{\Delta\varphi}{2\pi}$	*Aylanishlar sonini topish formulasi*
$\omega = 2\pi\nu = \frac{2\pi}{T}$, $\nu = \frac{1}{T} = \frac{\omega}{2\pi}$, $T = \frac{1}{\nu} = \frac{2\pi}{\omega}$	*Burchak tezlik, aylanisha chastotasi va aylanish davri orasidagi bog‘lanish*
$\nu = \frac{n}{60}$, $\omega = \frac{\pi n}{30}$, $T = \frac{60}{n}$	*Minutiga aylanishlar sonidan burchak tezlik, aylanisha chastotasi va aylanish davrini aniqlash*
$T = \frac{t}{N}$, $\nu = \frac{N}{t}$, $\omega = 2\pi\frac{N}{t}$	*Ixtiyoriy vaqtdagi aylanishlar sonidan burchak tezlik, aylanisha chastotasi va aylanish davrini aniqlash*
$\vartheta = \frac{2\pi R}{T} = \frac{2\pi}{T}R = \omega R$ $\vec{\vartheta} = \vec{\omega} \times \vec{r}$	*Chiziqli tezlik va burchak tezlik orasida skalyar va vektorli bog‘lanish*
 $\vartheta_A = \omega \cdot PA$, $\vartheta_B = \omega \cdot PB$, $\vartheta_C = \omega \cdot PC$,... *Oniy markazni aniqlash formulasi*	 $\vartheta_A \cos\alpha = \vartheta_B \cos\beta$ *Oniy tezlikni aniqlash formulasi*

5-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Moddiy nuqta aylana bo‘ylab *4 m/s* tezlik bilan tekis aylanmoqda. Davrning to‘rtdan uch qismida jism tezligi o‘zgarishining modulini toping (*m/s*).

Berilgan:	*Yechilishi:*
$\upsilon = 4\ m/s.$	Aylanish davrining to‘rtdan uch qismida jismning aylanish tezligi past tarafga, ya’ni g‘ildirak past tarafga υ tezlik bilan aylanadi. Shuning uchun jism o‘ng tarafga υ tezlik bilan aylanadi, jismning aylanish tezligi bir biriga tik yo‘nalib qolganligi uchun davrning
$\Delta\upsilon = ?$	

tortdan bir qismidagi tezlikning o‘zgarish moduli pifagor teoremasidan

$$\Delta\upsilon = \sqrt{\upsilon^2 + \upsilon^2} = \sqrt{2}\upsilon = 4\sqrt{2}\ m/s.$$

bo‘ladi.

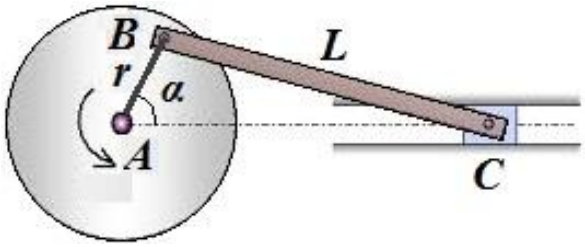
Javob: $\Delta\upsilon = 4\sqrt{2}\ m/s.$

Masala № 2. Yer radiusi *6400 km*. Yerning o‘z o‘qi atrofida aylanishida ekvatordagi nuqtaning chiziqli tezligi qanday bo‘ladi (m/s)?

Berilgan:	*Yechilishi:*
$T = 24\ soat$	Aylanma harakatda chizig‘iy tezlik quyidagicha topiladi:
$R = 6400\ km$	$\upsilon = \frac{2\pi R}{T} \approx 1674{,}7\ km/soat \approx 465\ m/s.$
$\upsilon = ?$	

Javob: 465 m/s.

Masala № 4. Rasmda avtomobil-larning motoridagi krivoship-shatun mexanizmining sxemasi berilgan. Bunda *L=BC* shatun uzuligi *r=AB* krivoship uzunligidan *3* marta uzun. Krivoshipning uzunlig *r=8 sm* va aylanish chastotasi $\nu = 20\,Hs$ ga teng. $\alpha = 60^0$ bo‘lgan paytda gorizontal slindrda haralatlanayotgan *C* porshenning tezligi nimaga teng?



Berilgan:	*Yechilishi:*
L=3r	Sinuslar teoremasidan foydalanib, *C* burchakni topamiz.
r=8 sm	$\frac{r}{\sin C} = \frac{L}{\sin\alpha};\ \ \sin C = \frac{r}{L}\sin\alpha = \frac{1}{3}\cdot\frac{\sqrt{3}}{2} = \frac{1}{2\sqrt{3}};\ \ \angle C = 16{,}8^0$
$\nu = 20\,Hs$	
$\alpha = 60^0$	Bundan *B* uchdagi tashqi burchak $\angle B' = 60^0 + 16{,}8^0 = 76{,}8^0$ ekani kelib chiqadi. *B* nuqtaning tezligi $\vartheta_B = \omega r = 2\pi\nu r \approx 10\,m/s$.
$\vartheta_C = ?$	Endi so’ralgan kattalikni topamiz.

$$\vartheta_B \cdot \cos B' = \vartheta_C \cdot \cos C;\ \ \rightarrow\ \ \vartheta_C = \frac{\cos C}{\cos B'}\vartheta_B = \frac{\cos 76{,}8^0}{\cos 16{,}8^0}\cdot 10 = 2{,}38\,m/s$$

Javob: $\vartheta_C = 2{,}38\,m/s$

Masala № 3. Velosipedchi egrilik radiusi *48 m* bo‘lgan burilishda *12 m/s* tezlikda harakatlanmoqda. Markazga intilma tezlanishni toping (*m/s²*).

Berilgan:	*Yechilishi:*
$\upsilon = 12\ m/s.$	Markazga intilma tezlanish quyidagicha topiladi:
$R = 48\ m.$	$a = \frac{\upsilon^2}{R} = 3\ m/s^2.$
$a = ?$	

Javob: $a = 3\ m/s^2$.

5-Amaliy mashg‘ulot topshirig‘i

5.1. Minutiga *1200* marta aylanayotgan ventilyator parragining ayianish davrini, aylanish chastotasini va burchak tezligini toping. J: *0,05 s; 20 Gs; 125,6 rad/s*

5.2. Diskning aylanish davri *5 s*. Aylanish o‘qidan *2 m* uzoqlikdagi nuqtaning chiziqli tezligi qanday? **Javob:** 2,512 m/s

5.3. “Vostok-5” yo‘ldosh kemasi Yer sirtidan $h = 230\ km$ balandlikda $t = 95\ soat$ vaqt davomida Yerni $N = 64$ marta aylangan bo‘lsa, u holda kemaning tezligi ϑ nimaga teng? Yer radiusi R=*6370 km*. **Javob:** $\vartheta = 7756\ m/s$

5.4. Yer radiusi *6400 km*. Yerning o‘z o‘qi atrofida aylanishida ekvatordagi nuqtaning chiziqli tezligi qanday bo‘ladi? Ekvatordan $\varphi = 41^0$ shimoliy kenglikda joylashgan Toshkent shahridagi nuqtaning chiziqli tezligi qanday? **Javob:** *465 m/s; 351 m/s*

5.5. Yerning Quyosh atrofida aylanishining chiziqli tezligi nimaga teng? *T = 365 sutka, r = 150·10⁶ km.* **Javob:** *2,99·10⁴ m/s*

5.6. Quyidagilar uchun burchak tezlikni aniqlang: a) soat milning aylanma harakatida; b) minut milining aylanma harakatida; c) sekund milining aylanma harakatida (*rad/s*). Bu burchak tezliklar qanday nisbatda? **Javob:** $a)\ \omega_1 = 1,454\cdot10^{-4}$; $b)\ \omega_2 = 1,745\cdot10^{-3}$; $c)\ \omega_3 = 0,1047$; $\omega_1 : \omega_2 : \omega_3 = 1:12:720$

5.7. Agar diametri *0,3 m* bo'lgan velosiped. G'ildiragining aylanish chastotasi *120 ayl/min* bo'lsa, velosiped tezligi qanday (*m/s*)? G‘ildirakning aylanishdagi burchak tezligi-chi? **Javob:** $0,6\pi$; 4π

5.8. Agar aylanayotgan disk ustidagi radiuslari ΔR ga farq qiladigan ikki nuqtaning chiziqli tezliklari orasidagi farq $\Delta\vartheta$ ga teng bo'lsa, diskning aylanish chastotasi va burchak tezligi qanday? **Javob:** $\nu = \frac{\Delta\vartheta}{2\pi\Delta R}$; $\omega = \frac{\Delta\vartheta}{\Delta R}$;

5.9. Quduqdan diametri $d = 20\ sm$ bo‘lgan valga o‘ralgan arqon yordamida chelakda suv chiqarilmoqda. Agar valni *15* marta aylantirganda suv olish mumkin bo‘lsa, u holda quduqning chuqurligi necha metrga teng? **Javob:** *9,42 m*

5.10. *8 rad/s* burchak tezlikka ega bo'lgan g'ildirak *40 minut*da necha marta aylanadi? Bunda u necha gradus burchakka buriladi? **Javob:** *3057 marta*; $1,1\cdot10^6$ *gardus*

5.11. Vodorod atomining elektroni $0{,}53\cdot10^{-10}$ *m* radiusli aylana bo'ylab $2{,}18\cdot10^{6}$ *m/s* chiziqli tezlik bilan harakatlanayotgan bo'lsa, elektronning aylanish chastotasini va markazga intilma tezlanishini aniqlang? **Javob:** $6{,}5\cdot10^{15}$ *Hz;* $9\cdot10^{22}$ m/s^2

5.12. Vertolyot $0{,}2$ m/s^2 tezlanish bilan vertikal pastga tusha boshladi. Agar vertolyot parragining aylanish chastotasi *50 ayl/s* bo'lsa, vertolyot *90 m* pasayguncha, parrak necha marta aylanadi? **Javob:** *1500 marta*

5.13. Poyezd egrilik radiusi *800 m* bo'lgan burilishda *20 m/s* tezlik bilan harakatlanayotganda uning markazga intilma tezlanishi qanday bo'ladi? J: $0{,}5$ m/s^2

5.14. GES turbinasining ishchi g'ildiragining diametri *7,5 m* bo'lib, u *93,8 ayl/min* chastota bilan aylanadi. Turbina kurakchalari uchlarining markazga intilma tezlanishini toping. **Javob:** *360* m/s^2

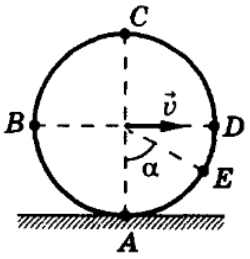
5.15. Avtomobil *72 km/soat* tezlik bilan harakatlanganda g'ildiraklarining aylanish chastotasi *8* s^{-1} bo'lsa, avtomobil g'ildiraklarining yo'lga tegadigan nuqtalarining markazga intilma tezlanishi topilsin. **Javob:** *1* km/s^2

5.16. Ikkita *M* va *K* nuqtalar rasmdagi kabi aylana bo‘ylab harakatlanmoqda. Bunda nuqtalarning burchak tezliklari mos holda $\omega_M = 0{,}2\,rad/s$, $\omega_K = 0{,}3\,rad/s$ ga teng. Boshlang‘ich paytda bu nuqtalarninng radiuslari orasidagi burchak $\pi/3$ ga teng. Oradan qancha *t* vaqt o‘tgach nuqtalar uchrashadilar? **Javob:** $t = \dfrac{50}{3}\pi \approx 52{,}3\ s$

5.17. Mushuk radiusi $R = 5m$ bo‘lgan aylana bo‘ylab sichqon tomonga $\vartheta_M = 40\,km/soat$ tezlik bilan yugura boshladi. Ular orasidagi masofa aylana uzunligining *1/8* qismiga teng bo‘lganda sichqon $\vartheta_S = 50\,km/soat$ tezlik bilan qocha boshladi. Oradan qancha *t* vaqt o‘tgach sichqon mushukdan yarim aylana yoyigacha uzoqlashib ketadi?

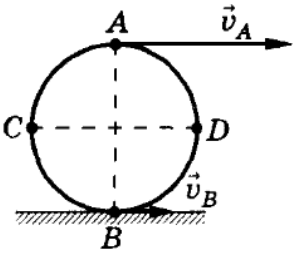
Javob: $t = \dfrac{3\pi R}{4\left(\vartheta_S - \vartheta_M\right)} \approx 4{,}24\ s$

5.18. Radiusi $R = 0{,}5\ m$ bo‘lgan bir jinsli disk gorizontal sirtda $\vartheta = 2\ m/s$ tezlik bilan sirpanishsiz aylanmoqda. Disk gardishidagi *A, B, C, D, E* nuqtalarining chiziqli tezlilarini aniqlang (*m/s*). Burchak $\alpha = 60^0$ ga teng. Diskdagi tezligi $\vartheta = 2\ m/s$ bo‘lgan barcha nuqtalarining geometrik o‘rnini aniqlang. **Javob:**



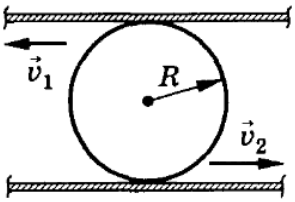
$\vartheta_A = 0;\ \vartheta_B = 2\sqrt{2};\ \vartheta_C = 4;\ \vartheta_D = 2\sqrt{2};\ \vartheta_E = 2;$ *markazi A nuqtada, radiusi* $R = 0{,}5\ m$ *bo‘lgan yoyning barcha nuqtalarida*.

5.19. R radiusli xalqa gorizontal sirtda sirg‘anib aylanmoqda. Biror vaqtda yuqorigi *A* nuqtaning tezligi $\vartheta_A = 6\ m/s$ ga, quyi *B* nuqtaning tezligi esa $\vartheta_B = 2\ m/s$ ga teng. Shu vaqtda *AB* diametrga perpendikulyar bo‘lgan *CD* diametr uchlaridagi tezlik qanday? G‘ildirak markazidagi tezlik-chi)? Aylanishlarning oniy



markazi qayerda? **Javob:** $\vartheta_B = \vartheta_D = 2\sqrt{5};\ \vartheta_O = 4;$ *B nuqtadan R ga teng masofa pastda*

5.20. Slindr rasmdagi kabi ϑ_1 va ϑ_2 tezliklar bilan harakatlanayotgan parallel reykalar orasida joylashgan. Slindrning burchak tezligi hamda o‘qining chiziqli tezligi nimaga teng? Aylanishlarning oniy markazi qayerda? **Javob:** $\omega = \frac{\vartheta_1 + \vartheta_2}{2R};\ \vartheta = \frac{\vartheta_1 - \vartheta_2}{2};$ *slindr markazidan* $x = \frac{\vartheta_1 - \vartheta_2}{\vartheta_1 + \vartheta_2} R$ *ga teng masofada tepada yoki pastda*



5.21. *1 m* uzunlikdagi tayoq yerda yotipdi. Tayoqning bir uchini o‘zgarmas *12 sm/s* tezlik bilan ko‘tarila boshlandi. Tayoqning bu uchi yerdan *80 sm* balandlikda bo‘lgan paytda ikkinchi uchining tezligi nimaga teng bo‘ladi? **Javob:** *16 sm/s*

5.22. Tekislikda tayoqcha harakatlanmoqda. Biror vaqt onida tayoqchaning bir uchining tezligi tayoqcha bo‘ylab yo‘nalgan va $\vartheta_1 = 24\ sm/s$ gat eng. Shu paytda ikkinchi uchi tezligi tayoqcha bilan $\beta = 60^0$ burchak tashkil etadi. Ikkinchi uchning tezligi nimaga teng? **Javob:** $\vartheta_2 = 48\ sm/s$

6-MAVZU: Tekis o‘zgaruvchan aylanma harakat. Burchak tezlanish. Umumiy tezlanishning miqdor va yo‘nalishi. Burchak tezlanish va chiziqli tezlanish orasidagi bog‘lanish.

Mavzuga oid muhim formulalar

$\varepsilon = \frac{\omega - \omega_0}{t} = \frac{\Delta\omega}{t} = tg\alpha$	*O‘rtacha burchak tezlanish formulasi*
$\varepsilon = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt} = \dot{\omega} \quad yoki \quad \varepsilon = \frac{d^2\varphi}{dt^2} = \ddot{\varphi}$	*Oniy burchak tezlanish formulasi*
$\omega = \omega_0 + \varepsilon t$ $\begin{cases} \omega = \omega_0 + \lvert\varepsilon\rvert t & -tezlanuvchan \\ \omega = \omega_0 - \lvert\varepsilon\rvert t & -sekinlanuvchan \end{cases}$	*Oniy burchak tezlikni aniqlash formulasi*
$\Delta\varphi = \frac{\omega + \omega_0}{2} t \quad (1)$ $\Delta\varphi = \frac{\omega^2 - \omega_0^2}{2\varepsilon} t \quad (2)$ $\Delta\varphi = \omega_0 t + \frac{\varepsilon t^2}{2} \quad (3)$	*Tekis o‘zgaruvchan aylanma harakatda burilish burchagi (burchak siljishi) ni topishning 3 ta formulasi*
$\varphi = \varphi_0 + \omega_0 t + \frac{\varepsilon t^2}{2}$	*Tekis o‘zgaruvchan aylanma harakat uchun harakat tenglamasi*
$a_\tau = \varepsilon R$ $\vec{a}_\tau = \vec{\varepsilon} \times \vec{r}$	*Chiziqli tezlanish va burchak tezlanish orasida skalyar va vektorli bog‘lanish*
$\vec{a}_{um} = \vec{a}_n + \vec{a}_\tau$ $a_{um} = \sqrt{a_n^2 + a_\tau^2} = \sqrt{\varepsilon^2 + \omega^4}\, R$	*Umumiy tezlanishning miqdor va yo‘nalishini aniqlash formulalari*
$tg\mu = \frac{a_n}{a_n} = \frac{\omega^2}{\varepsilon}$	*Tezlik va tezlanish orasidagi burchani aniqlash formulasi*

6-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Jismning tangensial tezlanishi *6 m/s²*, markazga intilma tezlanishi *8 m/s²* ga teng bo‘lsa, uning natijaviy tezlanishi qanday (m/s²)? Natijaviy tezlanish harakat yo‘nalishi bilan qanday burchak tashkil etadi?

Berilgan:

$a_\tau = 6\ m/s^2$

$a_n = 8\ m/s^2$

$a_{um} = ?$

Yechilishi:

Jismning tangensial va normal tezlanishlari bir biriga perpendikulyar yo‘nalgan bo‘ladi, shuning uchun umumiy tezlanishni pifagor teoremasi orqali topamiz:

$$a_{um} = \sqrt{a_t^2 + a_n^2} = 10\ m/s^2$$

Umumiy tezlanish va harakat yo‘nalishi orasidagi burchak tagensidan foydalanamiz.

$$tg\mu = \frac{a_n}{a_t} = \frac{8}{6} = \frac{4}{3};\ \rightarrow\ arctg\frac{4}{3} = 53^0$$

Javob: $a_{um} = 10\ m/s^2$; $\mu = 53^0$.

Masala № 2. Gorizontga burchak ostida otilgan jismning ko‘tarilish balandligi *3 m*, trayektoriyaning eng yuqori nuqtasidagi egrilik radiusi *2 m* bo‘lsa, jism gorizontga qanday burchak ostida otilgan?

Berilgan:

$h_{\max} = 3m$

$R = 2m$

$\alpha = ?$

Yechilishi:

Jismning ko‘tarilish balandligi va trayektoriyaning eng yuqorigi nuqtadagi egrilik radiusi

$$h_{\max} = \frac{\vartheta_0^2 \sin^2\alpha}{2g} \text{ va } R = \frac{\vartheta_x^2}{a_n} = \frac{\vartheta_0^2 \cos^2\alpha}{2g}$$

bo‘ladi. Ularning nisbati

$$\frac{h_{\max}}{R} = \frac{tg^2\alpha}{2} = \frac{3}{2}$$

bo‘ladi. Bundan esa

$$tg^2\alpha = 3,\ \rightarrow\ tg\alpha = \sqrt{3},\ \rightarrow\ \alpha = \frac{\pi}{3}$$

natija kelib chiqadi.

Javob: *α=60°*

Masala № 3. Jism aylana bo'ylab $\omega = 2 + 0,5t[rad]$ tenglama bilan ifodalanadigan burchak tezlik bilan harakat qilmoqda. U *20 s* da necha marta aylanadi?

Berilgan:

$\omega = 2 + 0,5t[rad]$

t=20 s

$N = ?$

Yechilishi:

$\omega = \omega_0 + \varepsilon t$ formulaga ko‘ra $\omega_0 = 2rad/s$ va $\varepsilon = 0,5rad/s^2$ ekanini aniqlaymiz.

$\Delta\varphi = \omega_0 t + \frac{\varepsilon t^2}{2}$ formulaga ko‘ra burilish burchagi

$$\Delta\varphi = 2t + 0,25t^2 = 2\cdot 20 + 0,25\cdot 400 = 140\,rad$$

ga teng bo‘ladi. Jami aylanishlar soni

$N = \frac{\Delta\varphi}{2\pi} = \frac{140\,rad}{6,28\,rad} \approx 22$ marta bo‘ladi.

Javob: *N=22*

Masala № 4. Harakat boshlanishidan *2 sek* o‘tgach tekis tezlanuvchan harakat qilayotgan g‘ildirak gardishidagi nuqtaning to‘la tezlanishi vektori shu

nuqta chiziqli tezligi yo‘nalishi bilan 60^0 burchak tashkil qilsa, g‘ildirakning burchak tezlanishi topilsin.

Berilgan:

$\omega_0 = 0$

$\alpha = \vec{a} \wedge \vec{\vartheta} = 60^0$

$t=2\ s$

$\varepsilon = ?$

Yechilishi:

So‘ralgan burchak tangensi

$$tg\mu = \frac{a_n}{a_t} = \frac{\omega^2 r}{\varepsilon r} = \frac{\omega^2}{\varepsilon} = \frac{(\omega_0 + \varepsilon t)^2}{\varepsilon} = \varepsilon t^2$$

formulaga ko‘ra

$$\varepsilon = \frac{tg\mu}{t^2} = \frac{tg60^0}{2^2} = \frac{\sqrt{3}}{4} = 0,43 rad/s^2$$

bo‘ladi.

Javob: $\varepsilon=0,43\ rad/s^2$

Masala № 5. Radiusi $R=10\ sm$ bo‘lgan g‘ildirak shunday aylanadiki, g‘ildirak radiusining burilish burchagi bilan vaqt orasidagi bog‘lanish $\varphi = A + Bt + Ct^3$ tenglama orqali berilgan, bunda $B = 2 rad/s$ va $C = 1 rad/s^3$. Harakat boshlangandan 2 sek vaqt o‘tgach, g‘ildirak gardishidagi nuqtalar uchun quyidagi kattaliklar: 1) burchak tezlik, 2) chiziqli tezlik, 3) burchak tezlanish, 4) tangensial tezlanish, 5) normal tezlanish topilsin.

Berilgan:

$\varphi = A + Bt + Ct^3$

$R=10\ sm$

$B=2\ rad/s$

$C=1\ rad/s^3$

$t=2\ s$

---

1) $\omega=?$

2) $\upsilon=?$

3) $\varepsilon=?$

4) $a_n=?$

5) $a_t=?$

Yechilishi:

1) Burchak tezlik burchakdan vaqt bo‘yicha olingan 1-tartibli hosilaga teng.

$$\omega = \dot{\varphi} = B + 3Ct^2 = 2 + 3 \cdot 1 \cdot 2^2 = 14\ rad/s$$

2) Chiziqli tezlikni topamiz.

$$\vartheta = \omega R = 14 \cdot 0,1 = 1,4\ m/s$$

3) Burchak tezlanish burchakdan vaqt bo‘yicha olingan 1-tartibli hosilaga teng.

$$\varepsilon = \dot{\omega} = 6Ct = 6 \cdot 1 \cdot 2 = 12\ rad/s^2$$

4) Normal tezlanishni topamiz.

$$a_n = \omega^2 R = 14^2 \cdot 0,1 = 19,6\ m/s^2$$

5) Tangensial tezlanishni

$$a_t = \varepsilon R = 12 \cdot 0,1 = 1,2\ m/s^2$$

Javob: $1)\ \omega = 14 rad/s;\ 2)\ \vartheta = 1,4 m/s;\ 3)\ \varepsilon = 12 rad/s^2;\ a_n = 19,6 m/s^2;\ a_n = 1,2 m/s^2$

6-amaliy mashg‘ulot topshirig‘i

6.1. Moddiy nuqta aylana bo‘ylab tekis harakat qilmoqda. Bunda tangensial (a_τ) va normal (a_n) tezlanishlar qanday bo‘ladi? Bunda tezlik va tezlanish vektorlari orasidagi burchak qanday? **Javob:** $a_\tau=0;\ a_n \neq 0;\ \pi/2$

6.2. Jism aylana bo'ylab $\omega = 2 + 0{,}5t\ [rad]$ tenglama bilan ifodalanadigan burchak tezlik bilan harakat qilmoqda. U *20 s* da necha marta aylanadi? **Javob:** *22*

6.3. Jismning tangensial tezlanishi *6 m/s²*, markazga intilma tezlanishi *8 m/s²* ga teng bo‘lsa, uning natijaviy tezlanishi qanday (*m/s²*)? Bunda tezlanish va tezlik vektorlari o‘zaro qanday burchak tashkil etadi? **Javob:** *10 m/s²; 36,87⁰*

6.4. Radiusi $R = 10\ sm$ bo‘lgan diskning burilish burchagi $\varphi = 4 + 3t + t^2\ [rad]$ qonun bo‘yicha o‘zgaradi. Diskning burchak tezligi va chiziqli tezligi qanday qonun bo‘yicha o‘zgaradi? Bunda burchak tezlanishi hamda tangensial tezlanish nimaga teng? **Javob:** $\omega = 3 + 2t\ [rad/s];\ \vartheta = 0{,}3 + 0{,}2t\ [m/s];\ \varepsilon = 2\ [rad/s^2];\ a_\tau = 0{,}2\ [m/s^2]$

6.5. Moddiy nuqta aylana bo‘ylab $\varepsilon = 1\ rad/s^2$ o‘zgarmas tezlanish bilan tinch holatdan harakat boshladi. Oradan $t = 1s$ vaqt o‘tgan onda tezlik va tezlanish orasidagi burchak nimaga teng bo‘ladi? **Javob:** *45⁰*

6.6. Maxovik harakat boshlangandan *1 min* vaqt o‘tgach *720 ayl/min* chastotaga erishadi. Maxovikning burchak tezlanishi va hamda shu o‘tgan vaqtdagi aylanishlar soni topilsin. **Javob:** $\varepsilon = 1{,}26\,rad/s^2;\ N = 360\,ayl$

6.7. Tekis sekinlashib aylanayotgan g‘ildirak ishqalanish mavjudligi tufayli *1 min* vaqt davomida o‘z chastotasini *300 ayl/min* dan *180 ayl/min* gavha kamaytirdi. G‘ildirakning burchak tezlanishi hamda shu vaqt davomidagi aylanishlar soni topilsin. **Javob:** $\varepsilon = -0{,}21 rad/s^2;\ N = 240\,ayl$

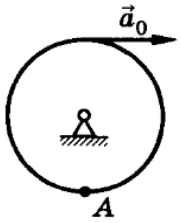
6.8. Nuqta R=20 sm radiusli aylana bo‘ylab o‘zgarmas $a_t = 5 m/s^2$ tangensial tezlanish bilan harakatlanadi. Harakat boshlanishidan qancha vaqt o‘tgach nuqtaning a_n normal tezlanishi: 1) tangensial tezlanishiga teng bo‘ladi; 2) tangensial tezlanishidan ikki marta katta bo‘ladi? **Javob:** *1) 0,2 sek; 2) 0,28 sek*

6.9. Moddiy nuqta tinch holatdan boshlab doimiy tangensial tezlanish bilan harakatlana boshlaydi. Nuqta bir marta aylangan paytda uning tezligi va tezlanishi orasidagi burchak nimaga teng bo‘ladi? Ikki marta aylanganda-chi? **Javob:** $\varphi = arctg(4\pi) = 85^0 27';\ \varphi = arctg(8\pi) = 87^0 43'$

6.10. Avtomobil yo‘lning radiusi *R=40 m* bo‘lgan egrilangan qismida $\ell = A + Bt + Ct^2$ qonun bo‘yicha harakatlanmoqda. Bu yerda $A = 5m;\ B = 12\,m/s;\ C = -0{,}5\ m/s^2$ ga teng. Avtomobilning *t=4 s* vaqt onidagi tezligini va burchak tezligini hamda tangensial, normal va to‘la tezlanishlarini aniqlang. **Javob:** $\vartheta = 8m/s;\ \omega = 0{,}2\,rad/s;\ a_\tau = -1m/s^2;\ a_n = 1{,}6\,m/s^2;\ a = 1{,}887\,m/s^2$

6.11. Moddiy nuqta *R=3 m* radiusli aylana bo‘ylab $\varphi = 2 + 2t - t^2\ [rad]$ qonunga muvofiq harakatlanmoqda. Nuqtaning to‘xtaguncha bosib o‘tgan yo‘li va sarflangan vaqtini aniqlang. $t_1 = 0{,}5\,sek$ vaqt onidagi to‘la tezlanishi nimaga teng? **Javob:** $\ell = 9\,m;\ t = 1s;\ a = 3\sqrt{5} = 6{,}71\ m/s^2$

6.12. Radiusi $R=0,5\ m$ bo‘lgan shkiv unga o‘ralgan ip yordamida rasmdagi kabi aylanma harakatga keltiriladi. Ipning uchi $a_0 = 0,1\ m/s^2$ tezlanish bilan tortiladi. $t=2\ s$ vaqtdan keyin shkivning quyi A nuqtasining tangensial, normal va to‘la tezlanishini aniqlang?



Javob: $a_\tau = 0,1\ m/s^2;\ \ a_n = 0,08\ m/s^2;\ a = 0,128\ m/s^2$

6.13. Ikki shkiv tasmali uzatma orqali bog‘langan. Birinchi shkiv minutiga *600* marta, ikkinchisi esa *3000* marta aylanadi. Agar ikkinchi shkivning diametri $d_2 = 10\,sm$ bo‘lsa, u holda birinchi shkivning diametri qanday? Bunda uzatmaning uzatish soni nimaga teng? **Javob:** $d_1 = 50\,sm;\ U = 1/5$

6.14. G‘ildirak o‘zgarmas $\varepsilon = 2\,rad/s^2$ burchak tezlanish bilan aylanadi. Harkat boshlangandan *0,5 sek* o‘tgach g‘ildirakning to‘la tezlanishi $a = 13,6\,sm/s^2$ ga teng bo‘lsa, uning radiusini aniqlang. **Javob:** *6,1 m*

6.15. Nuqta $R=10\ sm$ radiusli aylana bo‘ylab o‘zgarmas a_t tangensial tezlanish bilan harakatlanadi. Agar harakat boshlangandan keyingi beshincha marta aylanish oxirida nuqtaning tezligi $\vartheta = 79,2\,sm/s$ ga yetgan bo‘lsa, nuqtaning a_t tangensial tezlanishi topilsin. **Javob:** $a_t = 10\,sm/s^2$

6.16. Nuqta aylana bo‘ylab shunday harakatlanadiki, $s = A + Bt + Ct^2$ tenglama orqali brilgan, bunda $B = -2\,m/s$ va $C = 1m/s^2$. Agar harakat boshlanishidan $t_1 = 2\,s$ o‘tgach nuqtaning normal tezlanishi $a_{n1} = 0,5m/s^2$ ga teng bo‘lsa, harakat boshlanishidan $t_2 = 3s$ o‘tgandan keying nuqtaning chiziqli tezligi, tangensial, normal va to‘la tezlanishlarini aniqlang. **Javob:** $\vartheta_2 = 4m/s;\ a_t = 2m/s^2;$ $a_{n2} = 2m/s^2;\ a_2 = 2,83m/s^2$

6.17. Radiusi $R=5\ sm$ bo‘lgan g‘ildirak shunday aylanadiki, g‘ildirak radiusining burilish burchagi bilan vaqt orasidagi bog‘lanish $\varphi = A + Bt + Ct^2 + Dt^3$ tenglama orqali berilgan, bunda $D = 1rad/s^3$. Harkatning har sekundida g‘ildirak gardishida yotgan nuqtalar uchun tangensial tezlanish Δa_t ning o‘zgarishi topilsin. **Javob:** $\Delta a_t = 0,3m/s^2$

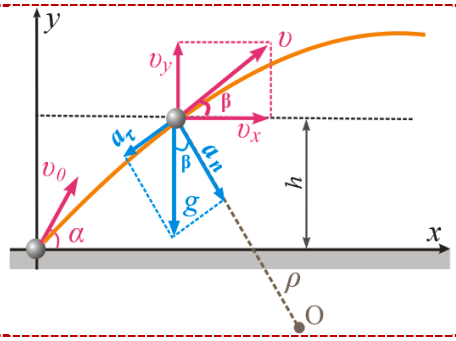
6.18. Radiusi $R=5\ sm$ bo‘lgan g‘ildirak shunday aylanadiki, g‘ildirak gardishidagi nuqtalar chiziqli tezligining vaqtga bog‘lanishi $\vartheta = At + Bt^2$ tenglama orqali beriladi, bunda $A = 3sm/s^2$ va $B = 1sm/s^3$. Ixtiyotiy vaqt oni uchun to‘la tezlanish vektori va radius orasidagi burchak tangensini aniqlash formulasini keltririb chiqaring. Harakat boshlangandan *t=1 sek* va *t=3 sek* vaqt o‘tgandan keyin to‘la tezlanish vektori bilan radius orasidagi burchakni toping. **Javob:** $tg\alpha = \dfrac{(3+2t)R}{(3t+t^2)^2};\ \alpha_1 = 72,3^0;\ \alpha_2 = 15,5^0$

7-MAVZU: Gorizontal otilgan jismlarning harakati. Gorizontga nisbatan burchak ostida otilgan jismlarning harakati. Burchak ostida otilgan jism uchun ixtiyoriy ondagi normal tezlanish, tangensial tezlanish hamda trayektoriyaning egrilik radiusini aniqlash.

Mavzuga oid muhim formulalar

$\begin{cases} \vartheta_{0x} = \vartheta_0 \cos\alpha \\ \vartheta_{0y} = \vartheta_0 \sin\alpha \end{cases}$	*Gorizontga burchak ostida otilgan jism tezligining otilish onidagi proyeksiyalari*
$\begin{cases} \vartheta_x = \vartheta_{0x} = \vartheta_0 \cos\alpha = const \\ \vartheta_y = \vartheta_{0y} - gt = \vartheta_0 \sin\alpha - gt \end{cases}$	*Gorizontga burchak ostida otilgan jism tezligining ixtiyoriy vaqt onidagi proyeksiyalari*
$\begin{cases} x = \vartheta_0 t \cos\alpha \\ y = y_0 + \vartheta_0 t \sin\alpha - gt^2/2 \end{cases}$	*Gorizontga burchak ostida otilgan jismning harakat tenglamasi*
$y = y_0 + tg\alpha\, x - \dfrac{g}{2\vartheta_0^2 \cos^2\alpha} x^2$	*Gorizontga burchak ostida otilgan jismning trayektoriya tenglamasi*
$\begin{cases} t_k = \dfrac{\vartheta_0 \sin\alpha}{g} \\ t_{uch} = \dfrac{2\vartheta_0 \sin\alpha}{g} \end{cases} \quad \begin{cases} h_{\max} = \dfrac{\vartheta_0^2 \sin^2\alpha}{2g} \\ \ell_{uch} = \dfrac{\vartheta_0^2 \sin 2\alpha}{g} \end{cases}$	*Yer sirtidan gorizontga burchak ostida otilgan jismning ko'tarilish vaqti, uchish vaqti, maksimal ko'tarilish masofasi va uchish uzoqligini aniqlash formulalari*
$t_{uch} = \sqrt{\dfrac{2h}{g}}, \quad l_{uch} = \vartheta_0 \sqrt{\dfrac{2h}{g}}$ $\vartheta_{tush} = \sqrt{\vartheta_0^2 + 2gh} = \sqrt{\vartheta_0^2 + (g\,t_{uch})^2}$ $tg\alpha_{tush} = \dfrac{\sqrt{2gh}}{\vartheta_0}$	*Yer sirtidan biror balandlikdan turib gorizontal holda otilgan jismning uchish vaqti, uchish uzoqligi, tushish tezligi va tushish burchagini aniqlash formulalari*
$\begin{cases} t_{uch} = \dfrac{\sqrt{\vartheta_0^2 \sin^2\alpha + 2g\,h} + \vartheta_0 \sin\alpha}{g} \\ \ell_{uch} = \vartheta_0 \cos\alpha\, t_{uch} \end{cases}$ $\begin{cases} \vartheta_{tush} = \sqrt{\vartheta_0^2 + 2g\,h} \\ tg\beta_{tush} = \dfrac{\vartheta_y}{\vartheta_x} = \dfrac{\sqrt{(\vartheta_0 \sin\alpha)^2 + 2g\,h}}{\vartheta_0 \cos\alpha} \end{cases}$	*Yer sirtidan biror balandlikdan turib gorizontga burchak ostida otilgan jismning uchish vaqti, uchish uzoqligi, tushish tezligi va tushish burchagini aniqlash formulalari*
Gorizontga burchak ostida otilgan jismning uchish trayektoriyasining ixtiyoriy nuqtasidagi normal tezlanishi, tangensial tezlanishi va trayektoriyaning egrilik radiusini aniqlash formulalari	

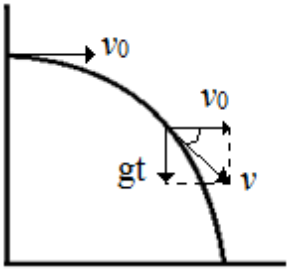
$$\begin{cases} a_n = \cos\beta \cdot g = \dfrac{\vartheta_x}{\vartheta} g \\ a_\tau = \sin\beta \cdot g = \dfrac{\vartheta_y}{\vartheta} g \\ \rho = \dfrac{\vartheta^2}{a_n} \end{cases}$$



7-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Tosh gorizontal yo‘nalishda otildi. *3 s* dan keyin tezlik vektori yer sirti bilan *60°* burchak hosil qilgan bo‘lsa, toshning boshlang‘ich tezligi qanday (*m/s*)?

Berilgan:	*Yechilishi:*
t=3s $\alpha = 60^o$ υ_0=?	Biror balandlikdan gorizontal otilgan jismning 3s dan keyingi vertikal yo‘nalishdagi tezligi $\upsilon_y = gt$ bo‘ladi va biz bu tezlik vektorini proeksiyalaymiz va bu bizga boshlag‘ich tezlikni topishimizda yordam beradi.



$$\frac{gt}{\upsilon_0} = tg\alpha\ ; \quad \upsilon_0 = \frac{gt}{tg\alpha}\ ; \quad \upsilon_0 = \frac{10 \cdot 3}{\sqrt{3}} = \frac{30}{\sqrt{3}}\ m/s.$$

Javob: $30/\sqrt{3}$.

Masala № 2. Balandligi 80 m bo‘lgan minoradan jism *600 m/s* tezlik bilan gorizontal yo‘nalishda otildi. Havoning qarshiiigi nisobga olinmasa, jismning uchush uzoqligi qanday (*km*) bo‘ladi?

Berilgan:	*Yechilishi:*
υ_0=600 m/s h=80 m S=?	Biror balandlikdan gorizontal otilgan jismning uchish uzoqligi quyidagi ifoda yordamida aniqlanadi:

$$S = \upsilon_0 \cdot \sqrt{\frac{2h}{g}}\ ; \quad S = 600 \cdot \sqrt{\frac{2 \cdot 80}{10}} = 2{,}4\ km.$$

Javob: *S=2,4 km*

Masala № 3. Gorizontga burchak ostida *10 m/s* tezlik bilan otilgan jismning uchish davomidagi minimal tezligi *6 m/s* bo‘lsa, uning uchish vaqti qanday (*s*) bo‘ladi? *g= 10 m/s²*.

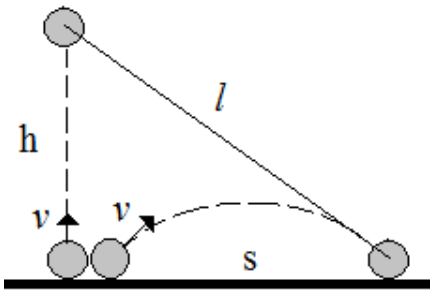
Berilgan:	*Yechilishi:*
v_0 =10 m/s v_{min}=6 m/s	Bu holda minimal tezlik traektoriyaning eng yuqori nuqasida bo‘ladi va u gorizontal yo‘nalishdagi v_{min}= v_x tezlikka teng.
t=?	$$v_x = v_0 \cdot cos\alpha$$ ekanidan foydalanib jismning gorizontga qanday burchak ostida otilganligini topib olamiz va $t = \frac{2v_0 sin\alpha}{g}$ formula orqali jismni uchish vaqtini topib olamiz. $cos\alpha = \frac{6}{10} = \frac{3}{5}$. Triginometrik $sin\alpha = \sqrt{1 - cos^2\alpha}$ ayniyati orqali sinα ni topib olamiz.

$$sin\alpha = \sqrt{1 - \frac{9}{25}} = \frac{4}{5}; \qquad t = \frac{2 \cdot 10 \cdot \frac{4}{5}}{10} = 1{,}6 \text{ s}.$$

Javob: *t=1,6 s*

Masala № 4. Bir vaqtning o‘zida ikkita jism bir nuqtadan bir xil 10 m/s boshlang‘ich tezlik bilan biri vertikal va ikkinchisi gorizontga nisbatan 30° burchak ostida yuqoriga otildi. 1 s dan keyin jismlar orasidagi masofa qanday bo‘ladi (m)?

Berilgan:	*Yechilishi:*
v=10 m/s $\alpha = 30^o$ t=1 s	Rasmda ko‘rib turganingizday biz *l* masofani topishimiz kerak. Uning uchun avvalo jismlarning t vaqtdan keyingi vaziatlarini topishimiz kerak. Birinchi jismni qancha vaqt davomida yuqoriga ko‘tarilishini $t = \frac{v}{g}$ formula
h=?	



orqali topsak 1 sekund chiqishi, ya’ni maksimal ko‘tarilishbalandligida ekanini ayon bo‘ladi. Ikkinchi jismni uchish vaqtini $t = \frac{2v_0 sin\alpha}{g}$ formula orqali topsak 1 sekund chiqadi, y’ani biz bundan jism allaqachon erga tushganini xulosa qilamiz! Ikki jism orasidagi l masofa esa $l = \sqrt{h^2 + S^2}$ pifagor teoremasi orqali topilasi. S va h masofalar esa quyidagicha topiladi:

$$S = \frac{v^2 sin2\alpha}{g} \qquad h = \frac{v^2}{2g};$$

$$S = \frac{10^2 \cdot \frac{\sqrt{3}}{2}}{10} = 5\sqrt{3}\, m; \qquad h = \frac{10^2}{2 \cdot 10} = 5\, m\,; \quad \ell = \sqrt{5^2 + \left(5\sqrt{3}\right)^2} = 10\, m.$$

Javob: ℓ=10 m

Masala № 5. Gorizontga burchak ostida otilgan jismning ko‘tarilish balandligi *3 m*, trayektoriyaning eng yuqori nuqtasidagi egrilik radiusi *2 m* bo‘lsa, jism gorizontga qanday burchak ostida otilgan?

Berilgan:	*Yechilishi:*
$h_{\max}=3m$ $R=2m$	Jismning ko‘tarilish balandligi va trayektoriyaning eng yuqorigi nuqtadagi egrilik radiusi $h_{\max}=\frac{\vartheta_0^2\sin^2\alpha}{2g}$ va $R=\frac{\vartheta^2}{a_n}=\frac{\vartheta_x^2}{g}=\frac{\vartheta_0^2\cos^2\alpha}{g}$
$\alpha=?$	bo‘ladi. Ularning nisbati $\frac{h_{\max}}{R}=\frac{tg^2\alpha}{2}=\frac{3}{2}$

bo‘ladi. Bundan esa

$$tg^2\alpha=3,\ \rightarrow\ tg\alpha=\sqrt{3},\ \rightarrow\ \alpha=\frac{\pi}{3}$$

natija kelib chiqadi.

Javob: *α=60°*

Masala № 6. Yer sirtidan gorizontga *60⁰* burchak ostida *100 m/s* boshlang‘ich tezlik bilan jism otildi. Oradan *4 s* vaqt o‘tgan onadagi tangensial tezlanish, normal tezlanish va trayektoriya (shoxi pastga qaragan parabola) ning egrilik radiusi nimaga teng?

Berilgan:	*Yechilishi:*
υ_0=100 m/s $\alpha=60^0$ t=2 s	Yer sirtidan burchak ostida otilgan jismning ixtiyoriy *t* vaqt onidagi tezlikning proyeksiyalari va tezlikning o‘zini aniqlaymiz. $\begin{cases}\vartheta_x=\vartheta_{0x}=\vartheta_0\cos\alpha=100\cdot\cos60^0=50\,m/s\\ \vartheta_y=\vartheta_{0y}-gt=\vartheta_0\sin\alpha-gt=100\cdot\sin60^0-10\cdot4=50\sqrt{3}-40=46,6\,m/s\end{cases}$ $\vartheta=\sqrt{\vartheta_x^2+\vartheta_y^2}=\sqrt{50^2+46,6^2}=68,35m/s$
$a_t=?$ $a_n=?$ R=?	Endi so’ralgan kattaliklarni aniqlaymiz. $\begin{cases}a_n=\cos\beta\cdot g=\frac{\vartheta_x}{\vartheta}g=\frac{50}{68,35}\cdot10=7,31m/s^2\\ a_\tau=\sin\beta\cdot g=\frac{\vartheta_y}{\vartheta}g=\frac{46,6}{68,35}\cdot10=6,81m/s^2\\ \rho=\frac{\vartheta^2}{a_n}=\frac{68,35^2}{7,31}=297\,m\end{cases}$

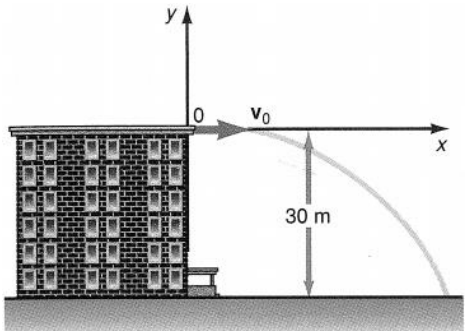
Javob: $a_n=7,31m/s^2;\ a_\tau=6,81m/s^2;\ \rho=297\,m$

7-amaliy mashg‘ulot topshirig‘i

Gorizontal hoda otilgan jism harakati.

7.1. Tepalikdan gorizontal otilgan jism *5 s* dan so‘ng yerga tushgan bo‘lsa, tepalik balandligi qanday? **Javob:** *125 m*

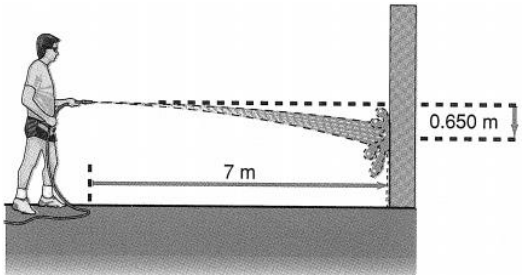
7.2. Jism *30 m* balandlikdagi binoning tepasidan *20 m/s* boshlang‘ich tezlik bilan rasmda ko‘rsatilgani kabi gorizontal holda otildi. Quyidagilarni aniqlang: *a)* jismning uchish vaqtini; *b)* jismning binodan qancha masofaga borib tushishini; *c)* yerga urilish tezligini; *d)* tushish burchagini; e) ko‘chishni. $g = 9{,}8\ m/s^2$. **Javob:** *a) 2,47 s; b) 49,4 m; c) 31,4 m/s; d) 50,4⁰; e) 57,8 m*



7.3. Tosh gorizontal yo‘nalishda otildi. *5 s* dan keyin tezlik vektori yer sirti bilan *60°* burchak hosil qilgan bo‘lsa, toshning boshlang‘ich tezligi nimaga teng? **Javob:** $50/\sqrt{3}\ m/s$

7.4. *h* balandlikdan ϑ_0 boshlang‘ich tezlik bilan gorizontal otilgan jism borib tushgan nuqtaga tushishi uchun uni *h/2* balandlikdan qanday gorizontal tezlik bilan otish kerak? **Javob:** $\sqrt{2}\upsilon_0$

7.5. Nasosga ulangan suv purkovchi shlangdan otilib chiqayotgan suvning tezligini aniqlash maqsadida shlangni rasmdagi kabi gorizontal holda tutib turilibdi. Shlangdan *7 m* masofadagi vertikal devorga tik holda otilib chiqayotgan suyuqlik oqimi gorizontal sathdan *0,65 m* pastroq sathdagi nuqtaga uriladi. Shlangdan suv qanday tezlikda otilib chiqmoqda? Suyuqlik oqimi devorga qanday burchak ostida uriladi? Havoning qarshiligini hisobga olmang. $g = 9{,}8\ m/s^2$. **Javob:** *19,22 m/s; 79,5⁰*



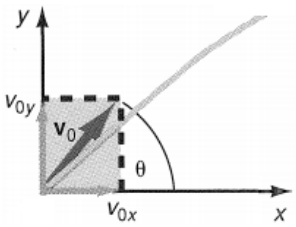
7.6. Samolyot gorizontal yo‘nalishda *8 km* balandiikda *720 km/soat* tezlik bilan uchmoqda. Uchuvchi bombani nishonga aniq tushirishi uchun nishonga qanday masofa (gorizontal yo‘nalishda) qolganda tashlashi kerak bo‘ladi? Havoning qarshiligini hisobga olmang. **Javob:** *8 km*

7.7. Balandligi *105 m* bo‘lgan qoya chetida turgan bola qo‘lidagi toshni *20 m/s* tezlik bilan gorizontal otdi. Toshning yerga urilish paytidagi tezligi nimaga teng? Tosh yerga qanday burchak ostida uriladi? $g=10\ m/s^2$. **Javob:** *50 m/s; 66,4⁰*

7.8. Jism tog‘ cho‘qqisidan *50 m/s* tezlik bilan gorizontal holda otilgan. Uning harakat boshidan *4 s* o‘tgan paytdagi markazga intilma tezlanishi, tangensial tezlanishi hamda parabolaning egrilik radiusi qanday? **Javob:** *7,8 m/s²; 6,26 m/s²; 525,64 m*

Gorizontga burchak ostida otilgan jism harakati.

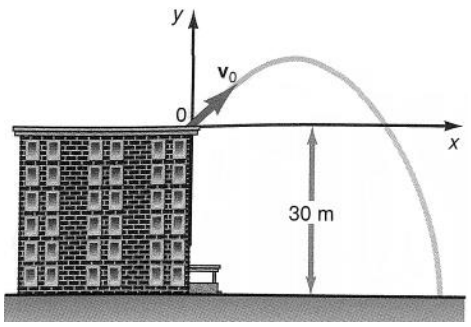
7.9. Sharcha gorizontga *30°* burchak ostida *30 m/s* boshlang‘ich tezlik bilan otildi. Boshlang‘ich tezlik vektorining gorizontal va vertikal tashkil etuvchilari nimaga teng? J: *26 m/s; 15 m/s*



7.10. Uzoqlikka sakrash bo‘yicha o‘tkazilgan chempionatda g‘olib 6,5 *m* natija ko‘rsatdi. Agar u Oyda bo‘lganda edi bu

natija nimaga teng bo‘lar edi? Marsda bo‘lganda-chi? Erkin tushish tezlanishining qiymati Oyda *1,62 m/s²* ga, Marsda esa *3,71 m/s²* ga teng. $g = 9{,}8\ m/s^2$. **Javob:** *39,32 m; 17,17 m*

7.11. *30 m* balandlikdagi binoning tepasidan jism gorizontga 30^0 burchak ostida *36 m/s* tezlik bilan rasmdagi kabi otildi. Quyidagilarni aniqlang: *a)* jismning yerdan maksimal ko‘tarilish balandligini; *b)* trayektoriyaning eng yuqorigi nuqtasiga ko‘tarilguncha o‘tgan vaqni; *c)* uchish vaqtini; *d)* yerga urilish oldidagi tezlikni; *e)* uchish masofasini; *f)* tushish burchagini; *g)* ko‘chishni. $g = 9{,}8\ m/s^2$. **Javob:** *a) 46,53 m ; b) 1,84 s; c) 4,92 s; d) 43,4 m/s; e) 153,4 m; f) 44^0; g) 156,3 m*



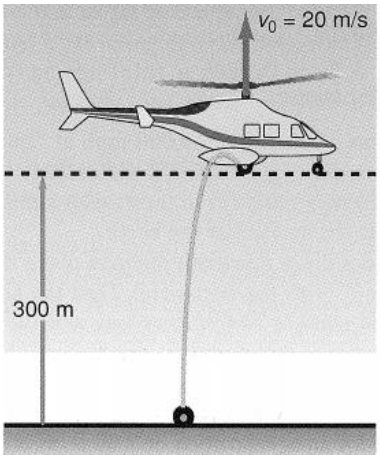
7.12. Zambarakdan gorizontga burchak ostida otilgan snaryad *45 m* balandlikka ko‘tarildi. Uning uchish vaqtini toping. *g=10 m/s²*. J: *6 s*

7.13. Yer sirtidan gorizontga nisbatan $\alpha_1 = 60^0$ burchak ostida $\vartheta_{01} = 100\ m/s$ boshlang‘ich tezlik bilan otilgan jism va $\alpha_2 = 30^0$ burchak ostida otilgan jismlarning uchish vaqtlari teng. 2-jism qanday boshlang‘ich tezlik bilan otilgan? Bunda ularning uchish masofalari nisbati nimaga teng? Maksimal ko‘tarilish balandliklari nisbati-chi? *g=10 m/s²*. **Javob:** $\vartheta_{02} = 173\ m/s$; $\frac{\ell_1}{\ell_2} = \frac{1}{3}$; $\frac{h_{max1}}{h_{max2}} = 1$

7.14. Yer sirtidan gorizontga nisbatan $\alpha_1 = 60^0$ burchak ostida $\vartheta_{01} = 100\ m/s$ boshlang‘ich tezlik bilan otilgan jism va $\alpha_2 = 30^0$ burchak ostida otilgan jismlarning uchish masofalari teng. 2-jism qanday boshlang‘ich tezlik bilan otilgan? Bunda ularning uchish vaqtlari nisbati nimaga teng? Maksimal ko‘tarilish balandliklari nisbati-chi? *g=10 m/s²*. **Javob:** $\vartheta_{02} = 100\ m/s$; $\frac{t_1}{t_2} = \sqrt{3}$; $\frac{h_{max1}}{h_{max2}} = 3$

7.15. Yer sirtidan gorizontga nisbatan α burchak ostida ϑ_0 boshlang‘ich tezlik bilan otilgan jism va *h* balandlikdan gorizontal holda otilgan jismlarning uchish vaqtlari bir xil bo‘lsa, *h* balandlik nimaga teng? **Javob:** $\frac{2\vartheta_0 \sin\alpha}{\sqrt{2g}}$

7.16. *20 m/s* tezlik bilan tik holda yuqoriga ko‘tarilayotgan vertolyotdan po‘lat sharcha tushib ketganda vertolyot yerdan *300 m* balandlikda edi. Sharcha yerga nisbatan qancha balandlikkacha ko‘tarila oladi? Sharchaning yerga tushgunicha qancha vaqt o‘tadi? Sharcha yerga qanday tezlik bilan uriladi? Havoning qarshiligini e’tiborga olmang. $g = 10\ m/s^2$. **Javob:** *320 m; 10s; 80 m/s*



7.17. Yerning ta'sir maydonida harakatlanayotgan jism gorizont bilan 53^0 burchak tashkil etgan paytda jismning markazga intilma tezlanishi va tangensial tezlanishi nimaga teng bo'ladi? **Javob:** $a_n = 6\ m/s^2;\ a_\tau = 8\ m/s^2$

7.18. Yer sirtidan *60 m/s* ga teng boshlang'ich tezlik bilan 60^0 burchak ostida otilgan jism uchun harakat tenglamasini va trayektoriya tenglanmasini yozing. **Javob:** $\begin{cases} x = 30t \\ y = 30\sqrt{3}t - 5t^2 \end{cases};\quad y = \sqrt{3}x - \frac{1}{180}x^2$

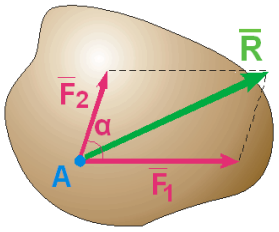
7.19. Yer sirtidan *50 m* balandlikdan *80 m/s* ga teng boshlang'ich tezlik bilan 30^0 burchak ostida otilgan jism uchun harakat tenglamasini va trayektoriya tenglanmasini yozing. Bunda tezlikning o'qlardagi proyeksiyalari va tezlik vaqt bo'yicha qanday o'zgaradi? **Javob:** $\begin{cases} x = 40\sqrt{3}t \\ y = 50 + 40t - 5t^2 \end{cases};\quad y = 50 + \frac{1}{\sqrt{3}}x - \frac{1}{960}x^2;\quad \begin{cases} \vartheta_x = 20\sqrt{3} \\ \vartheta_y = 40 - 5t \end{cases};$

$\vartheta = \sqrt{2800 - 400t + 25t^2}$

7.20. Koptokni $h = 2m$ balandlikdan gotizontga nisbatan $\alpha = 30^0$ burchak ostida pastga qiyalatib boshlang'ich $\vartheta_0 = 10\,m/s$ tezlik bilan otildi. Koptokning yerga ketma-ket ikki marta urilishi orasidagi masofa s ni aniqlang. Urilishni absalyut elastik deb, erkin tushish tezlanishini $g = 10\ m/s^2$ deb hisoblang. **Javob:** *13,96 m*

8-MAVZU: Nyuton (dinamika) qonunlari. Kuch, massa va zichlik tushuncahalari. Dinamikaning ikki masalasi. Kuch vaqtning, masofaning, tezlikning funksiyasi bo‘lganda harakat tenglamasi va tezlik tenglamasini aniqlash.

Mavzuga oid muhim formulalar

$\vec{F} = m \cdot \vec{a}, \quad F = ma$	*Nyuton (Dinamika) ning ikkinchi qonunini vektor va skalyar ko‘rinishlari*
$\rho = \frac{m}{V}, \quad 1\frac{g}{sm^3} = 1000\,\frac{kg}{m^3}$	*Zichlik*
$F_{og'} = mg$	*Og‘irlik kuchi*
$m\vec{a} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots + \vec{F}_n = \sum_{i=1}^{n} \vec{F}_i = \vec{R}$	*Nyutonning ikkinchi qonunini kuchlar sistemasi uchun geometrik ko‘rinishda berilishi*
$ma_x = F_{1x} + F_{2x} + F_{3x} + \ldots + F_{nx} = \sum_{i=1}^{n} F_{ix} = R_x$ $ma_y = F_{1y} + F_{2y} + F_{3y} + \ldots + F_{ny} = \sum_{i=1}^{n} F_{iy} = R_y$ $ma_z = F_{1z} + F_{2z} + F_{3z} + \ldots + F_{nz} = \sum_{i=1}^{n} F_{iz} = R_z$	*Nyutonning ikkinchi qonunini kuchlar sistemasi uchun analitik ko‘rinishda (proyeksiyalar orqali) berilishi*
Bir nuqtaga qo‘yilgan ikki kuch $\vec{R} = \vec{F}_1 + \vec{F}_2$ $\lvert\vec{R}\rvert = \sqrt{\lvert\vec{F}_1\rvert^2 + \lvert\vec{F}_2\rvert^2 + 2\lvert\vec{F}_1\rvert\lvert\vec{F}_2\rvert\cos\gamma}$ 	
$F_X = m\frac{d^2x}{dt^2} = m\ddot{x},\ F_Y = m\frac{d^2y}{dt^2} = m\ddot{y},\ F_Z = m\frac{d^2z}{dt^2} = m\ddot{z}$	*Nyutonning ikkinchi qonunini differensial ko‘rinishda berilishi*
$F = \sqrt{F_X^2 + F_Y^2 + F_Z^2}$ $\cos\left(\vec{F} \wedge x\right) = \frac{F_X}{F},\ \cos\left(\vec{F} \wedge y\right) = \frac{F_y}{F},\ \cos\left(\vec{F} \wedge z\right) = \frac{F_z}{F}$	*Proyeksiyalar ma’lum bo‘lganda teng ta’sir etuvchining miqdor va yo‘nalishini aniqlash*
$\begin{cases} \vec{F}_{1,2} = -\vec{F}_{2,1} \\ F_{1,2} = -F_{2,1} \end{cases}$	*Nyuton (Dinamika) ning uchinchi qonunini vektorli va skalyar ko‘rinishlari*
$\frac{a_1}{a_2} = \frac{m_2}{m_1}$	*Tezlanishlar nisbati massalarning teskari nisbatiga teng*
Tezlanish $a = a(t)$ *ko‘rinishda berilgandab, tezlik* $\vartheta = \vartheta(t)$ *va koordinata* $x = x(t)$ *tenglamalarini aniqlash formulalari*	

$$\vartheta = \vartheta_0 + \int_0^t a(t)\,dt, \qquad x = x_0 + \int_0^t \vartheta(t)dt = x_0 + \int_0^t \left(\vartheta_0 + \int_0^t a(t)\,dt \right) dt$$

Tezlanish $a = a(x)$ *ko'rinishda berilganda, tezlik* $\vartheta = \vartheta(x)$ *va vaqt* $t = t(x)$ *tenglamalarini aniqlash formulalari*

$$\vartheta = \sqrt{\vartheta_0^2 + 2\int_{x_0}^{x} a(x)dx}, \qquad t = \int_{x_0}^{x} \frac{dx}{\sqrt{\vartheta_0^2 + 2\int_{x_0}^{x} a(x)dx}}$$

Tezlanish $a = a(\vartheta)$ *ko'rinishda berilganda, vaqt* $t = t(\vartheta)$ *va koordinata* $x = x(\vartheta)$ *tenglamalarini aniqlash formulalari*

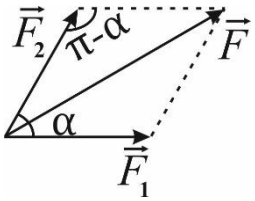
$$t = \int_{\vartheta_0}^{\vartheta} \frac{d\vartheta}{a(\vartheta)}, \quad x = x_0 + \int_{\vartheta_0}^{\vartheta} \frac{\vartheta\, d\vartheta}{a(\vartheta)}$$

8-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Jismning bir nuqtasiga 2 ta *10 N* dan bo'lgan kuchlar o'zaro 60° burchak ostida ta'sir etmoqda. SHu kuchlarning teng ta'sir etuvchisini toping (N). $cos60^o = 0{,}5;\ \sqrt{3} = 1{,}73.$

Berilgan:
$F_1=F_2=F_0=10$ N
$\alpha=60°$
F=?

Yechilishi: Teng ta'sir etuvchi kuchni kosinuslar teoremasidan foydalanib topamiz.



$$F^2 = F_1^2 + F_2^2 - 2 \cdot F_1 \cdot F_2 \cdot \cos(\pi - \alpha).$$

Masala shartiga ko'ra $F_1 = F_2 = F_0$ buni va $\cos(\pi - \alpha) = -\cos\alpha$ ekanligini inobatga olib quyidagini yozamiz:

$$F^2 = F_0^2 + F_0^2 + 2 \cdot F_0 \cdot F_0 \cdot \cos\alpha.$$

$$F = \sqrt{F_0^2 + F_0^2 + 2 \cdot F_0 \cdot F_0 \cdot \cos\alpha} = F_0 \cdot \sqrt{2 \cdot (1 + \cos\alpha)} = 10 \cdot \sqrt{2 \cdot \left(1 + \frac{1}{2}\right)} \approx 17{,}3\ N.$$

Javob: F=17,3.

Masala № 2. Moddiy nuqtaga 6 N kuch ta'sir etadi. Uning harakat tezligi $v_x = 10 + 2t$ qonun bo'yicha o'zgaradi. Nuqtaning massasi qanday (kg)?

Berilgan:
F=6 N
$v = 10 + 2t$
m=?

Yechilishi: Tezlikning o'zgarish tenglamasidan tezlanishni topamiz.

$$\begin{cases} v = v_0 + at \\ v = 10 + 2t \end{cases} \Rightarrow \quad a = 2\ m/s^2.$$

Nyutonning ikkinchi qonuniga asosan

$$a = \frac{F}{m} \quad \Rightarrow \quad m = \frac{F}{a} = \frac{6}{2} = 3\ kg.$$

Javob: m= 3 kg.

Masala № 3. Massasi *6 t* bo‘lgan, yuk ortilmagan avtomobil *0,6 m/s²* tezlanish bilan harakatlana boshladi. Agar u o‘sha tortish kuchida joyidan *0,4 m/s²* tezlanish bilan qo‘zg‘alsa, unga ortilgan yukning massasi necha tonna?

Berilgan:
m_1=6 t
a_1=0,6 m/s²
a_2=0,4 m/s²
F=const
Δm=?

Yechilishi:
Nyutonning ikkinchi qonuniga asosan quyidagilarni yozamiz:

$$\begin{cases} F = m_1 \cdot a_1 \\ F = m_2 \cdot a_2 \end{cases} \Rightarrow m_1 \cdot a_1 = m_2 \cdot a_2 \Rightarrow m_2 = \frac{a_1}{a_2} \cdot m_1.$$

$$\Delta m = m_2 - m_1 = m_1 \cdot \left(\frac{a_1}{a_2} - 1\right) = 6 \cdot \left(\frac{0{,}6}{0{,}4} - 1\right) = 3\ t.$$

Javob: $\Delta m = 3\ t$.

Masala № 4. Ko‘ndalang kesim yuzi $3mm^2$ bo‘lgan mis sim o‘ramning massasi *1,78 kg*. Simning uzunligini toping. Misning zichligi $8{,}9\frac{g}{sm^3}$.

Berilgan:
$S = 3mm^2$
m=1,78 kg
$\rho = 8{,}9\frac{g}{sm^3}$
m=?

Yechilishi: XBSda yuza $S = 3mm^2 = 3 \cdot 10^{-6} m^2$ga, zichlik esa $\rho = 8{,}9\frac{g}{sm^3} = 8900\frac{kg}{m^3}$ga teng bo‘ladi. Hajm formulasi $V = S\ell$ ni zichlik formulasi $\rho = \frac{m}{V}$ ga qo‘ysak, $\rho = \frac{m}{S\ell}$ bo‘ladi. Bundan $\ell = \frac{m}{\rho S} = \frac{1{,}78kg}{8900\frac{kg}{m^3} \cdot 3 \cdot 10^{-6} m^2} \approx 66{,}67\,m$ natija chiqadi.

Javob: $\ell \approx 66{,}67\,m$.

Masala № 5. Massasi *0,2 kg* bo‘lgan moddiy nuqtaning harakati $x = 3\cos 2\pi t[sm],\ y = 4\sin \pi t[sm]$ tenglamalar bilan ifodalanadi. Bunda t – sekundlarda ifodalanadi. Nuqtaga ta’sir qiluvchi kuchni proyeksiyalarini vaqt bo‘yicha va koordinata bo‘yicha aniqlang.

Berilgan:
m=0,2 kg
$x = 3\cos 2\pi t[sm]$
$y = 4\sin \pi t[sm]$
$F_x = ?, F_y = ?$

Yechilishi:
Tezlanishning proyeksiyalarini aniqlaymiz.

$a_x = \ddot{x} = (3\cos 2\pi t)'' = -12\pi^2 \cos 2\pi t,\ yoki\ a_x = -4\pi^2 x\,[sm/s^2]$

$a_y = \ddot{y} = (4\sin \pi t)'' = -4\pi^2 \sin \pi t,\ yoki\ a_y = -\pi^2 y\,[sm/s^2]$

Kuchning proyeksiyalarini aniqlaymiz.

$F_x = ma_x = 0{,}2 \cdot (-2{,}4\pi^2 \cos 2\pi t) \approx -0{,}24\cos 2\pi t \cdot 10^{-2}[N],\ yoki$

$F_x = -0{,}08x \cdot 10^{-2}\ [N]$

$F_y = ma_y = 0{,}2 \cdot (-4\pi^2 \sin \pi t) \approx -0{,}08\sin \pi t[N],\ yoki$

$F_x = -0{,}02y\ [N]$

Javob: $F_x = -0{,}24\cos 2\pi t[N],\ yoki\ F_x = -0{,}08x\ [N]$

$F_y \approx -0,08\sin \pi t[N],\ yoki\ F_x = -0,02y\ [N]$

Masala №. 6. Moddiy nuqtaning tezlanishi $a = kt^2\ [sm/s^2]$ ifoda bilan aniqlanadi. Bunda t – sekundlarda ifodalanadi. *a)* Agar *t=0 s* da $\vartheta = -32\,sm/s$ ga, t=4 s da esa $\vartheta = +32\,sm/s$ ga tengligi ma'lum bo'lsa, u holda *k* konstantani aniqlang. *b) t=4 s* da *x=0* ekanligini bilgan holda nuqtaning harakat tenglamasini yozing.

Berilgan:

$a = kt^2$

t=0 s da $\vartheta = -32\,sm/s$

t=4 s da $\vartheta = +32\,sm/s$

t=4 s da *x=0*

$a)\ k = ?$

$b)\ x = x(t) - ?$

Yechilishi:

a) Tezlik formulasini hosil qilamiz.

$$a = \frac{d\vartheta}{dt} = kt^2, \rightarrow d\vartheta = kt^2 dt, \rightarrow \int_{\vartheta_0}^{\vartheta} d\vartheta = \int_0^t kt^2 dt,$$

$$\vartheta - \vartheta_0 = \frac{1}{3}kt^3, \rightarrow \vartheta = \vartheta_0 + \frac{1}{3}kt^3$$

t=0 s da boshlang'ich tezlik $\vartheta(0) = \vartheta_0 + \frac{1}{3}k0^3 = \vartheta_0 = -32\,sm/s$ ekan. *t=4 s* da esa tezlik $\vartheta(4) = \vartheta_0 + \frac{1}{3}k4^3 = -32 + \frac{64}{3}k = 32\ sm/s$ ekan. Bundan $k = 3\ sm/s^4$ hosil bo'ladi.

b) harakat tenglamasini aniqlaymiz.

$$\vartheta(t) = \frac{dx}{dt} = \vartheta_0 + \frac{1}{3}kt^3 = -32 + \frac{4}{3}t^3, \rightarrow dx = \left(-32 + \frac{4}{3}t^3\right)dt$$

$$\int_{x_0}^{x} dx = \int_0^t \left(-32 + \frac{4}{3}t^3\right)dt, \rightarrow x = x_0 - 32t + \frac{1}{3}t^4[sm/s]$$

t=4 s da *x=0* ekanidan boshlang'ich koordinata

$$x(4) = x_0 - 32\cdot 4 + \frac{1}{3}4^4 = 0,\ x_0 = 128 - \frac{256}{3} = -\frac{128}{3} = -42\frac{2}{3}[sm]$$

kelib chiqadi. Demak, harakat tenglamasi $x(t) = -42\frac{2}{3} - 32t + \frac{1}{3}t^4[sm]$ ko'rinishida bo'lar ekan.

Javob: $k = 3\,[sm/s^4];\ x(t) = -42\frac{2}{3} - 32t + \frac{1}{3}t^4[sm]$

Masala №. 7. Yer sirtidan Yer markazigacha ingichki quduq kovlangan deb tasavvur qilaylik. Yerning ichki qismida tushayotgan jism uchun erkin tushish tezlanishi $a = -g\frac{r}{R}\,(r < R)$ qonuniyatga bo'ysunishini bilgan holda Yer sirtidan quduqga tashlangan jism Yer markazida qanday tezlikka erishishi hamda tushguncha qancha vaqt ketishi topilsin.

Yechish: Yuqorida tezlik uchun topilgan $\vartheta = \sqrt{\vartheta_0^2 + 2\int_{x_0}^{x} a(x)dx}$ formulani berilgan masala uchun moslashtiramiz. Dastlabki tezlik $\vartheta_0 = 0$ hamda tezlanish uchun $a(r) = -g\frac{r}{R} = -\frac{g}{R}r$ formuladan foydalanamiz. Formulada $r = R - h$ – Yer markazidan jism turgan ixtiyoriy nuqtagacha bo'lgan masofadir. Demak, tushish tezligi $\vartheta = \sqrt{0 + 2\int_{r_0}^{r} a(r)dr} = \sqrt{2\cdot\left(-\frac{g}{R}\right)\int_{R+h}^{R} r\,dr} = \sqrt{-\frac{2g}{R}\frac{r^2}{2}|_{r_0}^{r}} = \sqrt{\frac{g}{R}\left(r_0^2 - r^2\right)} =$

$= \sqrt{\frac{g}{R}\left(R^2 - 0^2\right)} = \sqrt{gR} = \vartheta_I = 7900\,m/s$ ga, ya'ni 1-kosmik tezlikka teng bo'lar ekan. Ana endi tushish vaqtini topamiz. Buning uchun yuqoridagi chiqarilgan $t = \int_{x_0}^{x} \frac{dx}{\sqrt{\vartheta_0^2 + 2\int_{x_0}^{x} a(x)dx}}$ formulani masalamiz uchun moslashtiramiz. Bunda ham dastlabki tezlik $\vartheta_0 = 0$ hamda tezlanish uchun $a(r) = -\frac{g}{R}r$ formuladan foydalanamiz. Shunda $t = \int_{r_0}^{r} \frac{dr}{\sqrt{0 + 2\int_{r_0}^{r} a(r)dr}} = \int_{r_0}^{r} \frac{dr}{\sqrt{\frac{g}{R}\left(r_0^2 - r^2\right)}} = \sqrt{\frac{R}{g}}\int_{r_0}^{r} \frac{dr}{\sqrt{r_0^2 - r^2}} =$

$= \sqrt{\frac{R}{g}}\ arctg\left(\frac{r}{\sqrt{r_0^2 - r^2}}\right)\Bigg|_{r_0}^{r} = \sqrt{\frac{R}{g}}\left(arctg\left(\frac{r}{\sqrt{r_0^2 - r^2}}\right) - arctg\left(\frac{r_0}{\sqrt{r_0^2 - r_0^2}}\right)\right) = \sqrt{\frac{R}{g}}\left(arctg\,0 - arctg1\right) =$

$= \frac{\pi}{4}\sqrt{\frac{R}{g}} = \frac{\pi\vartheta_I}{4g} = \frac{3{,}1416\cdot 7900}{4\cdot 9{,}81} = 632c \approx 10{,}5\min.$ da Yer markaziga yetib borar ekan.

Ushbu masaladan foydalanib, quduqqa tashlangan jism Yerning ichki ixtiyoriy nuqtasida bo'lgandagi tezligi va bu nuqtaga kelguncha sarflagan vaqtini topish mumkin. Masalan, jism Yer radiusi yarmidagi tezligi va bu nuqtaga kelguncha ketgan vaqtini aniqlashimiz mumkin. Jism $\vartheta = \sqrt{\frac{g}{R}\left(r_0^2 - r^2\right)} = \sqrt{\frac{g}{R}\left(R^2 - \frac{R^2}{4}\right)} = \frac{\sqrt{3}}{2}\sqrt{gR} = \frac{\sqrt{3}}{2}\vartheta_I = 6842\ m/s$ tezlikka erishar ekan. Yarim radius uzunligini bosib o'tish uchun esa

$t = \sqrt{\frac{R}{g}}\left(\frac{\pi}{4} - arctg\left(\frac{r}{\sqrt{r_0^2 - r^2}}\right)\right) = \frac{\vartheta_I}{g}\left(\frac{\pi}{4} - arctg\left(\frac{R/2}{\sqrt{R^2 - R^2/4}}\right)\right) = \frac{\vartheta_I}{g}\left(\frac{\pi}{4} - \frac{\pi}{6}\right) = \frac{\pi}{12}\frac{\vartheta_I}{g} = \frac{632}{3} = 211c \approx 3{,}5\ \min$

vaqt sarflaydi.

Javob: $\vartheta = \frac{\sqrt{3}}{2}\vartheta_I = 6842\ m/s;\quad t = \frac{\pi}{12}\frac{\vartheta_I}{g} = 211c$

Masala № 8. Jismning tezlanishi $a=-0,4\vartheta\ [sm/s^2]$ tenglamasi bilan aniqlanadi. Kuzatish onida dastlabki tezlik $\vartheta_0=30\ sm/s$ ekanligini bilgan holda jism to'xtaguncha ketgan vaqt va bosib o'tilgan yo'lni aniqlang. Tezlik 10 marta kamayishi uchun ketgan vaqt va bosib o'tilgan yo'lni aniqlang.

Yechish: Vaqt tenglamasi yuqoridagi $t=\int\limits_{\vartheta_0}^{\vartheta}\frac{d\vartheta}{a(\vartheta)}$ formuladan topiladi. Bunda vaqt tenglamasi $t=\int\limits_{\vartheta_0}^{\vartheta}\frac{d\vartheta}{-0,4\vartheta}=-\frac{5}{2}\ln\vartheta\Big|_{\vartheta_0}^{\vartheta}=-\frac{5}{2}\ln\frac{\vartheta}{\vartheta_0}$ ko'rinishda bo'ladi. Bundan tezlik vaqt bo'yicha $\vartheta=\vartheta_0 e^{-0,4t}$ qonunga ko'ra eksponensial ravishda kamayishini keltirib chiqaramiz. Koordinata vaqtga $x=x_0+\int\limits_0^t\vartheta_0 e^{-0,4t}dt=x_0-2,5\vartheta_0\left(e^{-0,4t}-1\right)$ tenglama bo'yicha, tezlikka $x=x_0+\int\limits_{\vartheta_0}^{\vartheta}\frac{\vartheta d\vartheta}{a(\vartheta)}=x_0+\int\limits_{\vartheta_0}^{\vartheta}\frac{\vartheta d\vartheta}{-0,4\vartheta}=x_0-2,5\int\limits_{\vartheta_0}^{\vartheta}d\vartheta=x_0-2,5(\vartheta-\vartheta_0)$ tenglama bo'yicha bog'langan. Keltirib chiqarilgan tenglamalardan foydalanib masalani ishlaymiz. Jism to'xtaguncha $t=-\frac{5}{2}\ln\frac{\vartheta}{\vartheta_0}=-\frac{5}{2}\ln\frac{0}{\vartheta_0}=-\frac{5}{2}\cdot(-\infty)=\infty$ cheksiz ko'p vaqt o'tib, bunda jism $s=x-x_0=-2,5\vartheta_0\left(e^{-0,4t}-1\right)=2,5\vartheta_0=75\,sm$ yoki $s=x-x_0=-2,5(\vartheta-\vartheta_0)=2,5\vartheta_0=75\,sm$ masofa bosib o'tar ekan. Jismning tezligi 10 marta kamayguncha $t=-\frac{5}{2}\ln\frac{\vartheta}{\vartheta_0}=-\frac{5}{2}\ln\frac{1}{10}=5,76\ s$ vaqt o'tib, bu orada jism $s=x-x_0=-2,5(\vartheta-\vartheta_0)=-2,5(3-30)=67,5\,sm$ masofa o'tar ekan.

Javob: *t=5,76 s; s=67,5 sm*

8-amaliy mashg'ulot topshirig'i

8.1. *12 kg* massali yuk dinamometr orqali rasmdagi kabi vertikal devorga osilgan. Bunda dinamometrning ko'rsatishi qanday? Yukka ta'sir qiluvchi kuchlarni va dinamometrga ta'sir qiluvchi kuchlarni alohida-alohida tasvirlang. $g=10m/s^2$ deb oling. **Javob:** *Dinamometr 120 N kuchni ko'rsatadi*

8.2. Massasi 5 g bo'lgan havo shari havoda tekis tushayotgan bo'lsa, sharga ta'sir qiluvchi og'irlik kuchi qanday? Teng ta'sir etuvchi kuch-chi ? **Javob:** *50 mN; 0*

8.3. Massasi *100 t* bo'lgan manyovr teplovozi tinch turgan vagonni turtib yubordi. O'zaro ta'sirlashish vaqtida vagonning tezlanishi teplovozning tezlanishidan modul bo'yicha *5* marta katta bo'lgan. Vagonning massasi qanday? **Javob:** *20 t*

8.4. Quyidagi hollar uchun teng ta'sir etuvchini aniqlang: a) jismning bir nuqtasiga qo'yilgan modullari *6 N* va *8 N* bo'lgan o'zaro perpendikular kuchlar uchun; b) jismning bir nuqtasiga o'zaro *120°* burchak ostida qo'yilgan modullari *3 N* dan

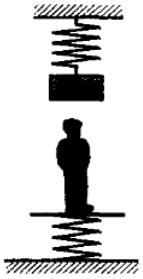
bo‘lgan ikkita kuch uchun; c) jismning bir nuqtasiga o‘zaro *60°* burchak ostida qo‘yilgan modullari *10 N* dan bo‘lgan ikkita kuch uchun? **Javob:** *a) 10 N; b) 3 N; c) 17,3 N*

8.5. Massasi *6 t* bo‘lgan, yuk ortilmagan avtomobil *0,6 m/s²* tezlanish bilan harakatlana boshladi. Agar u o‘sha tortish kuchida joyidan *0,4 m/s²* tezlanish bilan qo‘zg‘alsa, unga ortilgan yukning massasi necha tonna? **Javob:** *3 t*

8.6. *6 N* kuch ta’sir etayotgan jismning harakat tenglamasi $x = 5 + 2t + 3t^2$ (m) ko‘rinishda bo‘lsa, jismning massasi qanday? **Javob:** *1 kg*

8.7. Massasi *200 g* bo‘lgan jismning harakat tenglamasi $x = 5 + 2t + 3t^2 + t^3$ [m] ko‘rinishida bo‘lsa, u holda bu jismga ta’sir etuvchi kuch qanday ko‘rinishda o‘zgaradi? **Javob:** *F(t)=1,2+1,2 t [N]*

8.8. Gorizontal silliq stol ustida turgan *20 kg* massali jismga *10 N* kuch ta’sir qiladi. Jismning tezlanishini hamda $t = 6s$ vaqtda bosib o‘tgan yo‘li va erishgan tezligini aniqlang? **Javob:** $a = 0{,}5 m/s^2$; $\ell = 9m$; $\vartheta = 3 m/s$

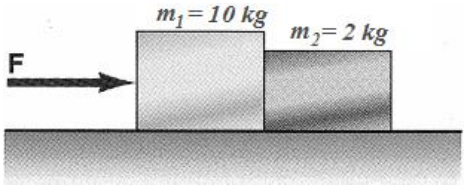


8.9. Rasmdagi kabi shiftga osilgan prujinali taroziga massasi $m = 150 kg$ bo‘lgan yuk osilgan. Yukning tagidagi ikkinchi prujinali tarozi ustida $P = 700 N$ og‘irlikdagi odam turibdi. Agar odam yukni $F = 350 N$ kuch bilan: a) ko‘tarishga harakat qilsa; b) shuncha kuch bilan pastga tortsa, tarozilarning ko‘rsatishlari qanday bo‘ladi? **Javob:** $a) P_1 = 1150 N, P_2 = 1050 N$ $b) P_1 = 1850 N, P_2 = 350 N$

8.10. *m* massali jism doimiy *F* kuch ta’sirida to‘g‘ri chiziq bo‘ylab harakatlanadi. Vaqtning biror t_0 onida jism x_0 koordinatada turibdi. Jism ixtiyoriy *t* vaqtda *x* koordinatada bo‘lishi uchun uning t_0 vaqtdagi tezligi ϑ_0 qanday bo‘lishi kerak?

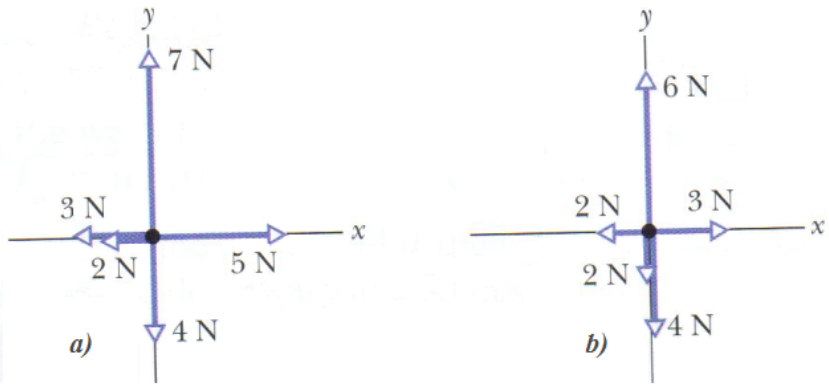
Javob: $\vartheta_0 = \dfrac{x - x_0}{t - t_0} - \dfrac{F}{2m}(t - t_0)$

8.11. $F = 20 N$ kuch ikkita blokka rasmdagidek ta’sir qilmoqda. Agar bloklar silliq sirtda turgan bo‘lsa, u holda har bir blokning tezlanishini toping. 1-blokning 2-blokka va 2-blokning 1-blokka ta’sir kuchlarini aniqlang. Har bir blokka ta’sir qiluvchi barcha kuchlarni chizmada tasvirlang.

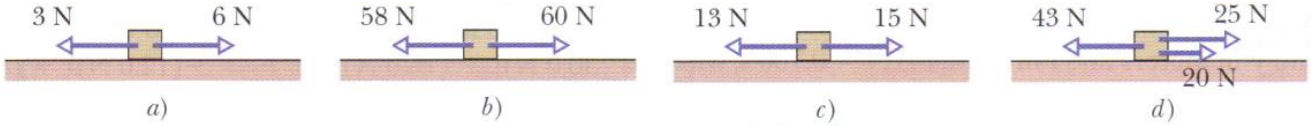


Javob: $a_1 = a_2 = 1{,}667 m/s^2$; $F_{1\to 2} = 3{,}333 N$; $F_{2\to 1} = -3{,}333 N$

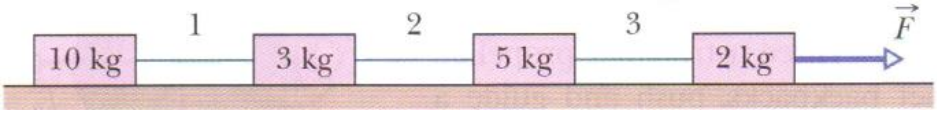
8.12. Rasmda kuchlar sistemasi berilgan bo‘lib, bu hollar uchun teng ta’sir etuvchi kuchni proyeksiyalarini hamda teng ta’sir etuvchi kuchni aniqlang. **Javob:** *a)* $R_x = 0, R_y = 3N, R = 3N$ *; b)* $R_x = 1N, R_y = 0, R = 1N$



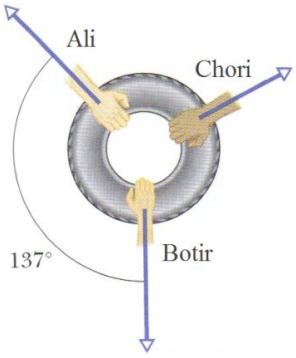
8.13. Massasi $m = 2\,kg$ bo‘lgan qutiga quyida rasmda ko‘rsatilgan holatlardagi kabi gorizontal kuchlar ta’sir etadi. Har bir holat uchun tezlanishning Ox o‘qiga proyeksiyasini aniqlang. **Javob:** $a)\,a_x = 1{,}5\,m/s^2;\ b)\,a_x = 1\,m/s^2;$ $c)\,a_x = 1\,m/s^2;\ d)\,a_x = 1\,m/s^2$



8.14. Gorizontal silliq sirtda turgan jismlar sistemasi quyidagi rasmdagi kabi noma’lum F kuch ta’sirida $a = 40\,sm/s^2$ tezlanish bilan tortib ketilmoqda. F kuch nimaga teng? Jismlarni bog‘lovchi iplardagi taranglik kuchlari-chi? **Javob:** $F = 8\,N;\ T_1 = 4N;\ T_2 = 5{,}2\,N;\ T_3 = 7{,}2\,N$



8.15. Gorizontal holda yotgan avtomobil shinasiga Ali, Botir va Chori rasmdagi kabi yo‘nalishlarda tortmoqdalar. Bunda uchta kuch ta’sirida shina tinch holda qoladi. Ali $F_A = 250\,N$ kuch bilan, Chori esa $F_{Ch} = 220\,N$ kuch bilan tortmoqda. Bunda F_{Ch} kuchning yo‘nalishi berilmaganiga e’tibor qiling. Botirning ta’sir kuchi F_B nimaga teng? $\vec{F}_{Ch}$ kuchning $\vec{F}_B$ kuchga nisbatan yo‘nalishi-chi? **Javob:** $F_B = 321N;\ 129^0$



Kuch (yoki tezlanish) vaqtning, masofaning, tezlikning funksiyasi bo‘lganda harakat tenglamasi va tezlik tenglamasini aniqlash.

8.16. Jismning tezlanishi vaqt bo‘yicha $a = 6t - 12\ [sm/s^2]$ qonuniga ko‘ra o‘zgaradi. Agar jismning dastlabki tezligi $\vartheta_0 = 15\,[sm/s]$ va dastlabki koordinatasi $x_0 = 40\,[sm]$ bo‘lsa, tezlik va harakat tenglamalarini aniqlang. Jismning qancha vaqtda to‘xtashini, to‘xtaguncha qancha yo‘l o‘tishini hamda to‘xtagan paytdagi tezlanishni aniqlang. **Javob:** $\vartheta = 3t^2 - 12t + 15\ [sm/s];$ $x = t^3 - 6t^2 + 15t + 40\,[sm];\ t = 5\,sek;\ s = 50\,sm;\ a = 18\ sm/s^2$

8.17. Yuqori balandliklardan tushayotgan jism uchun erkin tushish tezlanishi $a=-g\left(\frac{R}{r}\right)^2\ (r>R)$ qonuniyatga bo‘ysunishini bilgan holda Yer sirtidan $h=R$ radiusga teng balandlikdan erkin tushayotgan jism Yerga qanday tezlikda urilishi hamda tushguncha qancha vaqt ketishi topilsin. **Javob:**

8.18. Gidravlik tormoz mexanizmining slindridagi porshen suyuqlik qarshiligi tufayli tezlanishi tezlikka $a=-k\,\vartheta\,[sm/s^2]$ qonunga ko‘ra chiziqli bog‘langan. Porshen harakati uchun $\vartheta=\vartheta(t), x=x(t)$ va $\vartheta=\vartheta(x)$ tenglamalarini keltirib chiqaring. **Javob:** $\vartheta=\vartheta_0 e^{-kt}[sm/s];\ x=-\frac{\vartheta_0}{k}\left(e^{-kt}-1\right)[sm];\ \vartheta=\vartheta_0-k\,x$

9-MAVZU: Ishqalanish va uning turlari. Ishqalanish kuchlari. Ishqalanish ta'sirida gorizontal tekislikda harakat.

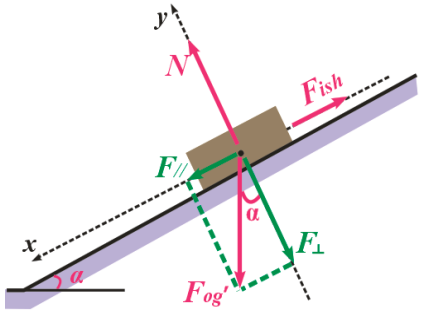
Mavzuga oid muhim formulalar

$F_{dinam} = -\mu N$	*Sirpanish ishqalanish kuchini aniqlashning umumiy formulasi*
$0 \le F_{stat} < F_{dinam}$ *yoki* $0 \le F_{stat} < \mu N$	*Sirpanish ishqalanishi va tinchlikdagi ishqalanish orqasidagi bog'lanish*
$F_{dum} = -\lambda \frac{mg}{R}, \quad \frac{\lambda}{R} = f$	*Dumalashdagi ishqalanish kuchi*

Qiya sirtdagi jismning sirtga tik holda ta'sir qiladigan normal bosim kuchi hamda jismga ta'sir qiluvchi statik va dinamik ishqalanish kuchlari

$$\begin{cases} N = F_{\perp} = mg\cos\alpha \\ F_{//} = mg\sin\alpha \end{cases}$$

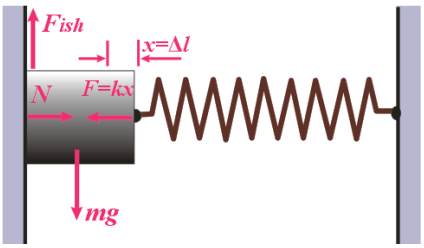
$$Agar \begin{cases} \vartheta = 0 \\ \vartheta \neq 0 \end{cases} bo'lsa, \begin{cases} F_{stat} = F_{//} = mg\sin\alpha \\ F_{dinam} = \mu N = \mu mg\cos\alpha \end{cases}$$



Vertikal sirtda prujina yordamida ushlab turiladigan jismning sirtga tik holda ta'sir qiladigan normal bosim kuchi hamda jismga ta'sir qiluvchi statik va dinamik ishqalanish kuchlari

$$N = F_{elas} = kx$$

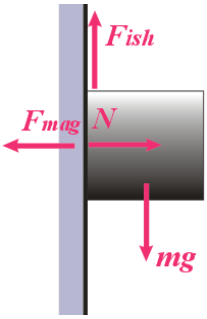
$$Agar \begin{cases} \vartheta = 0 \\ \vartheta \neq 0 \end{cases} bo'lsa, \begin{cases} F_{stat} = mg \\ F_{dinam} = \mu N = \mu kx \end{cases}$$



Vertikal sirtda magnit kuch yordamida ushlab turiladigan jismning sirtga tik holda ta'sir qiladigan normal bosim kuchi hamda jismga ta'sir qiluvchi statik va dinamik ishqalanish kuchlari

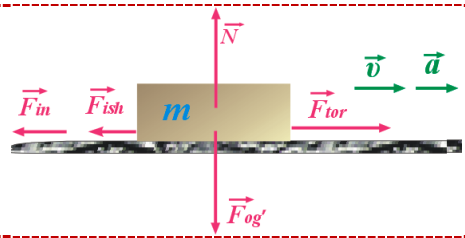
$$N = F_{mag}$$

$$Agar \begin{cases} \vartheta = 0 \\ \vartheta \neq 0 \end{cases} bo'lsa, \begin{cases} F_{stat} = mg \\ F_{dinam} = \mu N = \mu F_{mag} \end{cases}$$



Gorizontal sirtdagi jismni tezlanish bilan harakatlantirish sharti

$$F_{tor} = F_{ish} + F_{in} = m(\mu g + a)$$



Gorizontal sirtdagi jismning ishqalanish tufayli to'xtash jarayonida yuzaga keladigan

sekinlanish (manfiy tezlnish)

$a = \mu g$

9-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Massasi *1 kg* bo‘lgan taxta bo‘lagi iskanjada *500 N* kuch bilan siqib qo‘yilgan. Taxt bilan iskanja orasidagi ishqalanish koeffitsienti $\mu = 0{,}4$. Shu vaziyatda taxtaga ta’sir etuvchi ishqalanish kuchi qanday (*N*)? *g=10 m/s²*.

Berilgan:

$m = 1kg$
$F = 500N$
$\mu = 0.4$

F_{ishq}

Yechilishi:

Taxta shu holatda turishi uchun ishqalanish kuchi og'irlik kuchiga teng bo'lishi ker*ak*.

$F_{ishq} = mg = 1 \cdot 10 = 10N$

Javob: *10 N*

Masala № 2. Balandligi *30 sm* va uzunligi *50 sm* bo‘lgn qiya tekislikda *5 kg* massali brusok muvozanatda qolishi uchun uni qanday (N) kuch bilan tekislikka tik bosib turish kerak bo‘ladi? Brusok bilan tekislik orasidagi ishqalanish koeffitsenti *0,4* ga teng.

Berilgan:

$h = 30sm$
$l = 50sm$
$m = 5kg$
$\mu = 0.4$

F=?

Yechilishi:

Brusok muvozanatda bo'lishi uchun

$F_{ishq} = Px = mg\sin\alpha$ *bo'lishi* ker*ak*.

$F_{ishq} = \mu N$

$\sin\alpha = \frac{h}{l} = \frac{3}{5} = 0.6$

y o'qiga proyeksiya olamiz.

$\cos\alpha = \sqrt{1 - \sin\alpha} = 0.8$

$N - F - mg\cos\alpha = 0, \rightarrow \quad N = F + mg\cos\alpha$

$F_{ishq} = \mu(mg\cos\alpha + F), \rightarrow \quad \mu = (mg\cos\alpha + F) = mg\sin\alpha$

$F = \frac{mg\sin\alpha}{\mu} - mg\cos\alpha, \rightarrow \quad F = mg(\frac{\sin\alpha}{\mu} - \cos\alpha)$

$F = 50(\frac{0.6}{0.4} - 0.8) = 35N$

Javob: $35N$

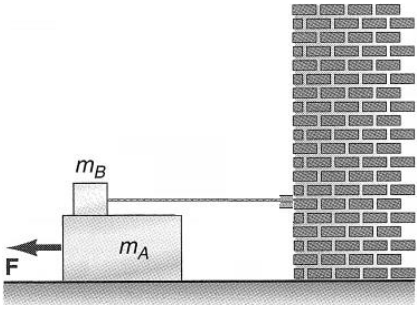
Masala № 3. Og‘irligi *180 kN* bo‘lgan beton plita er sirtida tekis sudralmoqda. Tortish kuchi *54 kN* bo‘lib, gorizontal yo‘nalgan. Ishqalanish koeffitsientini toping.

Berilgan:	*Yechilishi:*
$P = 180kN$ $F = 54kN$	$F - F_{ishq} = ma$ *Beton tekis harakatlanayotgani uchun* $a = 0$ *bo'ladi.* $F = F_{ishq} = \mu N, \quad \rightarrow \quad N = Pg$
$\mu = ?$	$F = \mu P, \quad \rightarrow \quad \mu = \frac{F}{P} = \frac{54}{180} = 0.3$

Javob: *0,3.*

Masala № 4. Rasmdagi *A* jismni o'zgarmas tezlik bilan tortish uchun kerak bo'lgan *F* kuchni aniqlang. Bunda barcha ishqalanuvchi sirtlardagi ishqalanish koeffitsiyenti $\mu = 0,3$ ga, jismlarning massalari esa $m_A = 6kg, m_B = 2kg$ ga teng. $g = 10\ m/s^2$.

Berilgan:	*Yechilishi:*
$\mu = 0,3$ $m_A = 6\,kg$ $m_B = 2\,kg$	A jismni tortib chiqarish uchun bu jismning yuqorigi va pastki sirtlaridagi ishqalanish kuchlarini yengadigan tortuvchi kuch qo'yish kerak bo'ladi.
$F = ?$	



$$F = F_{ish.A} + F_{ish.B} = \mu(m_A + m_B)g + \mu m_B g = (m_A + 2m_B)\mu g = (6+4)\cdot 0,3\cdot 10 = 30\,N$$

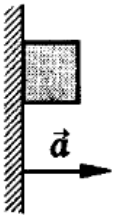
Javob: $F = (m_A + 2m_B)\mu g = 30\,N$

9-amaliy mashg'ulot topshirig'i

9.1. Bola chanani o'zgarmas tezlik bilan tortib ketyapti. Tortish kuchi *100 N* ga teng bo'lib, harakat yo'nalishi bilan *30°* li burchak hosil qiladi. Bunda ishqalanish kuchi qanday (*N*) bo'ladi? *sin30°=0,5; cos30°=0,87.* **Javob:** *8,7 N*

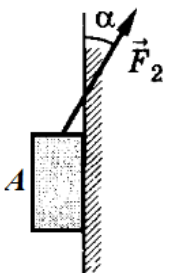
9.2. Massasi *1 kg* bo'lgan taxta bo'lagi iskanjada *500 N* kuch bilan siqib qo'yilgan. Taxt bilan iskanja orasidagi ishqalanish koeffitsiyenti $\mu = 0,2$. Shu vaziyatda taxtaga ta'sir etuvchi ishqalanish kuchi qanday? $g=10\ m/s^2$. **Javob:** *10 N;*

9.3. Rasmdagi vertikal devorning kamida qanday *a* tezlanish bilan gorizontal yo'nalishda harakatlanganda brusok tinch qolishini aniqlang. Brusok va devorning orasidagi ishqalanish koeffitsiyenti μ ga teng. $g = 10\ m/s^2$. **Javob:** $\mu = \frac{a}{g}$

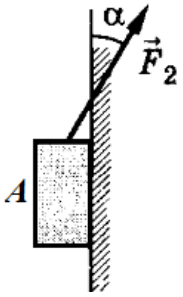


9.4. Jismning aylanuvchi disk sirtiga ishqalanish koeffitsiyenti μ. Agar aylanish chastotasi ν bo'lsa, disk ustiga qo'yilgan kichik jism aylanish markazidan ko'pi bilan qanday masofada qo'zg'almay tura oladi? **Javob:** $r = \frac{\mu g}{4\pi^2\nu^2}$

9.5. Massasi $m = 2\,kg$ bo‘lgan A magnittosh vertikal po‘lat devorga $F_1 = 20\,N$ kuch bilan yopishib tinch turibdi. Bunda magnittoshga rasmdagi kabi devor bilan $\alpha = 30^0$ burchak tashkil etuvchi $F_2 = 30\,N$ kuch qo‘yilgan. Ishqalanish kuchi nimaga teng? Ishqalanish koeffitsiyentining eng kichik qaysi qiymatida magnittosh tinch turadi? $g = 10\ m/s^2$. **Javob:** $F_{ish} = F_2\cos\alpha - mg = 6N;\ \mu_{\min} = \dfrac{F_{ish}}{F_1 + F_2\sin\alpha} = 0{,}17$



9.6. Massasi $m = 2\,kg$ bo‘lgan A magnittosh vertikal po‘lat devorga $F_1 = 20\,N$ kuch bilan yopishib turibdi. Bunda magnittoshga rasmdagi kabi devor bilan $\alpha = 30^0$ burchak tashkil etuvchi $F_2 = 40\,N$ kuch qo‘yilgan. Ishqalanish koeffitsiyenti $\mu = 0{,}2$ bo‘lsa, magnittosh qaysi tomonga va qanday tezlanish bilan harakat qiladi? $g = 10\ m/s^2$ **Javob:** $a = 3{,}3\ m/s^2$ *tezlanish bilan yuqoriga*.

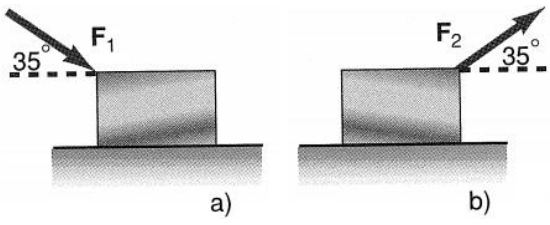


9.7. Har birining massasi *4 kg* bo‘lgan uch g‘isht ustma-ust qo‘yilgan. O‘rtadagi g‘ishtni sug‘urib olish uchun kamida necha nyuton kuch kerak bo‘ladi? G‘ishtning orasidagi ishqalanish koeffitsiyenti *0,4*. **Javob:** *48 N*

9.8. m massali magnittosh vertikal po‘lat devorga yopishgan holda sekin pastga tomon sirg‘anmoqda. Agar magnittosh va po‘lat devor orasidagi tortish kuchi F_{mag} ga, ishqalanish koeffitsiyenti esa μ ga teng bo‘lsa, u holda magnittosh va devor orasidagi ishqalanish kuchi nimaga teng? Magnittoshni vertikal holda tepaga harakatga keltirish uchun unga qanday kuch qo‘yish kerak? **Javob:** μF_{mag}; $mg + \mu F_{mag}$

9.9. Radiusi *R* va balandligi *h* bo'lgan silindr turgan qiya tekislikning qiyalik burchagi asta-sekin oshirilib borganda, silindr sirpanishi yoki yiqitishi mumkin. Bu ikkala nodisa bir paytda yuz berishi ucnun ishqalanish koeffitsyenti qanday bo’lishi kerak? J: *2R/h*

9.10. Massasi 20 kg bo‘lgan yashikni gorizontal polda rasmdagi kabi burchak ostida ta’sir qiluvchi kuch yordamida o‘zgarmas tezlik bilan harakatlantirilmoqda. Yashik va pol orasidagi ishqalanish koeffitsiyenti $\mu = 0{,}3$ ga teng. Ushbu savollarga javob bering: *a)* qanday F_1 kuch bilan yashikni pastga qiyalatib bosish kerak; *b)* qanday F_2 kuch bilan yashikni tepaga qiylatib tortish kerak; *c)* yashikni siljitish uchun qaysi biri yaxshiroq? **Javob:**

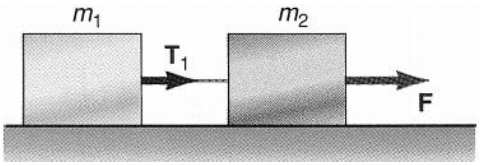


$F_1 = \dfrac{\mu}{\cos\alpha - \mu\sin\alpha}mg = 92{,}72N;\ \ F_2 = \dfrac{\mu}{\cos\alpha + \mu\sin\alpha}mg = 60{,}53N$; *ikkinchisi yaxshiroq*

9.11. Avtomobil tortish kuchining og‘irlik kuchiga nisbati k ga va qarshilik koeffitsiyenti μ ga teng bo‘lsa, u qanday tezlanish bilan harakatlanadi? (g – erkin tushish tezlanishi). **Javob:** $(k-\mu)g$

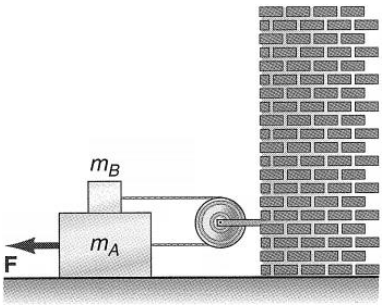
9.12. Avtomobil *5 m/s²* tezlanish bilan harakat qilishi uchun uning tortish koeffitsiyenti (tortish kuchining og‘irlik kuchiga nisbati) qanday bo‘lishi kerak? Qarshilik koeffitsiyenti *0,08* ga teng. **Javob:** *0,58*

9.13. O‘zaro ip bilan bog‘langan gorizontal sirtdagi ikkita jismni o‘zgarmas tezlik bilan tortish uchun qanday F kuch kerak bo‘ladi? Bunda ipning taranglik kuchi T_1 nimaga teng? Jismlarning massalari $m_1 = 2kg$, $m_2 = 5kg$ ga, ularning sirtga ishqalanish koeffitsiyentlari esa $\mu_1 = 0,3$, $\mu_2 = 0,2$ ga teng. $g = 10\ m/s^2$. **Javob:** $F = 16\,N; T_1 = 6N$



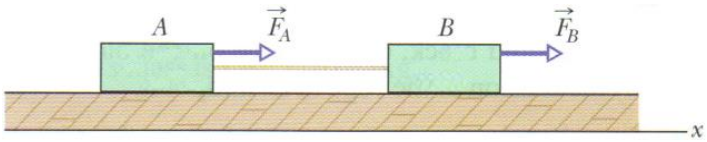
9.14. Elektrovoz temiryo'l sostavini joyidan qo'zg'atishda maksimal tortish kuchini *650 kN* ga yetkazdi. Agar qarshilik koeffitsiyenti *0,005* ga teng bo'lsa, massasi *3250 t* bo'lgan sostavga elektrovoz qanday tezlanish beradi? **Javob:** *15 sm/s²*

9.15. * Rasmdagi jismlar sistemasini o‘zgarmas tezlik bilan tortish uchun kerak bo‘lgan F kuchni aniqlang. Bunda barcha ishqalanuvchi sirtlardagi ishqalanish koeffitsiyenti $\mu = 0,3$ ga, jismlarning massalari esa $m_A = 6kg$, $m_B = 2kg$ ga teng. $g = 10\ m/s^2$. **Javob:** $F = (m_A + 3m_B)\mu g = 36N$



9.16. Agar yuqoridagi masala shartida jismlar sistemasini $a = 2\ m/s^2$ tezlanish bilan tortib ketilayotgan bo‘lsa, F kuch nimaga teng bo‘ladi? **Javob:** $F = (m_A + 3m_B)\mu g + (m_A + m_B)a = 52N$

9.17. Rasmdagi A blokning massasi $m_A = 4kg$ va B blokning massasi $m_B = 6kg$ gat eng bo‘lib, ular o‘zaro yengil ip orqali bog‘langan. A blokka $F_A = 12\,N$, B blokka esa $F_B = 24\,N$ kuch qo‘yilgan. Sirtdagi ishqalanish koeffitsiyenti $\mu = 0,1$ ga teng bo‘lsa, jismlar sistemasining tezlanishi nimaga teng? Ipdagi taranglik kuchi-chi? **Javob:** $a = 2,6\ m/s^2; T = 2,4\,N$



10-MAVZU: Jismlarning ishqalanish ta'sirida qiya tekislikdagi harakati.

Mavzuga oid muhim formulalar

$tg\alpha_0 = \mu$	*Qiya sirtdagi jismni o'z-o'zidan harakat boshlanish burchagi*
$tg\alpha_0 < \mu$	*Qiya sirtdagi jismni tinch turish shatri*
$tg\alpha_0 \geq \mu$	*Qiya sirtdagi jismni harakatlanish shatri*
$a = g(\sin\alpha - \mu\cos\alpha)$	*Qiyalik burchagi* $\alpha_0 \geq arctg\,\mu$ *bo'lgan sirtdagi jismning tezlanishi*
$a = g(\sin\alpha + \mu\cos\alpha)$	*O'z inersiyasi bo'yicha qiya sirt bo'ylab tepaga harakatlanayotgan jismning sekinlanishi (manfiy tezlanishi)*
$F_{tor} = mg(\sin\alpha + \mu\cos\alpha)$	*Jismni qiya sirt bo'ylab tepaga tekis tortib chiqarish uchun kerak bo'lgan kuch*
$F_{tor} = m(g\sin\alpha + \mu g\cos\alpha + a)$	*Jismni qiya sirt bo'ylab tepaga tezlanish bilan tortib chiqarish uchun kerak bo'lgan kuch*
$F_{tor} = mg(\mu\cos\alpha - \sin\alpha)$	*Qiyalik burchagi* $\alpha_0 < arctg\,\mu$ *bo'lgan sirtdagi jismni qiya sirt bo'ylab pastga tekis tortib tushirish uchun kerak bo'lgan kuch*
$F_{tor} = m(\mu g\cos\alpha - g\sin\alpha + a)$	*Qiyalik burchagi* $\alpha_0 < arctg\,\mu$ *bo'lgan sirtdagi jismni qiya sirt bo'ylab pastga tezlanish bilan tortib tushirish uchun kerak bo'lgan kuch*
$F_{tut} = mg(\sin\alpha - \mu\cos\alpha)$	*Qiyalik burchagi* $\alpha_0 \geq arctg\,\mu$ *bo'lgan sirtdagi jismni siljib ketmaslik uchun joyida tutib turuvchi kuch*

10-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Laboratoriya ishini bajarishda quyidagi ma'lumotlar olindi: qiya tekislikning uzunligi *1 m*, balandligi *20 sm*, yog'och brusokning massasi *200 g*, brusokni yuqoriga harakatlantirayotganda dinamometr bilan o'lchangan tortish kuchi *1 N*. Ishqalanish koeffitsiyentini toping.

Berilgan:

$\ell = 100\,sm$

$h = 20\,sm$

$m = 200\,g$

F=1 N

$\mu = ?$

Yechilishi:

Qiyalik burchagi sinusi va kosinusini aniqlaymiz.

$$\sin\alpha = \frac{h}{\ell} = 0,2;\ \ \cos\alpha = \sqrt{1-\sin^2\alpha} = 0,98$$

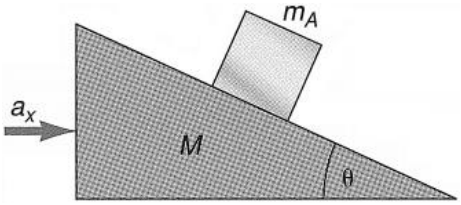
Jismni qiyalik bo'ylab tepaga tekis tortib chiqish uchun kerak bo'lgan kuch $F = F_p + F_{ish} = mg\sin\alpha + \mu mg\cos\alpha$ bo'ladi.

Bundan soralgan kattalikni aniqlaymiz.

$$\mu = \frac{F}{mg\cos\alpha} - tg\alpha = \frac{1}{0,2\cdot 10\cdot 0,98} - \frac{0,2}{0,98} \approx 0,306$$

Javob: *0,306*

Masala № 2. Rasmdagi qiya *M* blokni shunday a_x tezlanish bilan harakatlantiriladiki, bunda uning silliq ustidagi kichikroq m_A blok tinch qoladi. a_x tezlanish nimaga teng? Kichik blokni silliq sirt bo'ylab siljib ketmasligi uchun gorizontal yo'nalgan qanday kuch qo'yish kerak bo'ladi?



$M = 10\,kg;\ m_A = 2\,kg;\ \theta = 37^0;\ g = 10\ m/s^2$

Berilgan:

$M = 10\,kg$

$m_A = 2\,kg$

$\theta = 37^0$

$g = 10\ m/s^2$

$a_x = ?,\ F = ?$

Yechilishi:

A blok $m_A g$ og'irligining qiya sirtga tik tashkil etuvchisi $m_A g\cos\theta$ sirtga bosadi, qiya sirt bo'yicha tashkil etuvchisi $m_A g\sin\theta$ esa blokni sirt bo'ylab pastga sirpantirishga intiladi. Xuddi shuningdek, M qiyalik a_x tezlanish bilan gorizontal holda tortilganda A blokdagi $m_A a$ inersiya kuchining qiya sirtga tik tashkil etuvchisi $m_A a\sin\theta$ sirtga bosadi, qiya sirt bo'yicha tashkil etuvchisi $m_A a\cos\theta$ blokni sirt bo'ylab tepaga sirpantirishga intiladi.

Qiya sirtning reaksiya kuchi $N = m_A g\cos\theta + m_A a\sin\theta$ ga, ishqalanish kuchi $F_{ish} = \mu N = \mu\left(m_A g\cos\theta + m_A a\sin\theta\right) = 0$ ga teng. Shuning uchun,

$m_A g\sin\theta = m_A a\cos\theta,\ \rightarrow\ a = tg\theta\cdot g = 0,75\cdot 9,81 = 7,53 m/s^2$

bo'ladi. Kuch esa $F = \left(m_A + M\right)a = \left(2+10\right)\cdot 7,35 = 88,2\,N$ bo'ladi.

Javob: $a_x = 7,35\ m/s^2;\ F = 88,2\,N$

10-amaliy mashg'ulot topshirig'i

10.1. Qiyaligi 45° bo'lgan qiya tekislikda jismni ushlab turish uchun *3 N*, uni yuqoriga tekis tortish uchun *7 N* kuch talab qilinsa, ishqalanish koeffitsiyenti qanday? **Javob:** 0,4

10.2. Qiya tekislikning balandligi uzunligining yarmiga teng bo'lsa, jism qiya tekislikdan sirpanib tushmasligi uchun ishqalanish koeffitsiyenti kamida qanday bo'lishi kerak? **Javob:** *0,58*

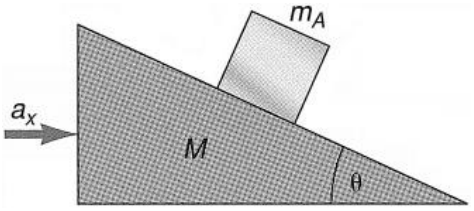
10.3. Massasi *30 kg* bo'lgan g'o'laga qiyalik burchagi *60°* bo'lgan qiya tekislik bo'ylab ko'tarilishda *30 N* kuchi ta'sir qiladi. Ishqalanish koeffitsiyentini toping. **Javob:** *0,2*

10.4. Qiyalik burchagi α bo'lgan qiya tekislikda aravachani tutib turish uchun qiya tekislik bo'ylab yuqoriga yo'nalgan F_1 yuqoriga chiqarish uchun esa F_2 kuch qo'yish lozim. Qarshilik koeffitsiyentini toping. **Javob:** $\mu = \frac{F_2 - F_1}{F_2 + F_1} tg\alpha$

10.5. Laboratoriya ishini bajarishda quyidagi ma'lumotlar olindi: qiya tekislikning uzunligi *1 m*, balandligi *20 sm*, yog'och brusokning massasi *200 g*, brusokni yuqoriga harakatlantirayotganda dinamometr bilan o'lchangan tortish kuchi *1 N*. Ishqalanish koeffitsiyentini toping. **Javob:** *0,31*

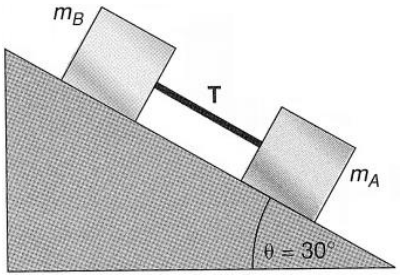
10.6. Uzunligi *13 m* va balandligi *5 m* bo'lgan qiya tekislikda massasi *26 kg* bo'lgan yuk yotibdi. Ishqalanish koeffitsiyenti *0,5* ga teng. Yukni yuqoriga chiqarish uchun tekislik bo'ylab unga qanday kuch qo'yish lozim? Tushirish uchun-chi? **Javob:** *220 N; 20 N*

10.7. * Rasmdagi qiya M blokni shunday a_x tezlanish bilan harakatlantiriladiki, bunda uning silliq ustidagi kichikroq m_A blok tinch qoladi. a_x tezlanish nimaga teng? Kichik blokni silliq sirt bo‘ylab siljib ketmasligi uchun gorizontal yo‘nalgan qanday kuch qo‘yish kerak bo‘ladi? $M = 10kg;\ m_A = 2kg;\ \theta = 37^0;\ g = 10\ m/s^2$ **Javob:** $a_x = 7{,}53\ m/s^2;\ F = 86{,}7\ N$



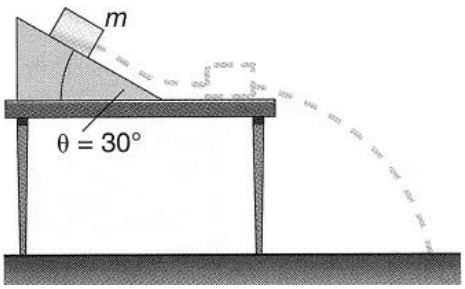
10.8. Yuqoridagi masalani bloklar orasidagi ishqalanish koeffitsienti $\mu = 0{,}2$ ga teng bo‘lganda m_A blok pastga va tepaga siljib ketmaslik sharti uchun yeching. **Javob:** $a_x = 5{,}5\ m/s^2;\ F = 66\ N;\ a_x = 9{,}5\ m/s^2;\ F = 114\ N$

10.9. Rasmda qiyaligi $\theta = 30^0$ bo‘lgan sirtda A va B jismlar ip bilan bog‘langan holat tasvirlangan. Bunda jismlarning massalari $m_A = 4kg, m_B = 2kg$ ga va ularning qiya sirtga ishqalanish koeffitsiyentlari $\mu_A = 0{,}3,\ \mu_B = 0{,}4$ ga teng. Jismlarning tezlanishi nimaga teng? Ipdagi tarangik kuchi nimaga teng? $g = 10\ m/s^2$. **Javob:**



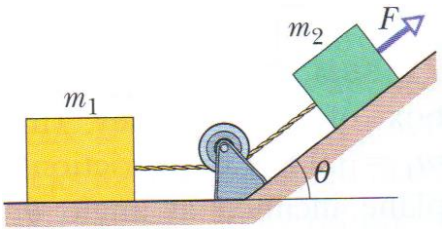
$$a = g\sin\alpha - \frac{\mu_A m_A + \mu_B m_B}{m_A + m_B} g\cos\alpha = 2{,}31 m/s^2;\ T = \frac{(\mu_B - \mu_A) m_A m_B}{m_A + m_B} g\cos\alpha = 1{,}155\ N$$

10.10. * $m = 0{,}5kg$ massali blok uzunligi $\ell = 2m$ va qiyaligi $\theta = 30^0$ bo‘lgan silliq qiya sirtdan sirpanib tushadi. So‘ngra balandligi $h = 1m$ bo‘lgan stolning ishqalanish koeffitsiyenti $\mu = 0{,}3$ bo‘lgan ustki gorizontal sirtida sekinlanuvchan harakat qiladi. Qiyalik oxiridan stol chetigacha masofa $x = 0{,}5m$ ga

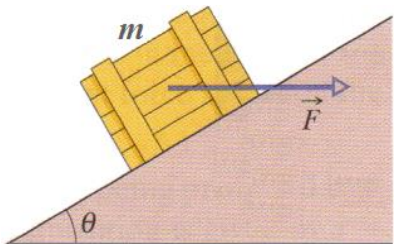


teng. Blok stol ostidan qancha *S* uzoqqa borib tushadi? Yerga urilish tezligi qanday? $g = 10\ m/s^2$. **Javob:** $S = 1{,}84 m;\ \vartheta = 5{,}83 m/s$

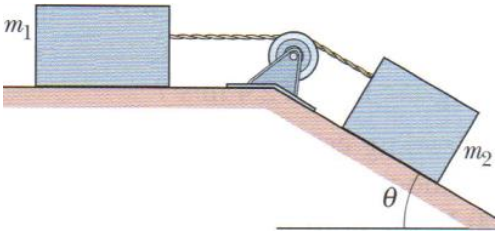
10.11. Qiymati *12 N* ga teng bo‘lgan kuch burchagi $\theta = 37^0$ bo‘lgan qiya sirtda turgan $m_2 = 1kg$ massali yashikka rasmdagi kabi qo‘yilgan. Bu yashik shkiv orqali o‘tgan vaznsiz arqon yordamida polda turgan $m_1 = 4kg$ massali boshqa yashikka ulangan. Pol, qiya sirt va shkiv ishqalanishsiz. Yashiklarning tezlanishi nimaga teng? Arqondagi taranglik kuchi-chi? $g = 10\ m/s^2$. **Javob:** $a = 1{,}2\ m/s^2;\ T = 4{,}8\ N$



10.12. * Massasi $m = 100kg$ bo‘lgan silliq qiya sirtdagi yashik rasmdagidek gorizontal yo‘nalgan $\vec{F}$ kuch yordamida sirt bo‘ylab tepaga o‘zgarmas tezlik bilan tortib chiqarilmoqda. Qiyalik burchagi $\theta = 37^0$ ga teng. Aniqlang: *a)* $\vec{F}$ kuch qiymatini; b) qiya sitr tomonidan yashikka ta’sir qiluvchi *N* reaksiya kuchini. $g = 10\ m/s^2$. **Javob:** $F = mgtg\alpha = 750\ N;\ N = mg\cos\alpha + F\sin\alpha = 1250\ N$



10.13. * Rasmda qiya $(\sin\theta = 0{,}6)$ sitrda $m_2 = 10kg$ massali jism shkivdan o‘tkazilgan yengil arqon yordamida gorizontal sirtdagi $m_1 = 15kg$ massali boshqa jismga bog‘langani tasvirlangan. Sirtlardagi ishqalanish koeffitsiyentlari $\mu = 0{,}1$ ga teng. Shkiv yengil va ishqalanishsiz. Aniqlang: *a)* jismlarning tezlanishini; *b)* ipning taranglik kuchini. $g = 10\ m/s^2$ deb oling. **Javob:** $a)\ a = \dfrac{m_2\sin\theta - \mu(m_1 + m_2\cos\theta)}{m_1 + m_2} g = 1{,}52\ m/s^2;$



$b)\ T = \dfrac{(\sin\theta + \mu(1 - \cos\theta))m_1 m_2}{m_1 + m_2} g = 37{,}2\ N;$

11-MAVZU: To‘g‘ri chiziqli tekis harakat. O’rtacha va oniy tezlik. Harakatning nisbiyligi. Tezliklarni qo‘shish.

Mavzuga oid muhim formulalar

$F_{qar} = mg$	*Og‘irlik kuchi va qarshilik kuchi ta’sirida jismning tekis tushish sharti*
$a = g - \frac{F_{qar}}{m}$	*Og‘irlik kuchi va qarshilik kuchi (qarshilik kuchi o‘zgarmas) ta’sirida tik yuqoriga otilgan jismning o‘rtacha tezlanishi*
$a = g + \frac{F_{qar}}{m}$	*Og‘irlik kuchi va qarshilik kuchi (qarshilik kuchi o‘zgarmas) ta’sirida pastga tushayotgan jismning o‘rtacha tezlanishi*
$F_{qar} = \alpha \vartheta, \quad \vartheta_{\max} = \frac{mg}{\alpha}$	*Nisbatan kichik tezliklarda muhitning qarshilik kuchi tezlikning birinchi darajasiga proporsional. Bunda erkin tashlangan jismning erishiladigan maksimal tezlik.*
$F_{qar} = \beta \vartheta^2, \quad \vartheta_{\max} = \sqrt{\frac{mg}{\beta}}$	*Katta tezliklarda esa muhitning qarshilik kuchi tezlikning kvadratiga proporsional. Bunda erkin tashlangan jismning erishiladigan maksimal tezlik.*

11-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Buyum *50 m* balandlikdan *5 s* davomida tushdi. Havoning o'rtacha qarshilik kuchi og'irlik kuchining qanday qismini tashkil qiladi?

Berilgan:

$h=25\ m$

$t=2,5\ s$

$g=10\ m/s^2$

$\frac{F_q}{F_{og'}} = ?$

Yechilishi:

Dastlab, jismning tushish tezlanishini aniqlaymiz.

$$h = \frac{at^2}{2}, \Rightarrow a = \frac{2h}{t^2} = \frac{2 \cdot 50}{5^2} = 4\ m/s^2$$

Nyutonning 2-qonunidan foydalanamiz.

$$ma = F_{og'} - F_q \,|: F_{og'}, \rightarrow \frac{ma}{F_{og'}} = 1 - \frac{F_q}{F_{og'}}, \rightarrow$$

$$\frac{F_q}{F_{og'}} = 1 - \frac{ma}{mg} = 1 - \frac{a}{g} = 1 - \frac{4}{10} = 0,6$$

Javob: 0,6

Masala № 2. Samolyot gorizontal bo‘ylab uchmoqda. Havo qarshiligi tezlik kvadratiga proporsional va tezlik *1 m/s* bo‘lganda *0,5 N* ga teng. Tortish kuchi doimiy bo‘lib, u *30760 N* ga teng va uchish yo‘nalishi bilan 10^0 burchak tashkil qiladi. Samolyotning maksimal tezligi aniqlansin.

Berilgan:

$F_q = \beta \vartheta^2$

$\beta = 0{,}5\ \frac{N \cdot s^2}{m^2}$

$F_{tor} = 30760\ N$

$\alpha = 10^0$

$\vartheta_{max} = ?$

Yechilishi:

Tortish kuchining *Ox* o'qidagi proyeksiyasi havoning ro'baro' qarshiligini yengadi.

$$F_{tor.X} = F_q, \ \rightarrow \ F_{tor} \cdot \cos 10^0 = \beta \vartheta_{max}^2, \ \vartheta_{max} = \sqrt{\frac{F_{tor} \cdot \cos 10^0}{\beta}} =$$

$$= \sqrt{\frac{30760 \cdot 0{,}9848}{0{,}5}} = 246\ \ m/s$$

Javob: $\vartheta_{max} = 246\, m/s$

Masala № 3. Og'irligi *p* ga teng bo'lgan jism ϑ_0 boshlang'ich tezlik bilan vertikal yuqoriga otildi. U qanday *t* vaqtda qanday *h* balandlikka ko'tariladi? Havoning qarshiligini $R = k^2 p \vartheta^2$ formula bilan ifodalash mumkin, bunda $\vartheta -$ jismning harakat tezligi.

Berilgan:

p, ϑ_0,

t, h

$F_q = k^2 p \vartheta^2$

h=?

t=?

Yechilishi:

Nyutonning 2-qonunidab foydalanib ko'tarilish vaqtini topamiz.

$$ma = -F_{og'} - F_q, \ \rightarrow \ \frac{p}{g}\frac{d\vartheta}{dt} = -p - k^2 p \vartheta^2, \ \rightarrow \ \frac{d\vartheta}{dt} = -g\left(1 + k^2 \vartheta^2\right), \ \rightarrow$$

$$dt = -\frac{1}{g}\frac{d\vartheta}{1 + k^2 \vartheta^2} = -\frac{1}{gk^2}\frac{d\vartheta}{\frac{1}{k^2} + \vartheta^2}, \quad \rightarrow \quad \int_0^t dt = -\frac{1}{gk^2} \cdot \int_{\vartheta_0}^{\vartheta} \frac{d\vartheta}{\left(\frac{1}{k}\right)^2 + \vartheta^2}$$

$$t = -\frac{1}{gk^2} \cdot k \cdot arctg\left(k\vartheta\right)\Big|_{\vartheta_0}^0 = \frac{1}{kg} \cdot arctg\left(k\vartheta_0\right)$$

Nyutonning 2-qonunidab foydalanib ko'tarilish balandligini topamiz.

$$ma = -F_{og'} - F_q, \ \rightarrow \ \frac{p}{g} \cdot \frac{d\vartheta}{dt} \cdot \frac{dy}{dy} = -p - k^2 p \vartheta^2, \ \rightarrow \ \frac{\vartheta d\vartheta}{dy} = -g\left(1 + k^2 \vartheta^2\right), \ \rightarrow$$

$$dy = -\frac{1}{g} \cdot \frac{\vartheta d\vartheta}{1 + k^2 \vartheta^2} = -\frac{1}{2gk^2} \cdot \frac{d\left(k^2 \vartheta^2\right)}{1 + k^2 \vartheta^2}, \quad \rightarrow \quad \int_0^h dy = -\frac{1}{2gk^2} \cdot \int_{\vartheta_0}^{\vartheta} \frac{d\left(k^2 \vartheta^2\right)}{1 + k^2 \vartheta^2} = -\frac{1}{2gk^2} \cdot \int_{\vartheta_0}^{\vartheta} \frac{d\left(1 + k^2 \vartheta^2\right)}{1 + k^2 \vartheta^2}.$$

$$h = -\frac{1}{2gk^2} \cdot \ln\left(1 + k^2 \vartheta^2\right)\Big|_{\vartheta_0}^0 = \frac{1}{2gk^2} \cdot \ln\left(1 + k^2 \vartheta_0^2\right).$$

Javob: $h = \frac{\ln\left(\vartheta_0^2 k^2 + 1\right)}{2gk^2}; \quad t = \frac{1}{kg} arctg\left(k\vartheta_0\right)$

Masala № 4. Massasi *10 t* bo'lgan chang'ili samolyot gorizontal maydonga qo'ndi. Uchuvchi samolyotni qo'nayotgan paytda vertikal tezliksiz va vertikal tezlanishsiz yer yuziga olib keldi. Ro'baro' qarshilik kuchi tezlikning kvaqtratiga proporsional va tezlik *1 m/s* bo'lganida *10 N* ga teng. Ko'tarish kuchi tezlikning kvadratiga proporsional va tezlik *1 m/s* bo'lganida *30 N* ga teng.

Ishqalanish koeffitsiyenti $\mu=0,1$ deb samolyot to‘xtaguncha ketgan vaqt va sirpanib o‘tgan yo‘l aniqlansin. g=10 m/s^2.

Berilgan:

$m=10\ t$

$\mu=0,1$

$\vartheta=0,\ F_q\sim\vartheta^2$

$\beta_x=10\dfrac{N\cdot s^2}{m^2}$

$\beta_y=30\dfrac{N\cdot s^2}{m^2}$

$s=?$

$t=?$

Yechilishi:

Qo‘nish paytida vertikal tezlik va tezlanish bo‘lmagani uchun qanotlarning ko‘tarish kuchi va samolyot og‘irligi teng.

$$F_{og'}=F_{ko'tar},\ \rightarrow\ mg=\beta_y\vartheta_0^2,\ \rightarrow\ \vartheta_0=\sqrt{\frac{mg}{\beta_y}}=\sqrt{\frac{10^4\cdot10}{30}}=57,73\ m/s$$

Ixtiyoriy ondagi samolyot og‘irligini topamiz.

$$P=F_{og'}-F_{ko'tar}=mg-\beta_y\vartheta^2$$

Nyutonning 2-qonunidan foydalanib samolyotning to‘xtash vaqtini topamiz.

$$ma=-F_q-F_{ish},\ \rightarrow\ m\frac{d\vartheta}{dt}=-\beta_x\vartheta^2-\mu P=-\beta_x\vartheta^2-\mu\left(mg-\beta_y\vartheta^2\right)=-\left[\left(\beta_x-\mu\beta_y\right)\vartheta^2+\mu mg\right]$$

$$dt=-m\cdot\frac{d\vartheta}{\left(\beta_x-\mu\beta_y\right)\vartheta^2+\mu mg}=-\frac{m}{\beta_x-\mu\beta_y}\cdot\frac{d\vartheta}{\vartheta^2+\dfrac{\mu mg}{\beta_x-\mu\beta_y}},\quad\rightarrow$$

$$t=\int_0^t dt=-\frac{m}{\beta_x-\mu\beta_y}\cdot\int_{\vartheta_0}^{0}\frac{d\vartheta}{\vartheta^2+\dfrac{\mu mg}{\beta_x-\mu\beta_y}}=-\frac{m}{\beta_x-\mu\beta_y}\cdot\sqrt{\frac{\beta_x-\mu\beta_y}{\mu mg}}\cdot arctg\left(\vartheta\cdot\sqrt{\frac{\beta_x-\mu\beta_y}{\mu mg}}\right)\Bigg|_{\vartheta_0}^{0}=$$

$$=\sqrt{\frac{m}{\mu g\left(\beta_x-\mu\beta_y\right)}}\cdot arctg\left(\vartheta_0\cdot\sqrt{\frac{\beta_x-\mu\beta_y}{\mu mg}}\right)=\sqrt{\frac{m}{\mu g\left(\beta_x-\mu\beta_y\right)}}\cdot arctg\left(\sqrt{\frac{mg}{\beta_y}}\cdot\sqrt{\frac{\beta_x-\mu\beta_y}{\mu mg}}\right)=$$

$$=\sqrt{\frac{m}{\mu g\left(\beta_x-\mu\beta_y\right)}}\cdot arctg\left(\sqrt{\frac{\beta_x-\mu\beta_y}{\mu\beta_y}}\right)$$

Demak, samolyotning to‘xtash vaqti quyidagicha bo‘lar ekan:

$$t=\sqrt{\frac{10^4}{0,1\cdot10\left(10-0,1\cdot30\right)}}\cdot arctg\left(\sqrt{\frac{10-0,1\cdot30}{0,1\cdot30}}\right)=\frac{100}{\sqrt{7}}\cdot arctg\left(\sqrt{\frac{7}{3}}\right)=37,8\ s$$

Endi Nyutonning 2-qonunidan foydalanib samolyotning to‘xtash yo‘lini topamiz.

$$ma=-F_q-F_{ish},\ \rightarrow\ m\frac{d\vartheta}{dt}\cdot\frac{dx}{dx}=-\beta_x\vartheta^2-\mu P=-\left[\left(\beta_x-\mu\beta_y\right)\vartheta^2+\mu mg\right],\ \rightarrow\ m\frac{\vartheta d\vartheta}{dx}=$$

$$=-\left[\left(\beta_x-\mu\beta_y\right)\vartheta^2+\mu mg\right],\ \rightarrow\ dx=-m\cdot\frac{\vartheta d\vartheta}{\left(\beta_x-\mu\beta_y\right)\vartheta^2+\mu mg}=-\frac{m}{2\left(\beta_x-\mu\beta_y\right)}\cdot$$

$$\cdot\frac{d\left(\vartheta^2+\dfrac{\mu mg}{\beta_x-\mu\beta_y}\right)}{\vartheta^2+\dfrac{\mu mg}{\beta_x-\mu\beta_y}},\quad\rightarrow\quad s=\int_0^s dx=-\frac{m}{2\left(\beta_x-\mu\beta_y\right)}\cdot\int_{\vartheta_0}^{0}\frac{d\left(\vartheta^2+\dfrac{\mu mg}{\beta_x-\mu\beta_y}\right)}{\vartheta^2+\dfrac{\mu mg}{\beta_x-\mu\beta_y}}=-\frac{m}{2\left(\beta_x-\mu\beta_y\right)}\cdot$$

$$\cdot \ln\left|\vartheta^2+\frac{\mu mg}{\beta_x-\mu\beta_y}\right|\Bigg|_{\vartheta_0}^{0}=\frac{m}{2\left(\beta_x-\mu\beta_y\right)}\cdot\ln\left|\vartheta_0^2\cdot\frac{\beta_x-\mu\beta_y}{\mu mg}+1\right|=\frac{m}{2\left(\beta_x-\mu\beta_y\right)}\cdot\ln\left|\frac{\beta_x-\mu\beta_y}{\mu\beta_y}+1\right|=$$

$$=\frac{m}{2\left(\beta_x-\mu\beta_y\right)}\cdot\ln\left|\frac{\beta_x}{\mu\beta_y}\right|.$$

Demak, samolyotning to‘xtash masofasi quyidagicha bo‘lar ekan:

$$s=\frac{10^4}{2\cdot\left(10-0{,}1\cdot 30\right)}\cdot\ln\left|\frac{10}{0{,}1\cdot 30}\right|=\frac{5000}{7}\cdot\ln\left|\frac{10}{3}\right|=860\ m$$

Javob: *s=860 m; t=37,8 s.*

11-amaliy mashg‘ulot topshirig‘i

Qarshilik kuchi o‘zgarmas

11.1. Massasi *65 kg* bo'lgan sportchi *10 metrli* minoradan suvga sakrab, unga *13 m/s* tezlik bilan sho'ng'iydi. Havoning o'rtacha qarshilik kuchini toping. **Javob:** *35 kN*

11.2. Buyum *25 m* balandlikdan *2,5 s* davomida tushdi. Havoning o'rtacha qarshilik kuchi og'irlik kuchining qanday qismini tashkil qiladi? **Javob:** *0,2*

11.3. Massasi *4 kg* bo‘lgan jism havoda *8,5 m/s²* tezlanish bilan tushmoqda. Havoning qarshilik kuchini toping (*N*). **Javob:** *6 N*

11.4. Yuqoriga tik otilgan *80 g* massali jismga havoning *0,8 N* o'rtacha qarshilik kuchi ta’sir etayotgan bo‘lsa, jismning tezlanish moduli necha m/s² ga teng? **Javob:** *20 m/s²*

11.5. $m_1=80\,kg$ massali harbiy askar $a=2{,}5\ m/s^2$ tezlanish bilan parashyutda tushmoqda. Parashyutning massasi $m_2=5\,kg$ ga teng. Aniqlang: a) ochiq parashyutga havo tomonidan yuqoriga yo‘nalgan F_{qar} kuchni; b) parashyutga askar tomonidan pastga yo‘nalgan P kuchni. $g=9{,}8\ m/s^2$. **Javob:** $a)\,F_{qar}=620{,}5\,N;\ b)\,P=584\,N$

11.6. $\vartheta_0=30\ m/s$ boshlang‘ch tezlik bilan tik holda yuqoriga otilgan $m=0{,}4\,kg$ massali jism $t=2{,}5\,s$ vaqtda maksimal balandlikka yetgan bo‘lsa, u holda havoning o'rtacha qarshilik kuchi nimaga teng? $g=10\ m/s^2$. **Javob:** $F_{qar}=0{,}8\,N$

11.7. Gorizontga burchak ostida otilgan $m=1kg$ massali jismning eng yuqoriga ko‘tarilgan nuqtadagi to‘la tezlanishi $a=12\,m/s^2$ ga teng bo‘lsa, u holda havoning qarshilik kuchi nimaga teng? $g=9{,}8\ m/s^2$. **Javob:** $F_{qar}=6{,}92\,N$

Qarshilik kuchi o‘zgaruvchan, uning qiymati tezlikka bog‘liq

11.8. Avtomobilning tezligi *60* foizga ortsa, tezlik kvadratiga to‘g‘ri proporsional bo‘lgan havoning qarshilik kuchi necha marta va necha protsentga ortadi? **Javob:** *2,56 marta va 156 % ga ortadi*

11.9. $m_1 = 80\,kg$ massali parashyutchi havoda o‘zgarmas $\vartheta_1 = 5\,m/s$ tezlik bilan tushmoqda. Xuddi shu parashyutda $m_2 = 40\,kg$ massali bola qanday o‘zgarmas ϑ_2 tezlik bilan tushadi? Havoning qarshilik kuchini tezlikning kvadratiga proporsional deb hisoblang. **Javob:** $\vartheta_2 = \sqrt{\frac{m_2}{m_1}}\,\vartheta_1 = 3{,}53\,m/s$

11.10. Velosiped shinasi va yo‘l orasidagi ishqalanish koeffitsiyenti $\mu = 0{,}1$ ga teng. Bunda velosipedchining eng katta tezligi $\vartheta_{\max} = 10\,m/s$ ga teng bo‘lib, u bunga $F=200\ N$ kuch sarflamoqda. Olddan esadigan shamolning qarshiligi $F_{qar} = \beta\vartheta^2$ ko‘rinishida tezlikning kvadratiga proporsional. Velosiped va velosipedchining birgalikdagi massasi $m = 100\,kg$. Bunda β koeffitsiyent nimaga teng? **Javob:** $\beta = 1\,kg/m$

11.11. Massasi 100 g bo‘lgan sharcha og‘irlik kuchi ta’siri ostida pastga tushmoqda. Bunda sharcha havoning qarshiligiga uchraydi, sharcha harakati $x = 4{,}9t - 2{,}45\left(1 - e^{-2t}\right)$ tenglamaga binoan sodir bo‘ladi. Bunda x – metrelarda, t – sekundlarda o‘chanadi, Ox o‘qi esa vertikal bo‘ylab pastga yo‘nalgan deb oling. Hvoning R qarshilik kuchining vaqtga va tezlikka bog‘lanish tenglamalari $R = R(t)$ va $R = R(\vartheta)$ ni keltirib chiqaring. $g = 10\,m/s^2$ deb oling. **Javob:** $R(t) = 0{,}98\left(1 - e^{-2t}\right)\ [N]$; $R(\vartheta) = 0{,}2\vartheta\ [N]$

11.12. Massasi *2000 kg* bo‘lgan sport samolyoti gorizontal bo‘ylab *5 m/s*^{2} tezlanish bilan uchadi, uning shu ondagi tezligi *200 m/s*. Havoning qarshiligi tezlik kvadratiga proporsional va tezlik *1 m/s* bo‘lganda *0,5 N* ga teng. Qarshilik kuchi tezlika teskari tomonga yo‘nalgan deb hisoblab, vintning tortish kuchi aniqlansin. Vintning tortish kuchi uchish yo‘nalishi bilan 10^0 li burchak tashkil. Shuningdek shu gorizontal holat saqlanish uchun yana qancha ko‘tarish kuchi qo‘yish kerak? **Javob:** $F_{tor} = 30463\,N$; $F_{ko'tar} = 14310\,N$

11.13. Massasi *10 kg* va radiusi *r=8 sm* bo‘lgan sharning pastga tushish vaqtidagi eng katta tezligi topilsin. Havo qarshiligi $R = kS\vartheta^2$ ga teng. Bunda ϑ – sharning tushish tezligi; S – tushuvchi jismning o‘z harakatiga tik bo‘lgan tekislikka proyeksiyasi, ya’ni oldidan qaragandagi yuzasi, k – jism shakliga va havo zichligiga bog‘liq bo‘lgan koeffitsiyent bo‘lib, shar uchun havoda $k = 0{,}24\frac{N\cdot s^2}{m^4}$ ga teng. **Javob:** $\vartheta_{\max} = 142{,}5\,m/s$

11.14. Radiuslari teng va zichliklari ρ_1 va ρ_2 bo‘lgan turli materiallardan yasalgan ikkita shar havoda tushmoqda. Muhitning qarshiligi tezlikning kvadratiga proporsional deb

hisoblab, sharlar erishadigan eng katta tezliklarning nisbati aniqlansin. **Javob:** $\frac{\vartheta_{1.\max}}{\vartheta_{2.\max}} = \sqrt{\frac{\rho_1}{\rho_2}}$

11.15. Massasi *90 kg* bo‘lgan chang‘ichi 45^0 li nishab joyda chang‘i hassalarini ishlatmasdan tez tushib boradi. Chang‘ining qorga ishqalanish koeffitsiyenti $\mu=0,1$. Chang‘i harakatiga havoning qarshilik kuchi tezlik kvaqtratiga proporsional va *1 m/s* da *0,635 N* ga teng. Chang‘ichning erishish mumkin bo‘lgan eng kattta tezligi topilsin. Agar chang‘ichi chang‘ini yaxshi moy bilan moylab ishqalanish koeffitsiyentini *0,05* gacha kamaytirsa, endigi maksimal tezlik nimaga teng bo‘ladi? **Javob:** $\vartheta_{1.\max} = 29,73 m/s;\ \vartheta_{2.\max} = 30,55 m/s$

11.16. Kema tezligi kvadratiga proporsioanal va *1 m/s* da *1200 N* ga teng bo‘lgan suvning qarshilik kuchini yengib kema harakatlanmoqda. Vintlarning suvni itarish kuchi (ya’ni kemaning tortish kuchi) $T = 12 \cdot 10^5 \left(1 - \frac{\vartheta}{33}\right) [N]$ qonunga muvofiq o‘zgaradi. Bunda ϑ – kemaning tezligi bo‘lib, u *m/s* larda ifodalanadi. Kema erishish mumiin bo‘lgan maksimal tezlik nimaga teng? **Javob:** $\vartheta_{\max} \approx 20 m/s$

11.17. Samolyot boshlang‘ich vertikal tezliksiz sho‘ng‘iydi. Havoning qarshilik kuchi tezlikning kvaqtratiga proporsional. Shu paytdagi vertikal tezlik, o‘tilgan yo‘l va maksimal sho‘ng‘ish yezligi orasidagi bog‘lanish topilsin. **Javob:** $\vartheta = \vartheta_{\max}\sqrt{1 - e^{-2gs/\vartheta_{\max}^2}}$

11.18. Massasi *2 kg* bo‘lgan jism vertikal holda tik yuqoriga *20 m/s* tezlik bilan otilgan. Bu jism tezligi $\vartheta\ [m/s]$ ga teng bo‘lganda $R = 0,4\vartheta\ [N]$ bo‘lgan havo qarshiligiga uchraydi. Necha sekunddan keyin bu jism o‘zining eng yuqorigi holatiga erishish mumkin. **Javob:** *1,71 s;*

11.19. Massasi 10^7 *kg* bo‘lgan kema *16 m/s* tezlik bilan harakatlanadi. Suvning qarshiligi kema tezligining kvaqtratiga to‘g‘ri proporsional va *1 m/s* tezlikda *300 kN* ga teng. Kemaning tezligi *4 m/s* ga teng bo‘lguncha qanday masofani bosib o‘tadi? Kema bu masofani qancha vaqtda o‘tadi? **Javob:** *s=46,2 m; t=6,25 s*

11.20. Massasi *10 t* bo‘lgan chang‘ili samolyot gorizontal maydonga qo‘ndi. Uchuvchi samolyotni qo‘nayotgan paytda vertikal tezliksiz va vertikal tezlanishsiz yer yuziga olib keldi. Ro‘baro‘ qarshilik kuchi tezlikning kvaqtratiga proporsional va tezlik *1 m/s* bo‘lganida *10 N* ga teng. Ko‘tarish kuchi tezlikning kvadratiga proporsional va tezlik *1 m/s* bo‘lganida *30 N* ga teng. Ishqalanish koeffitsiyenti $\mu=0,1$ deb samolyot to‘xtaguncha ketgan vaqt va sirpanib o‘tgan yo‘l aniqlansin. g=10 m/s^2. **Javob:** *s=860 m; t=37,8 s.*

12-MAVZU: Bloklar. Jismning bir necha kuch ta’siri ostidagi harakati.

Mavzuga oid muhim formulalar

$P = m(g + a)$	*Tezlanish tik yuqoriga yo‘nalganda jismning og‘irligini aniqlash formulasi*
$P = m(g - a)$	*Tezlanish tik pastga yo‘nalganda jismning og‘irligini aniqlash formulasi*
$P = F_{og'} = mg$	*Tezlanish mavjud bo‘maganda jismning og‘irligi*
$a = \frac{m_2 - m_1}{m_2 + m_1} g, \quad T = \frac{2m_1 m_2}{m_1 + m_2} g$	*Vaznsiz blokdan o‘tkazilgan yengil ipga osilgan jismlarning tezlanishi va ipdagi taranglik kuchi*

12-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Erkin aylanuvchi blokga osilgan yuklarning $(m_2 > m_1)$ harakat tezlanishi va iplarning taranglik kuchi uchun formulalar chiqaring.

Berilgan:

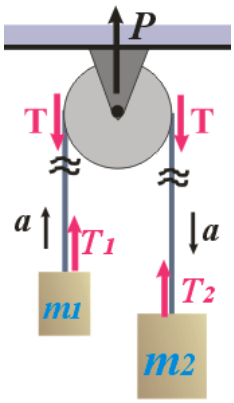
m_1

m_2

a=?

T=?

Yechilishi:



Bizga erkin aylanuvchi blok berilgan bo‘lib, unga o‘tkazilgan yengil ip uchlariga turli massali jismlar osilgan bo‘lsin. Bunda yuklar qanday tezlanish bilan harakatlanishi va ipdagi taranglik kuchi nimaga teng bo‘lishini hisoblab ko‘raylik. Kesish usulidan foydalanamiz, ya’ni arqonni kesib uning joyiga ikkinchi qismining ta’sir kuchini qo‘yish mumkin. Arqon bitta bo‘lgani uchun unda faqat bitta taranglik kuchi bo‘ladi, ya’ni arqonning ikkita uchida ikki xil taranglik kuchi bo‘lmaydi.

$$\begin{cases} T_1 = m_1(g + a) \\ T_2 = m_2(g - a) \end{cases}, \rightarrow \quad T_1 = T_2, \quad \rightarrow \quad m_1 g + m_1 a = m_2 g - m_2 a, \rightarrow \quad (m_1 + m_2)a = (m_2 - m_1)g, \quad \rightarrow$$

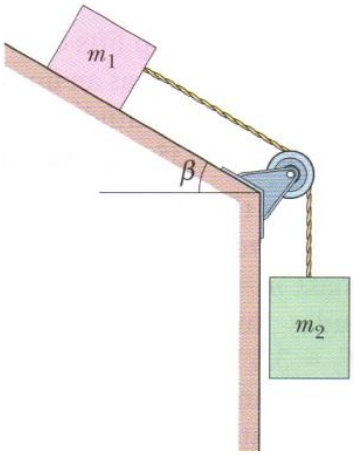
$$a = \frac{m_2 - m_1}{m_2 + m_1} g, \quad \rightarrow \quad T = T_1 = m_1(g + \frac{m_2 - m_1}{m_2 + m_1} g) = \frac{m_2 + m_1 + m_2 - m_1}{m_2 + m_1} m_1 g = \frac{2m_1 m_2}{m_2 + m_1} g$$

Demak, erkin aylanuvchi blokga osilgan yuklarning harakat tezlanishi va iplarning taranglik kuchi quyidagi formulalar yordamida aniqlanar ekan.

$$a = \frac{m_2 - m_1}{m_2 + m_1} g, \qquad T = \frac{2m_1 m_2}{m_2 + m_1} g$$

Javob: $a = \frac{m_2 - m_1}{m_2 + m_1} g, \; T = \frac{2m_1 m_2}{m_2 + m_1} g$.

Masala № 2. Rasmda qiya $(\sin\beta = 0{,}6)$ sitrda $m_1 = 10\,kg$ massali jism shkivdan o'tkazilgan yengil arqon yordamida erkin $m_2 = 15\,kg$ massali boshqa jismga osilgani tasvirlangan. Sirtdagi ishqalanish koeffitsiyenti $\mu = 0{,}1$ ga teng. Shkiv yengil va ishqalanishsiz. Aniqlang: *a)* jismlarning tezlanishini; *b)* ipning taranglik kuchini. $g = 10\ m/s^2$ deb oling.



Berilgan:
$(\sin\beta = 0{,}6)$
$m_1 = 10\,kg$
$m_2 = 15\,kg$
$\mu = 0{,}1$
$g = 10\ m/s^2$
$a = ?,\ T = ?$

Yechilishi:

Yuklar sistemasi biror a tezlanish bilan harakat qilayotgan bo'lsdin. Arqonning 1-yukni tortib pastga tushayotgan uchidagi taranglik kuchi

$$T = \mu m_1 g\cos\beta + m_1 a - m_1 g\sin\beta$$

ga, 2-uchidagi taranglik kuchi esa

$$T = m_2 g - m_2 a$$

ga teng bo'ladi. Ularni tenglashtirib tezlanishni topamiz.

$$\mu m_1 g\cos\beta + m_1 a - m_1 g\sin\beta = m_2 g - m_2 a,\ \rightarrow\ a(m_1 + m_2) = m_2 g + m_1(\sin\beta - \mu\cos\beta)g,\ \rightarrow$$

$$a = \frac{m_2 + m_1(\sin\beta - \mu\cos\beta)}{m_1 + m_2} g = \frac{15 + 10\cdot(0{,}6 - 0{,}1\cdot 0{,}8)}{10 + 15}\cdot 10 = 8{,}1\ m/s^2$$

Endi taranglik kuchini aniqlaymiz.

$$T = m_2(g - a) = m_2 g\left(1 - \frac{m_2 + m_1(\sin\beta - \mu\cos\beta)}{m_1 + m_2}\right),\ \rightarrow T = \frac{(1 + \mu\cos\beta - \sin\beta)m_1 m_2}{m_1 + m_2} g =$$

$$= \frac{(1 + 0{,}1\cdot 0{,}8 - 0{,}6)\cdot 10\cdot 15}{10 + 15}\cdot 10 = 28{,}8\,N$$

Javob: $a)\ a = 8{,}1\ m/s^2;\ \ b)\ T = 28{,}8\,N$

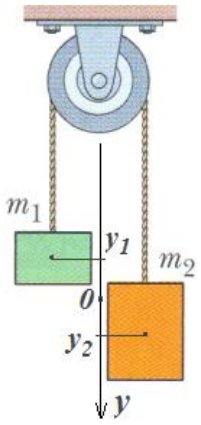
12-amaliy mashg'ulot topshirig'i

12.1. Massalari m_1 va m_2 bo'lgan ikki jism qo'zg'almas blok orqali o'tgan vaznsiz va cho'zilmaydigan ip bilan o'zaro bog'langan. Ularning tezlanishlari qanday ifoda bilan aniqlanadi? Agar jismlarning massalari *6* va *4 kg* bo'lsa, tezlanish nimaga teng bo'ladi? $g = 10\ m/s^2$. J: $a = g\dfrac{m_2 - m_1}{m_2 + m_1};\ 2\,m/s^2$

12.2. Yuqoridagi masala uchun jismlarni bog'lab turgan ipning taranglik kuchini aniqlovchi formulani keltirib chiqaring. Taranglik kuchini jismlarning massalari *6* va *4 kg* bo'lgan hol uchun hisoblang. J: $T = \dfrac{2m_1 m_2 g}{m_1 + m_2};\ 48\,N$

12.3. 25.1-masala sharti uchun shift qo‘zg‘almas blokni ushlab turadigan P reaksiya kuchini aniqlash formulasini keltirib chiqaring. J: $P = 2T = \dfrac{4m_1m_2g}{m_1+m_2}$

12.4. Rasmdagi qo‘zg‘lmas blokka osilgan jismlar dastlab $y=0$ koordinatada ushlab turilibdi. Jismlar qo‘yib yuborilgandan ixtiyoriy t vaqt o‘tgach jismlar sistemasining massalar markazining koordinatasi y_C, tezligi ϑ_C va tezlanishi a_C larni aniqlash formulalarini keltirib chiqaring. Massalar markazini aniqlashda $y_C = \dfrac{y_1m_1 + y_2m_2}{m_1+m_2}$ formuladan foydalaning. J: $y_C = \left(\dfrac{m_2-m_1}{m_2+m_1}\right)^2 \dfrac{gt^2}{2}$;



$\vartheta_C = \left(\dfrac{m_2-m_1}{m_2+m_1}\right)^2 gt$; $a_C = \left(\dfrac{m_2-m_1}{m_2+m_1}\right)^2 g$

12.5. Rasmda kabina stulida o‘tirgan quruvchi qo‘zg‘lmas blok orqali o‘tkazilgan blok orqali kabinani ko‘tarayotgani tasvirlangan. Kabina va quruvchining birgalikdagi massasi $m = 100\,kg$ ga teng. Aniqlang: *a)* tekis ko‘tarilish uchun quruvchi arqonning ikkinchi uchini qanday F kuch bilan pastga tortish kerak?; *b)* $a = 1{,}2\ m/s^2$ tezlanish bilan ko‘tarilish uchun-chi?; *c)* har ikkala holda blokni shift qanday P kuch bilan ushlab turish kerak? $g = 9{,}8\ m/s^2$ deb oling. J:

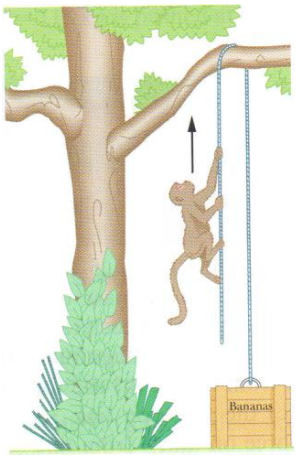
$a)\ F = \dfrac{1}{2}mg = 490\,N$; $b)\ F = \dfrac{1}{2}m(g+a) = 550\,N$;

$c)\ P = 980\,N; P = 1100\,N$

12.6. Oldingi masala shartidan foydalanib, arqonning uchini yerda turgan quruvchining hamkasbi pastga tortayotgan hol uchun yeching. J: $a)\ F = mg = 980\,N$;

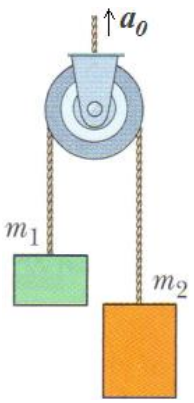
$b)\ F = m(g+a) = 1100\,N$; $c)\ P = 1960\,N; P = 2200\,N$

12.7. Rasmda bir uchi yukka bog‘lngan, ikkinichi uchidan maymun tirmashib ko‘tarilayotgan, silliq daraxt shoxi orqali o‘tkazilgan yengil va cho‘zilmas arqon tasvirlangan. Maymunning massasi $m_1 = 10\,kg$, yukning massasi $m_2 = 15\,kg$ ga teng. *a)* Yukni yerdan tekis ko‘tarish uchun maymun tepaga qanday tezlanish bilan ko‘tarilish kerak? *b)* Agar maymun joyida to‘xtab qolsa, yuk qanday tezlanish bilan pastga tusha boshlaydi va bunda arqonning taranglik kuchi nimaga teng bo‘ladi? J:



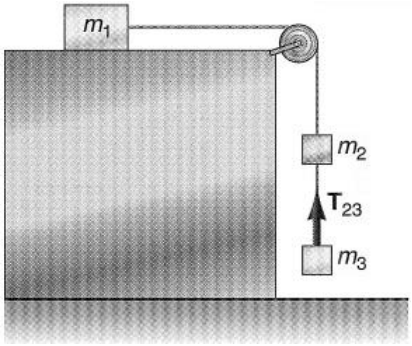
$a)\ a = 5\,m/s^2; b)\ a = 2\,m/s^2; T = 120\,N$

12.8. Massalari $m_1 = 6kg$ va $m_2 = 10kg$ bo‘lgan ikkita yuk blok orqali o‘tgan vaznsiz va cho‘zilmaydigan ip bilan o‘zaro bog‘langan. Blokni yuqoriga $a_0 = 2\ m/s^2$ tezlanish bilan ko‘tarilmoqda. Bunda yuklarning blokka nisbatan a va yerga nisbatan a_1 va a_2 tezlanishlari qanday? Yuklarni bog‘lovchi ipdagi taranglik kuchi-chi? J: $a = \frac{m_2 - m_1}{m_2 + m_1}(g + a_0) = 3\ m/s^2$; $a_1 = a_0 + a = 5m/s^2$;



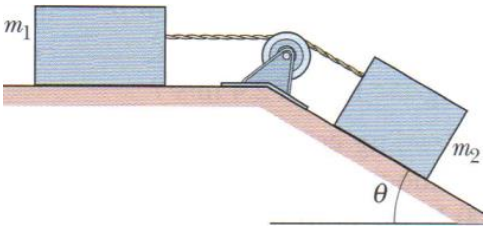
$a_2 = a_0 - a = -1m/s^2; T = \begin{cases} m_1(g + a_1) \\ m_2(g - |a_2|) \end{cases} = 90\ N$

12.9. * Rasmdagi jismlarning massalari $m_1 = 5kg$, $m_2 = 2kg$ va $m_3 = 3kg$ va gorizontal sirtdagi ishqalanish koeffitsiyenti $\mu = 0,2$ ga teng bo‘lsa, jismlarning tezlanishini hamda m_2 va m_3 yuklarni bog‘lovchi ipdagi taranglik kuchi T_{23} ni aniqlang. $g = 10\ m/s^2$ deb oling. J:



$a = \frac{m_2 + m_3 - \mu m_1}{m_1 + m_2 + m_3} g = 4\ m/s^2$; $T_{23} = \frac{(1+\mu) m_1 m_3}{m_1 + m_2 + m_3} g = 18\ N$

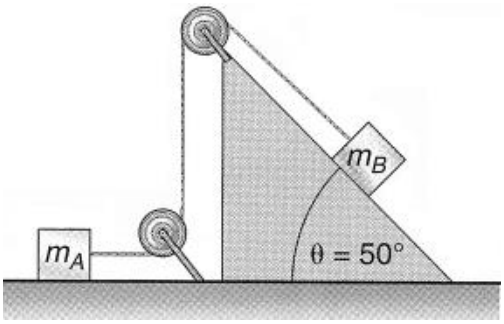
12.10. * Rasmda qiya $(\sin\theta = 0,6)$ sitrda $m_2 = 10kg$ massali jism shkivdan o‘tkazilgan yengil arqon yordamida gorizontal sirtdagi $m_1 = 15kg$ massali boshqa jismga bog‘langani tasvirlangan. Sirtlardagi ishqalanish koeffitsiyentlari $\mu = 0,1$ ga teng. Shkiv yengil va ishqalanishsiz. Aniqlang: *a)* jismlarning tezlanishini; *b)* ipning taranglik kuchini. $g = 10\ m/s^2$ deb oling. J:



$a)\ a = \frac{m_2 \sin\theta - \mu(m_1 + m_2\cos\theta)}{m_1 + m_2} g = 1,52\ m/s^2$;

$b)\ T = \frac{(\sin\theta + \mu(1 - \cos\theta)) m_1 m_2}{m_1 + m_2} g = 37,2\ N$;

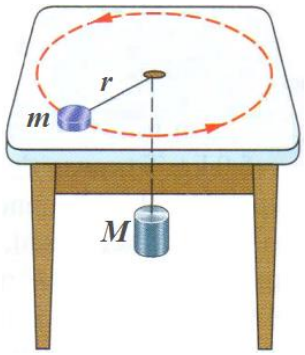
12.11. * Rasmda qo‘zg‘lmas vaznsiz bloklar orqali o‘tkazilgan yengil iplarga bog‘langan *A* va *B* jismlar tasvirlangan. Jismlarning massalari $m_A = 3kg, m_B = 5kg$ hamda jismlarning sirtlarga ishqalanish koeffitsiyentlari $\mu_A = 0,3$, $\mu_B = 0,2$ ga teng. Aniqlang: *a)* jismlarning tezlanishi va ipdagi taranglik kuchini; *b)* harakat boshlangandan $t = 0,5s$ vaqt o‘tgach jismlar qanday tezlikka erishadi va ular qancha



masofaga siljiydi? J: $a)\,a=\dfrac{(\sin\theta-\mu_B\cos\theta)m_B-\mu_A m_A}{m_A+m_B}g=2{,}86\,m/s^2;$

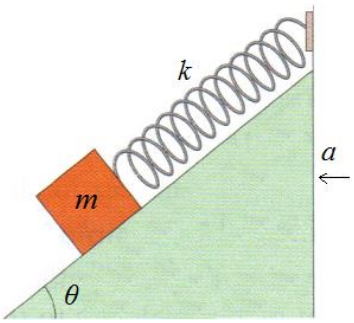
$T=\dfrac{(\mu_A+\sin\theta-\mu_B\cos\theta)m_A m_B}{m_A+m_B}g=17{,}58\,N;\ \ b)\,s=\dfrac{at^2}{2}=0{,}3575\,m;\ \vartheta=at=1{,}43\,m/s$

12.12. Rasmda vaznsiz arqonning bir uchiga gorizontal tekislikda $r=25\,sm$ radiusli aylana bo‘yicha aylanayotgan $m=1kg$ massali jism, ikkinchi uchiga esa $M=2{,}5kg$ massali yuk osilgani tasvirlangan. *m* jism qanday tezlikda aylanganda u *M* yukni muvozonatda ushlab tura oladi? Stol sirti mutlaqo silliq. $g=10\ m/s^2$ deb oling. J: $\vartheta=\sqrt{\dfrac{M}{m}gr}=2{,}5\,m/s$



12.13. * Agar yuqoridagi masala shartida qiya tekislik chap tomonga rasmdagi kabi $a=2\ m/s^2$ tezlanish bilan harakatlantirilayotgan bo‘lsa, u holda prujina qancha $\Delta\ell$ ga uzayadi? J:

$\Delta\ell=\dfrac{mg}{k}(\sin\theta-\mu cos\theta)-\dfrac{ma}{k}(cos\theta+\mu\sin\theta)=5{,}28\,sm$



13-MAVZU: Elastiklik kuchlari. Yer sirti va biror balandlik uchun og‘irlik kuchi hamda erkin tushish tezlanishi. Gravitatsion maydon kuchlanganligi.

Mavzuga oid muhim formulalar

$\Delta\ell = \ell - \ell_0, \qquad \varepsilon = \frac{\Delta\ell}{\ell_0}\cdot 100\%$	*Absalyut uzayish va nisbiy uzayish*
$F_{el} = -k\,\Delta\ell, \quad yoki \quad F_{el} = -k\,x$	*Bo‘ylama deformatsiya uchun Guk qonuni*
$\sigma = \frac{F}{S}, \quad yoki \quad \sigma = E\lvert\varepsilon\rvert$	*Mexanik kuchlanish*
$k = \frac{S\,E}{\ell_0}$	*Bo‘ylama bikrlikning material turi va geometrik o‘lchamlarga bog‘liqligi*
$M = -\kappa\,\theta$	*Boralma deformatsiya uchun Guk qonuni*
$g_0 = G\frac{M}{R^2} = 9{,}803\,\frac{m}{s^2}$	*Yer sirtida erkin tushish tezlanishi (yoki gravitatsion maydon kuchlanganligi)*
$g_h = G\frac{M}{(R+h)^2} = g_0\left(\frac{R}{R+h}\right)^2$	*Yer sirtidan h balandlikda erkin tushish tezlanishi*
$g_h = g_0\cdot\frac{r}{R} = g_0\cdot\frac{R-h}{R}$	*Yer sirtidan h chuqurlikda erkin tushish tezlanishi*

13-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Bikrligi *600 N/m* bo‘lgan vaznsiz prujina *9 sm* ga cho‘zilishi uchun gorizontal yo‘dagi *22,5 kg* massali aravachani qanday tezlanish bilan harakatlantirish kerak? (ishqalanish hisobga olinmasin).

Berilgan:
k=600 N/m
x=9sm
m=22,5 kg

a=?

Yechilishi:

Inersiya kuchini elastiklik kuchi yuzaga keltiradi.

$$F_{in} = F_e, \;\rightarrow\; ma = kx, \;\rightarrow\; a = \frac{kx}{m} = \frac{600\,N/m\cdot 0{,}09\,m}{22{,}5\,kg} = 2{,}4\;m/s^2$$

Javob: *2,4 m/s²*

Masala № 2. Uzunligi ℓ ga va bikrligi k ga teng bo'lgan prujina uzunliklari $\ell_1 = \frac{3}{4}\ell$ va $\ell_2 = \frac{1}{4}\ell$ bo'lgan ikki bo'lakka bo'lindi. Har bir bo'lakning bikrligini toping.

Berilgan:	*Yechilishi:*
k=600 N/m *x=9sm* *m=22,5 kg* *a=?*	Bikrlik formulasiga ko‘ra dastlabki bikrlik $k=\frac{SE}{\ell}$ bo‘lgan. Prujinani ikkiga bo‘lganda birinchi $\ell_1=\frac{3}{4}\ell$ uzunlikdagi qismning bikrligi $k_1=\frac{SE}{\ell_1}=\frac{SE}{\frac{3}{4}\ell}=\frac{4}{3}\frac{SE}{\ell}=\frac{4}{3}k$ ga, ikkinchi $\ell_2=\frac{1}{4}\ell$ uzunlikdagi qismning bikrligi esa $k_1=\frac{SE}{\ell_1}=\frac{SE}{\frac{1}{4}\ell}=4\frac{SE}{\ell}=4k$ ga teng bo‘ladi.

Javob: $k_1=\frac{4}{3}k;\ k_2=4k$

Masala № 3. Radiusi va massasi Yernikidan 3 marta katta bo‘lgan sayyora sirtida jismning og‘irlik kuchi Yer sirtidagidan qanday farq qiladi?

Berilgan:	*Yechilishi:*
$R=3R_{yer}$ $M=3M_{yer}$ $\frac{P}{P_{yer}}=?$	Har bir sayyora uchun og`irlik kuchi formulasini yozamiz $P_{yer}=mg_{yer}=m\frac{\gamma M_{yer}}{R_{yer}^2},\qquad P=m\frac{\gamma M}{R^2}$ $\frac{P}{P_{yer}}=\frac{m\gamma M}{R^2}\frac{R_{yer}^2}{m\gamma M_{yer}}=\left(\frac{R_{yer}}{R}\right)^2\frac{M}{M_{yer}}=\left(\frac{1}{3}\right)^2\cdot 3=\frac{1}{3}.$

$P_{yer}=3P$ Yerdagidan 3 marta kichik bo‘lar ekan

Javob: *3 marta kam bo'ladi*

Masala № 4. Uch Yer radiusiga teng balandlikda erkin tushish tezlanishi Yer sirtidagiga nisbatan qanday bo‘ladi?

Berilgan:	*Yechilishi:*
$h=3R$ $\frac{g_h}{g_0}=?$	h balandlikdagi erkin tushish tezlanishi formulasidan foydalanamiz. $g_h=\left(\frac{R}{R+h}\right)\cdot g_0=\left(\frac{R}{4R}\right)^2\cdot g_0=\frac{g_0}{16}.$ *3R* balandlikdagi erkin tushish tezlanishi Yer sirtidagi erkin tushish tezlanishidan 16 marta kichik ekan.

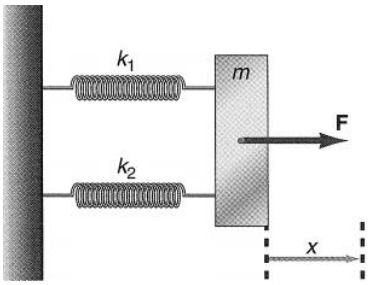
Javob: *16 marta kichik*

13-amaliy mashg‘ulot topshirig‘i

Elastiklik kuchlari

13.1. Bikrligi *600 N/m* bo‘lgan vaznsiz prujina *9 sm* ga cho‘zilishi uchun gorizontal yo‘dagi *22,5 kg* massali aravachani qanday tezlanish bilan harakatlantirish kerak? (ishqalanish hisobga olinmasin). **Javob:** *2,4 m/s²*

13.2. Uzunligi ℓ ga va bikrligi k ga teng bo'lgan prujina uzunliklari $\ell_1 = \frac{3}{4}\ell$ va $\ell_2 = \frac{1}{4}\ell$ bo'lgan ikki bo'lakka bo'lindi. Har bir bo'lakning bikrligini toping. **Javob:** $k_1 = \frac{4}{3}k;\ k_2 = 4k$



13.3. Bikrliklari k_1 va k_2 bo'lgan prujinalar ketma-ket ulansa, ularning umumiy bikrligi qanday bo'ladi? Bikrliklari k_1, k_2 va k_3 bo'lgan uchta prujinalar ketma-ket ulansa-chi? **Javob:** $k = \frac{k_1 k_2}{k_1 + k_2};\ k = \frac{k_1 k_2 k_3}{k_1 k_2 + k_2 k_3 + k_1 k_3}$

13.4. Uzunligi *1 m* bo'lgan po'lat simning uchiga massasi *260 g* bo'lgan jism biriktirilgan. Bu sim *2 ayl/s* chastota bilan aylantirilganda qancha uzayadi? Simning bikrligi *k=5000 N/m*. **Javob:** *8,2 mm*

13.5. Bikrligi *500 N/m* bo‘lgan prujina yordamida poda yotgan *4 kg* massali brusni tekis tortilganda prugina *10 sm* dan *15 sm* gacha uzaydi. Prujina gorizont bila 60^0 burchak tashkil etadi. Ishqalanish koeffitsiyentini aniqlang. $g = 10\ m/s^2$ deb oling. **Javob:** *0,44*

13.6. Yuk avtomobili massasi $m = 2t$ bo‘lgan yengil avtomobilini shatakka olib tekis tezlanuvchan harakat qiladi va $t = 50s$ vaqt ichida $s = 400m$ masofa bosib o‘tadi. Bunda yengil avtomobilni bog‘lovchi tros qanchaga uzayadi. Trosning bikrligi $k = 2 \cdot 10^6\ N/m$ ga teng. Ishqalanishni hisobga olmang. **Javob:** $\Delta\ell = 0,32\,mm$

13.7. Ikkita prujina rasmdagi kabi parallel ulangan. Ularning bikrliklari $k_1 = 500\,N/m$ va $k_2 = 300\,N/m$ ga teng. $F = 100\,N$ kuch rasmda ko‘rsatilgandek qo‘yilgan. Prujinalarda cho‘zilishlar bir xil deb olib, quyidagilarni aniqlang: *a)* m yukning siljishi x ni; *b)* 1-prujinadagi ekastiklik kuchi F_1 ni; *c)* 2-prujinadagi ekastiklik kuchi F_2 ni. **Javob:** $a)\, x = \frac{F}{k_1 + k_2} = 12,5\,sm;\ b)\, F_1 = \frac{k_1}{k_1 + k_2} F = 62,5\,N;\ c)\, F_2 = \frac{k_2}{k_1 + k_2} F = 37,5\,N$

13.8. $m = 1kg$ massali yuk bikrliga $k = 98\,N/m$ bo‘lgan lift shiftiga mahkamlangan prujinaga osilgan. Agar prujinaning erkin holdagi uzunligi $\ell_0 = 20\,sm$ bo‘lsa, uning yuk osilgan holdagi uzunligi ℓ_1 nimaga teng? *a)* lift $a = 4,9\ m/s^2$ tezlanish bilan ko‘tarilmoqda; *b)* lift $a = 4,9\ m/s^2$ tezlanish bilan pastga tushmoqda. $g = 9,8\ m/s^2$ deb oling. **Javob:** $a)\, \ell_1 = 35\,sm;\ b)\, \ell_1 = 25\,sm$

13.9. Vertikal o‘q atrofida aylanadigan gorizontal diskda $m = 100\,g$ massali sharcha yotibdi. Shayba disk o‘qi bilan bog‘langan. Agar diskning aylanishlar soni $\nu_1 = 2\,ayl/s$ dan oshmasa, u holda prujina deformatsiyalanmagan holatda bo‘ladi. Agar aylanishlar soni $\nu_2 = 5\,ayl/s$ bo‘lsa, prujina ikki marta uzayadi. Prujinaning bikrligini aniqlang. **Javob:** $k = 4\pi m\left(\nu_1^2 + 2\nu_2^2\right) = 67,82\ N/m$

Yer sirti va biror balandlik uchun og‘irlik kuchi hamda erkin tushish tezlanishi. Gravitatsion maydon kuchlanganligi.

13.10. Marsoxodning Marsdagi va Yerdagi massalarini hamda og‘irliklarini taqqoslang. Erkin tushish tezlanishi Marsda $g_{Mars} = 3{,}8\ m/s^2$ Yerda $g_{Yer} = 9{,}8\ m/s^2$. **Javob:** $m_{Mars} = m_{Yer};\ P_{Mars} = 0{,}388 P_{Yer}$

13.11. Yer sirtidan qanday balandlikda jismning og'irligi Yer sirtidagi og'irligidan *9* marta kichik bo'ladi? Qanday balandlikda *16* marta kichik bo'ladi? Qanday balandlikda *n* marta kichik bo'ladi? R – Yerning radiusi. **Javob:** $2R;\ 3R;\ \left(\sqrt{n}-1\right)R$

13.12. Yer radiusining yarmiga teng balandlikda erkin tushish tezlanishi qanday bo'ladi? **Javob:** *4.4 m/s²*

13.13. Venera planetasining o'rtacha zichligi $\rho = 5200\ kg/m^3$, radiusi $R = 6100\ km$. Venera sirtida erkin tushish tezlanishi qanday bo'lishini aniqlang. J: *8,8 m/s²*

13.14. Yer sirtidan necha *km* balandlikda Yerning tortish kuchi *36%* kamayadi? Yerning radiusi *R=6400 km*. **Javob:** *1600 km*

13.15. Yer sirtidan Yer radiusining yarmiga teng balandlikda erkin tushish tezlanishi nimaga teng? To'rt Yer radiusiga teng balandlikda-chi? Yer sirtidagi erkin tushish tezlanishi *g* ga teng. **Javob:** *g/2,25; g/25*

13.16. Agar Quyoshning radiusi Yer radiusidan *108* marta katta, zicnligi esa Yer zichligidan *4* marta kichik bo'lsa, Quyosh sirtida og'irlik kuchining tezlanishi qanday bo'ladi? Yer uchun *g=10 m/s²* deb hisoblang. **Javob:** *270 m/s²*

13.17. Massasi $10^{30}\ kg$, radiusi $10^6\ m$ bo‘lgan neytron yulduzning sirtida erkin tushish tezlanishi nimaga teng? **Javob:** $66700\ km/s^2$

14-MAVZU: Butun olam tortishish qonuni. Kepler qonunlari. Kosmik tezliklar.

Mavzuga oid muhim formulalar

$F = G\frac{m_1 m_2}{r^2}, \qquad F = G\frac{m_1 m_2}{r^3}\vec{r}$	*Butun olam tortishish qonunining skalyar va vektor ko'rinishda berilishi*
$G = 6,67 \cdot 10^{-11}\left[\frac{N \cdot m^2}{kg^2}\right]$	*Gravitatsion maydon doimiysi*
$F = G\frac{M_{Yer} m}{R_{Yer}^2}$	*Yer sirtidagi jismni Yer tortadigan kuch*
$\vartheta_{I.0} = \sqrt{G\frac{M_{Yer}}{R_{Yer}}}$ *yoki* $\vartheta_{I.0} = \sqrt{gR_{Yer}} = 7,9$ [km/ s]	*Yer sirti uchun 1-kosmik tezlik*
$\vartheta_{I.h} = \sqrt{G\frac{M_{Yer}}{R_{Yer}+h}}$ *yoki* $\vartheta_{I.h} = \sqrt{g_h\left(R_{Yer}+h\right)} = \vartheta_{I.0}\sqrt{\frac{R_{Yer}}{R_{Yer}+h}}$	*Yer sirtidan h balandlik uchun 1-kosmik tezlik*
$\vartheta_{II.0} = \sqrt{2gR_{Yer}} = \sqrt{2}\,\vartheta_{I.0} = 11,2$ [km/ s]	*Yer sirti uchun 2-kosmik tezlik*
$\vartheta_{II.h} = \sqrt{2G\frac{M_{Yer}}{R_{Yer}+h}} = \sqrt{2}\vartheta_{I.h}$	*Yer sirtidan h balandlik uchun 2-kosmik tezlik*
$\vartheta_{III} = 16,7$ [km/ s]	*3-kosmik tezlik*
$\frac{\Delta S}{\Delta t} = const$	*Keplerning 2-qonuni*
$\left(\frac{T_2}{T_1}\right)^2 = \left(\frac{a_2}{a_1}\right)^3$	*Keplerning 3-qonuni*
$T = 2\pi(\mathrm{R}+\mathrm{h})\sqrt{\frac{R+h}{GM}}$	*Kosmik kemaning planetani aylanish davri*

14-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Yer va Quyosh orasidagi gravitatsiya kuchini hisoblang. Yerning massasi $m = 5,97 \cdot 10^{24}\,kg$, Quyosning massasi $M = 2 \cdot 10^{30}\,kg$ ular orasidagi masofa $r = 1,5 \cdot 10^{11} m$ ga teng.

Berilgan:

$m = 5{,}97 \cdot 10^{24}\ kg$

$M = 2 \cdot 10^{30}\ kg$

$M = 2 \cdot 10^{30}\ kg$

$F = ?$

Yechilishi:

Butun olam tortish qonuniga ko‘ra

$$F = G\frac{Mm}{r^2} = 6{,}67 \cdot 10^{-11} \cdot \frac{2 \cdot 10^{30} \cdot 5{,}97 \cdot 10^{24}}{\left(1{,}5 \cdot 10^{11}\right)^2} = 3{,}54 \cdot 10^{24}\ N$$

bo’ladi.

Javob: $F = 3{,}54 \cdot 10^{24}\ N$

Masala № 2. Sun’iy yo‘ldosh orbitasining radiusi 9 marta ortsa, uning doiraviy orbita bo‘ylab aylanish davri qanday o‘zgaradi?

Berilgan:

$R_2 = 9R_1$

$\frac{T_2}{T_1} = ?$

Yechilishi:

Kepler qonuniga asosan yechiladi.

$$\left(\frac{T_2}{T_1}\right)^2 = \left(\frac{R_2}{R_1}\right)^3 = \left(\frac{9R_1}{R_1}\right)^3 = 9^3, \ \rightarrow \ \frac{T_2}{T_1} = \sqrt{9^3} = 3^3 = 27, \ \rightarrow \ T_1 = 27T_1$$

Javob: 27

Masala № 3. Massasi va radiusi yernikidan 2 marta katta bo‘lgan planeta uchun birinchi kosmik tezlik qanday (*km/s*)? Yerda birinchi kosmik tezlik *8 km/s*.

Berilgan:

$m = 2M_{yer}$

$R = 2R_{yer}$

$v_{Iyer} = 8m/s$

$v_I = ?$

Yechilishi:

Birinchi kosmik tezlikning formulalarini yozib, keyin ularning nisbatini olamiz.

$$v_1 = \sqrt{\frac{GM}{R}}, \quad v_{1yer} = \sqrt{\frac{GM_y}{R_y}}$$

$$\frac{v_{1y}}{v_1} = \sqrt{\frac{GM_y}{R_y} \cdot \frac{R}{GM}} = \sqrt{\frac{M_y}{R_y} \cdot \frac{2R_y}{2M_y}} = 1$$

$$v_1 = v_{1\,yer} = 8km/s$$

Javob: 8

Masala № 4. Birinchi kosmik tezlik 4 marta kamayadigan balandlik uchun erkin tushish tezlanishining qiymatini aniqlang. Yer sirti uchun $g_0 = 9{,}8\ m/s^2$.

Berilgan:

$\vartheta_{I.h} = \frac{\vartheta_{I.0}}{4}$

$g_h = ?$

Yechilishi:

Birinchi kosmik tezlikning h balandlik uchun formulasidan

$$\vartheta_{I.h} = \vartheta_{I.0}\sqrt{\frac{R}{R+h}} = \frac{\vartheta_{I.0}}{4}, \ \rightarrow \ \frac{R}{R+h} = \frac{1}{16}, \ \rightarrow \ h = 15R$$

hosil bo‘ladi. Bundan erkin tushish *h=15R* tezlanishining balandlikdagi qiymatini aniqlaymiz.

$$g_h = g_0\left(\frac{R}{R+h}\right)^2 = g_0\left(\frac{R}{R+15R}\right)^2 = \frac{g_0}{256} = 0{,}02656\,m/s^2$$

Javob: $0,02656\,m/s^2$

Masala № 5. Qaysi balandlikdan turib yuqoriga birinchi kosmik tezlikning yarmiga teng bo‘lgan tezlik bilan otilgan jism Yerning tortish maydonidfan chiqib ketadi?

Berilgan:

$\vartheta_{I.h} = \dfrac{\vartheta_{I.0}}{4}$

$g_h = ?$

Yechilishi:

Ikkinchi kosmik tezlikning h balandlik uchun qiymati Yer sirtidagi 1-kosmik tezlikning yarim qiymatiga teng. Bundan balandlikni topish mumkin.

$$\vartheta_{II.h} = \frac{\vartheta_{I.0}}{2}, \;\rightarrow\; \sqrt{2}\,\vartheta_{I.h} = \frac{\vartheta_{I.0}}{2}, \;\rightarrow\; \sqrt{2}\,\vartheta_{I.0}\sqrt{\frac{R}{R+h}} = \frac{\vartheta_{I.0}}{2}, \;\rightarrow$$

$$\frac{R}{R+h} = \frac{1}{8}, \;\rightarrow\; h = 7R$$

Javob: *7R*

14-amaliy mashg‘ulot topshirig‘i

14.1. Plutonning Quyoshga tortilish kuchi Yerning tortilish kuchidan necha marta kichik. Plutonning Quyoshdan uzoqligi Yerga nisbatan *40* marta uzoq bo‘lib, Pluton massasi esa Yerning massasidan taxminan *10* marta kichik deb oling. **Javob:** *16000 marta kichik*

14.2. Yer sirtida $m_1 = 140\,kg$ yukni ko‘tara oladigan sportchi Marsda necha kilogram yukni ko‘tara oladi? Erkin tushish tezlanishi Yerda $g_{Yer} = 9,81 m/s^2$ ga Marsda esa $g_{Yer} = 3,75 m/s^2$ ga teng. **Javob:** $m_1 = 366,2\,kg$

14.3. Vodorod atom yadroda turuvchi proton hamda yadro atrofida aylanuvchi elektrondan iborat. Agar atom radiusi $r = 5,29 \cdot 10^{-11} m$ ga, elektron massasi $m_e = 9,11 \cdot 10^{-31} kg$ ga va proton radiusi $m_p = 1,67 \cdot 10^{-27} kg$ ga teng ekanligi ma’lum bo‘lsa, u holda proton ve elektron orasidagi gravitatsion kuchni aniqlang. **Javob:** $3,626 \cdot 10^{-47}\ N$

14.4. Yer sirtidan qanday uzoqlikda kosmik kemaning Yerga tortish kuchi Yer sirtidagidan *100* marta kichik bo‘ladi? **Javob:** $h = 9R$ *uzoqlikda*

14.5. *M* massa ikkita *m* va *M-m* massali qismlarga ajratildi va biror masofaga uzoqlashtirildi. *m/M* nisbatning qanday qiymatida bu qismlar orasidagi tortish kuchi eng katta bo‘ladi? **Javob:** *1/2*

14.6. Quyosh va Yer bir vaqtda Oyni tortib turadi. Oyni Quyosh va Oy tortadigan gravitatsion kuchlar nisbati F_{Quyosh} / F_{Yer} ni aniqlang. Quyoshdan Yergacha va Quyoshdan Oygacha bo‘lgan masofalarni bir xil $r_1 = 1,5 \cdot 10^{11} m$ ga teng deb, Yerdan

Oygacha masofani esa $r_2 = 3{,}84 \cdot 10^8\, m$ ga teng deb oling. Quyosh massasi Yernikidan *330000* marta katta. **Javob:** 2,17

14.7. Oy va Yer orasidagi gravitatsion tortishish kuchi nimaga teng? Bu kuchni ushlab tura oladigan po‘lat trosning diametri nimaga teng? Po‘latning mustagkamlik chegarasi $\sigma_{\max} = 7{,}5 \cdot 10^4 \frac{N}{sm^2}$ ga teng. Oyning massasi $7{,}3 \cdot 10^{22}\, kg$ ga, Yerning massasi $5{,}97 \cdot 10^{24}\, kg$ ga va ular orasidagi masofa $r = 3{,}84 \cdot 10^8\, m$ ga teng. **Javob:** $F = 1{,}97 \cdot 10^{20}\, N;\ D = 578{,}6\, km$

14.8. Quyosh va Yer orasidagi tortshish kuchini toping. Quyoshdan Yergacha masofa $r = 1{,}5 \cdot 10^{11}\, m$ ga, Yerning massasi $5{,}97 \cdot 10^{24}\, kg$ ga va Quyoshning massasi $1{,}99 \cdot 10^{30}\, kg$ ga teng. **Javob:** $F = 3{,}52 \cdot 10^{22}\, N$

14.9. Somon yo‘li galaktikamizning tojini massasi $2 \cdot 10^{11}$ ta Quyosh massasiga teng. Quyoshdan galaktika markazigacha bo‘lgan masofa $3 \cdot 10^{20}\, m$ ga teng. Galaktika toji va Quyosh sistemasi orasidagi gravitatsion tortish kuchi nimaga teng? Quyosh sistemasining massasi $2 \cdot 10^{30}\, kg$ ga teng. **Javob:** $5{,}93 \cdot 10^{20}\, N$

14.10. Massalari *10 kg*, *20 kg* va *30 kg* bo‘lgan nuqtaviy jismlar *Ox* o‘qining mos holda *10 sm*, *50 sm* va *80 sm* koordinatalariga joylashtirilgan. *a) 10 kg* massali jismga; *b) 20 kg* massali jismga; *c) 30 kg* massali jismga ta’sir etuvchi natijaviy gravitatsion kuchni nanonyuton (*nN*) larda aniqlang. **Javob:** $F_A = 124{,}21 nN;$ $F_B = 361{,}29 nN;\ F_C = -485{,}5 nN$

Kepler qonunlari. Kosmik tezliklar

14.11. Mars planetasining radiusi *3380 km*, undagi erkin tushish tezlanishi *3,86 m/s²* bo'lsa, shu planeta uchun birinchi kosmik tezlikni hisoblang. **Javob:** *3,6 km/s*

14.12. Veneraning massasi *4,9·10²⁴ kg*, radiusi esa *6100 km* bo'lsa, shu planeta uchun birinchi kosmik tezlikni hisoblab chiqing. **Javob:** *7,3 km/s*

14.13. Agar Yerning sun'iy yo'ldoshi Yer sirtidan *1700 km* balandlikda aylana orbita bo'ylab harakatlansa, uning tezligi qanday bo'ladi? Yerning massasi $6 \cdot 10^{24}\, kg$, radiusi *6400 km*, gravitatsiya doimiysi $6{,}67 \cdot 10^{-11} \frac{N \cdot m^2}{kg^2}$. **Javob:** *7 km/s*

14.14. Zichligi Yerning zichligi bilan birday, radiusi esa Yerning radiusidan *2* marta kichik bo‘lgan planeta uchun birinchi kosmik tezlik qanday bo‘ladi? Yer uchun birinchi kosmik tezlik *8 km/s* ga teng. **Javob:** *4 km/s*

14.15. Saturn planetasining radiusi *60000 km*, undagi erkin tushish tezlanishi esa *11,44 m/s²* ga teng. Shu planeta uchun birinchi va ikkinchi kosmik tezliklarni toping. **Javob:** *26,2 km/s; 37 km/s*

14.16. *500 km* radiusli sferik asteroidning sirtida erkin tushish tezlanishi $3\,m/s^2$ bo‘lsa, bu asteroid uchun birinchi va ikkinchi kosmik tezliklar nimaga teng? **Javob:** $1225\,m/s; 1732\,m/s$

14.17. Biror R radiusli sayyora uchun 1-kosmik tezlikning qiymati ϑ ga teng. Bu sayyora sirtidan $h_1 = R,\ h_2 = 7R, h_3 = 17R,\ h_4 = 31R$ balandliklar uchun 2-kosmik tezlik nimaga teng? **Javob:** $\vartheta; \frac{\vartheta}{2}; \frac{\vartheta}{3}; \frac{\vartheta}{4}$

14.18. Massasi $10^{30}\,kg$, radiusi $10^6\,m$ bo‘lgan neytron yulduzning sirtida 1-kosmik tezlikning qiymati nimaga teng? **Javob:** $8167\,km/s$

14.19. Somon yo‘li galaktikamizning tojini massasi $2\cdot10^{11}$ ta Quyosh massasiga teng. Quyoshdan galaktika markazigacha bo‘lgan masofa $3\cdot10^{20}\,m$ ga, Quyosh massasi $2\cdot10^{30}\,kg$ ga teng. Quyosh sistemasining galaktika atrofida aylanishdagi doiraviy tezligi va aylanish davrini aniqlang. **Javob:** $298\ km/s;\ 2\cdot10^8\ yil$

14.20. $m = 20\,kg$ massali sun’iy yo‘ldosh noma’lum massali planeta atrofida $T = 2,4\,soat$ davr va $r = 8\cdot10^6\,m$ radiusli doiraviy orbitaga ega. Agar bu planeta sirtida erkin tushish tezlanishining qiymati $g = 8\,m/s^2$ ga teng bo‘lsa, u holda bu planeta radiusi R va massasi M nimaga teng? **Javob:** $T = \frac{2\pi r}{T}\sqrt{\frac{r}{g_0}} = 5815\,km;\ M = \frac{4\pi^2 r^3}{GT^2} = 4,11\cdot10^{24}\,kg$

14.21. Apollo kosmik stansiyasi Oy sirtidan $h = 112\,km$ balandlikda $T = 120\,\text{min}$ vaqtda to‘la bir marta aylanib chiqqan edi. Oyning radiusi $R=1730\ km$ ekanini bilgan holda Oyning massasini aniqlang. **Javob:** $M = \frac{4\pi^2(R+h)^3}{GT^2} = 7,23\cdot10^{22}\,kg$

14.22. Qo‘shaloq yulduzlarning har biri Quyosh massasiga ega bo‘lib, ular umumiy massa markazi atrofida aylanadi. Yulduzlar orasidagi masofa Quyosh va Yer orasidagi masofaga teng. Bu yulduzlarning aylanish davri necha Yer yiliga teng? **Javob:** *0,707 yil*

15-MAVZU: Mexanik energiya. Kinetik va potensial energiya.Mexanik ish va quvvat. FIK.

Mavzuga oid muhim formulalar

$A=\vec{F}\cdot\vec{s}=F\,s\cos\alpha$	*Mexanik ish*
$A=dA_1+dA_2+dA_3+\ldots+dA_\infty=\int_0^s F(s)\,ds$	*Mexanik ishni hisoblash*
$W_k=\frac{m\vartheta^2}{2}\quad yoki\quad W_k=\frac{p^2}{2m}=\frac{p\vartheta}{2}$	*Kinetik energiya*
$W_k=W_{k1}+W_{k2}+\ldots+W_{k3}=\sum_{i=1}^{n}W_{ki}=\sum_{i=1}^{n}\frac{m_i\vartheta_i^2}{2}$	*Jismlar sistemasining kinetik energiyasi*
$W_p=mgh$	*h balandlikdagi jismning potensial energiyasi*
$W_p=-G\frac{M\,m}{r}$	*Gravitatsion maydon potensial energiyasi*
$W_p=-G\frac{M\,m}{R}=-62,6\ MJ$	*Yer sirtidagi m=1 kg jismning gravitatsion maydon potensial energiyasi*
$A_{tash}=W_{p2}-W_{p1}=GMm\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$ $A_{grav}=W_{p1}-W_{p2}=GMm\left(\frac{1}{r_2}-\frac{1}{r_1}\right)$	*Massasi m bo'lgan jismni r1 masofadan r2 masofagacha siljitishda tashqi kuchning hamda gravitasion maydonning bajargan ishi*
$W_p=\frac{k\,x^2}{2}$	*Prujinaning potensial energiyasi*
$A_{tash}=W_{p2}-W_{p1}=\frac{k}{2}\left(x_2^2-x_1^2\right)$ $A_{elas}=W_{p2}-W_{p1}=\frac{k}{2}\left(x_2^2-x_1^2\right)$	*Prujinani x1 dan x2 gacha deformatsiyalshda tashqi kuchning hamda elastiklik kuchining bajargan ishi*
$N=\frac{A}{t},\qquad N=F\vartheta,\qquad N=\int_{\vartheta_1}^{\vartheta_2}F(\vartheta)\,d\vartheta$	*Quvvat formulalari*
$\eta=\frac{A_f}{A_{um}}\cdot 100\%$	*FIK*
$A_f=\eta A_{um},\qquad A_{isr}=(1-\eta)A_{um}$ $N_f=\eta N_{um},\qquad N_{isr}=(1-\eta)N_{um}$	*Foydali ish va isrof bo'lgan ish*
$\eta=\frac{\sin\alpha}{\sin\alpha+\mu\cos\alpha}=\frac{1}{1+\mu\,ctg\alpha}=\frac{tg\alpha}{tg\alpha+\mu}$	*Qiya tekislikning FIK*

15-Amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. O'zaro *60°* li burchak tashkil etuvchi *50 N* va *30 N* kuchlar ta'sirida jism teng ta'sir etuvchi kuch yo'nalishida *4,2 m* masofaga siljigan. Bunda qanday ish bajarilgan?

Berilgan:

$F_1 = 50\ N$

$F_2 = 30\ N$

$\ell = 4,2\ m$

$\alpha = 60^0$

A=?

Yechilishi:

Dastlab kuchlarning teng ta’sir etuvchissini aniqlaymiz.

$$F_{nat} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\alpha} = \sqrt{2500 + 900 + 2\cdot 50\cdot 30\cdot \cos 60^0} = 70\ N$$

Endi natijaviy kuchning bajargan ishini aniqlaymiz.

$$A = F_{nat}\cdot \ell = 70\cdot 4,2 = 294\ J$$

Javob: *294 J*

Masala № 2. Massasi *10 kg* bo'lgan jismga *2 min* davomida *5 N* kuch uzluksiz ta'sir qiladi. Bunda uning kinetik energiyasi necha *kJ* ga yetadi?

Berilgan:

$m = 10\ kg$

$t = 120\ s$

$F = 5\ N$

$\vartheta_0 = 0$

W_k*=?*

Yechilishi:

Bunda kuch impulsi $I = Ft = 5\cdot 120 = 600\ N\cdot s$ bo‘ladi. Kuch impulsi impuls o‘zgarishiga teng. $\Delta p = I = 600\ kg\cdot m/s$. Impuls o‘zgarishidan $\Delta p = p - p_0 = p = 600\ kg\cdot m/s$ oxirgi impuls kelib chiqadi. Energiya va impuls orasidagi bog‘lanishdan kinetik energiyani aniqlaymiz.

$$W_k = \frac{p^2}{2m} = \frac{600^2}{2\cdot 10} = 18000\ J = 18kJ$$

Javob: 18 *kJ*

Masala № 3. Massasi *1600 kg* bo'lgan “Epica” avtomobili *18 km/soat* tezlik bilan kelib devorga urildi. Urilish natijasida oldingi buferining pruoinasi *4 sm* ga deformatsiyalandi. Uning bikrligi qanday (*N/m*)?

Berilgan:

m=1600 kg

x=4 sm

$\vartheta = 5m/s$

$E_{k.\max} = ?$

Yechilishi:

Energiyaning saqlanish qonuniga ko‘ra avtomobilning dastlsbki kinetik energiyasi to‘siqqa urilganda prujinaning potensial energiyasi ko‘rinishiga o‘tadi.

$$E_{k.\max} = E_{p.\max},\ \rightarrow\ \frac{m\vartheta^2}{2} = \frac{k\,x^2}{2},\ \rightarrow\ k = m\left(\frac{\vartheta}{x}\right)^2 = 1600\cdot\left(\frac{5}{0,04}\right)^2 =$$

$$= 1600\cdot 125^2 = 2,5\cdot 10^7\ N/m$$

Javob: $2,5\cdot 10^7$ *N/m*

Masala № 4. Qiyaligi *0,6* ga teng bo'lgan qiya tekislikning FIKni (*%*) toping. Ishqalanish koeffitsiyenti *0,3* ga teng.

Berilgan:	*Yechilishi:*
$\mu = 0,3$ $\sin\alpha = 0,6$	Avval burchak kosinusini topamiz. $\cos\alpha = \sqrt{1-\sin^2\alpha} = 0,8$
η=?	Endi qiyalikning FIKni aniqlaymiz. $\eta = \frac{\sin\alpha}{\sin\alpha + \mu\cos\alpha}\cdot 100\% = \frac{0,6}{0,6+0,3\cdot 0,8}\cdot 100\% = 71,43\%$

Javob: 71,4 %

Masala № 5. Jilvirlash dastgohi charx toshining ish sirlidagi tezlik *30 m/s*. Ishlov berilayotgan detal toshga *100 N* kuch bilan bosiladi, ishqalanish koeffitsiyenti *0,2*. Dastgoh dvigatelining mexanik quvvati qanday? (Yuritma mexanizmidagi isroflar hisobga olinmasin).

Berilgan:	*Yechilishi:*
$R = 100\,N$ $\vartheta = 30\,m/s$ $\mu = 0,2$	Avval ishqalanish kuchini aniqlaymiz. $F_{ish} = \mu R = 0,2\cdot 100 = 20\,N$
N=?	Endi mexanik quvvatni aniqlaymiz. $N = F_{ish}\cdot\vartheta = 20\cdot 30 = 600W = 0,6\,kW$

Javob: *N=0,6 kW*

15-Amaliy mashg‘ulot topshirig‘i

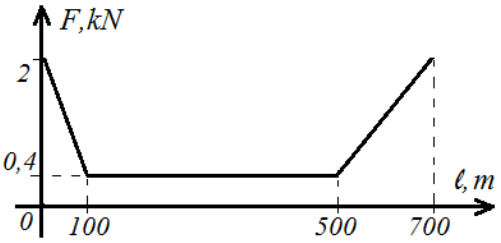
15.1. Yog'och oqizuvchi ishchi changakka *200 N* kuch qo'yib solni surmoqda. Agar kuch yo'nalishi bilan ko'chish yo'nalishi orasidagi burchak *45°* bo'lsa, solni *10 m* ga siljitgan ishchi qancha ish bajaradi? **Javob:** *1,4 kJ*

15.2. O'zaro *60°* li burchak tashkil etuvchi *50 N* va *30 N* kuchlar ta'sirida jism teng ta'sir etuvchi kuch yo'nalishida *4,2 m* masofaga siljigan. Bunda qanday ish bajarilgan? **Javob:** *294 J*

15.3. Qalinligi *3 sm* bo'lgan taxtaga uzunligi *7 sm* bo'lgan mix shunday qoqildiki, mixning yarmi teshib chiqdi. Uni taxtadan sug'urib olish uchun *500 N* kuch qo'yish kerak. Mixni sug'urib olish uchun qanday ish bajarish kerak? **Javob:** $27,5\,J$

15.4. Agar jismga ta’sir qilayotgan kuch *12 m* yo‘lda *0* dan *160 N* gacha tekis oshib borsa, u holda bu kuchning bajargan ishi nimaga teng? **Javob:** *960 J*

15.5. Massasi *1800 kg* bo‘lgan “Captiva” avtomobili joyidan qo‘zg‘alishda, tekis harakat chog‘ida va tormozlanib to‘xtashda ta’sir qiladigan kuchning yo‘lga bog‘lanish grafigini taxminan rasmdagi kabi deb faraz qilaylik. Bunda har bir qismdagi va jami bajatilgan ishni toping (*kJ*)? **Javob:**



$A_1 = 120;\ A_2 = 160;\ A_3 = 240;\ A_{um} = 520$

15.6. Massasi *1,4 t* bo'lgan «Kobalt» avtomobili joyidan qo'zg'alib, dastlabki *75* m yo'lni *10 s* ichida o'tsa, uning dvigateli qancha ish bajaradi? Harakatga qarshilik koeffitsiyenti *0,05* ga teng. $g = 10\ m/s^2$ deb oling. **Javob:** *210 kJ*

15.7. *4 kg* massali jism *8 m* balandlikdan tushib, qumga *4 sm* chuqurlikkacha kirgan bo'lsa, qumning o'rtacha qarshilik kuchi necha *kN* bo'lgan? **Javob:** *8 kN*

15.8. Dinamometming prujinasini *0* dan *10 N* gacha, *10* dan *20 N* gacha, *20* dan *30 N* gacha cho'zganda ishchi bajaradigan ishlarni taqqoslang. **Javob:** *1:3:5*

15.9. Kosmik kema ichida *0,4 kg* massali jism bikrligi *1000 N/m* bo'lgan prujinaga *20 m/s* tezlik bilan urilib, uni necha *sm* ga siqishi mumkin? **Javob:** *40 sm*

15.10. Taxtani teshib o'tish natijasida o'qning tezligi *2* marta kamaydi. O‘qning dastlabki energiyasining qanday qismi taxtani teshib o'tishga sarf bo'lgan? **Javob:** *¾*

15.11. Massasi $2 \cdot 10^{-26}$ *kg* bo'lgan uglerod atomining kinetik energiyasi $4{,}9 \cdot 10^{-19}$ *J* bo'lsa, uning harakat tezligi qanday? **Javob:** $7 \cdot 10^3$ *m/s*

15.12. Yerning Quyosh atrofidagi yillik aylanma harakatidagi kinetik energiyasini hisoblang. Yerning massasi $m = 5{,}96 \cdot 10^{24}\ kg$ ga, orbitaviy tezligi $\vartheta = 30\ km/s$ ga teng. **Javob:** $E = 2{,}682 \cdot 10^{33}\ J$

15.13. Jismning impulsi *100 kg·m/s*, kinetik energiyasi *200 J* bo'lsa, jismning massasi va tezligi qanday? **Javob:** *25 kg; 4m/s*

15.14. Massasi *10 t* bo'lgan avtomobil gorizont bilan *4°* burchak tashkil qiluvchi qiya yo'lda dvigateli o'chirilgan holda pastlikka harakatlanmoqda. *100 m* yo'lda og'irlik kuchi bajargan ishni toping. **Javob:** *700 J*

15.15. Massasi *500 g* bo‘lgan *40 sm* uzunlikdagi polda vertikal holda turgan sterjenni vertikal holida poldan shiftga tekkunga qadar ko‘tarishda *13 J* ish bajarilgan bo‘lsa, shiftdan polgacha bo‘lgan masofa nimaga teng? **Javob:** *3 m*

15.16. Yerning Quyosh atrofidagi yillik aylanma harakatidagi o‘zaro ta’sir potensial energiyasini hisoblang. Yerning massasi $m = 5{,}96 \cdot 10^{24}\ kg$ ga, Quyoshning massasi $M = 1{,}99 \cdot 10^{30}\ kg$ ga va Yerdan Quyoshgacha masofa $r = 1{,}5 \cdot 10^{11}\ m$ ga teng. Potensial energiyani hisoblashda $E_p = -G\dfrac{Mm}{r}$ formuladan foydalaning. **Javob:** $E_p = -5{,}274 \cdot 10^{33}\ J$

15.17. Oyning Yer atrofidagi aylanma harakatidagi o‘zaro ta’sir potensial energiyasini energiyasini hisoblang. Oyning massasi $m = 7{,}37 \cdot 10^{22}\ kg$ ga, Yerning massasi $M = 5{,}96 \cdot 10^{24}\ kg$ ga va Yerdan Oygacha masofa $r = 3{,}84 \cdot 10^{8}\ m$ ga teng. Potensial

energiyani hisoblashda $E_p = -G\frac{Mm}{r}$ formuladan foydalaning. **Javob:** $E_p = -7,63 \cdot 10^{28}\ J$

15.18. *20 m/s* tezlik bilan uchib kelayotgan, massasi *0,6 kg* bo'lgan futbol to'pini darvozabon 0,1 s ichida ushlab, to'xtatdi. Darvozabonning quvvatini toping (*W*). **Javob:** *1200 W*

15.19. Ko'tarma kranga o'rnatilgan dvigatelning quvvati *4500 W*. Bu kran yordamida necha *kg* massali yukni *12 m* balandlikka *0,5 minut*da ko'tarish mumkin? Dvigatelning FIK *80%*. **Javob:** *900 kg*

15.20. FIK *90 foiz* bo'lgan qo'zg'almas blok yordamida *300 N* yukni *12 m* balandlikka ko'tarishda bajarilgan ish qanday (*J*)? **Javob:** *4000 J*

15.21. Pulemyot *1 minut*da *600* dona o'qqa *800 m/s* boshlang'ich tezlik beradi. Agar har bir o'qning massasi *15 g* bo'lsa, pulemyotning foydali quvvati qancha ? **Javob:** *48 kW*

15.22. Qishloq va o'rmon xo'jaligi ishlari uchun mo'ljallangan samolyotning massasi *1 t*, yugurish uzunligi *300 m*, ko'tarilish tezligi *30 m/s*, qarshilik koeffitsiyenti 0,03 bo'lsa, uning yugurish vaqtidagi o'rtacha foydali quvvatini toping. **Javob:** *27 kW*

15.23. Tovushdan tez uchadigan samolyotning *2340 km/soat* tezlikdagi tortish kuchi *220 kN*. Samolyot dvigatellarining uchishning shu rejimidagi quvvatini toping. **Javob:** *143 MW*

16-MAVZU: Energiyaning saqlanish va aylanish qonuni (h<<R balandlikdan tushayotgan jism hamda prujinada tebranayotgan jism uchun).

Mavzuga oid muhim formulalar

Jismlar sistemasidan iborat yopiq sistema uchun energiyaning saqlanish qonuni $W_{um} = W_{k.1} + W_{p.1} = W_{k.2} + W_{p.2} = \ldots = W_{k.N} + W_{p.N} = const$	
Biror balandlikdan tashlangan, yer sirtidan otilgan jism uchun energiyaning saqlanish qonuni $mgh_{\max} = mgh + m\frac{\vartheta^2}{2} = m\frac{\vartheta_{\max}^2}{2}$	
$\vartheta_{tush} = \sqrt{2gh}$	*Biror balandlikdan erkin tashlangan jismning yerga urilish tezligi*
$\vartheta_{tush} = \sqrt{\vartheta_0^2 + 2gh}$	*Biror balandlikdan boshlang'ich tezlik bilam otilgan jismning yerga urilish tezligi*
$\vartheta = \sqrt{\vartheta_0^2 - 2gh}$	*Yer sirtidan otilgan jismning h balandlikdagi tezligi*
$h_{\max} = \frac{\vartheta_0^2}{2g}$	*Yer sirtidan otilgan jismning maksimal ko'tarilish balandligi*
$\frac{k x_{\max}^2}{2} = \frac{m\vartheta^2}{2} + \frac{kx^2}{2} = \frac{m\vartheta^2_{\max}}{2}$	*Elastik prujinaga osilgan jismning kihik tebranishlari uchun energiyaning saqlanish qonuni*
$\vartheta = \sqrt{\frac{k}{m}}\, x_{\max}$	*Biror masofaga cho'zib qo'yib yuborilgan prujinaga osilgan jismning muvozonat nuqtasidan o'tishdagi tezligi*
$\vartheta = \sqrt{\frac{k}{m}\left(x_{\max}^2 - x^2\right)}$	*Biror masofaga cho'zib qo'yib yuborilgan prujinaga osilgan jismning ixtiyoriy x nuqtadagi tezligi*

16-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Massasi *300 g* bo'lgan tosh yuqoriga tik otilganda, *20 m* balandlikkacha ko'tarildi. Tosh qanday eng katta kinetik energiyaga ega bo'lgan?

Berilgan:

$m=300\ g$

$h=20\ m$

$E_{k.\max} = ?$

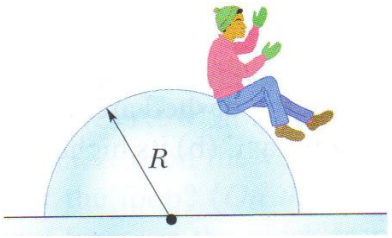
Yechilishi:

Energiyaning saqlanish qonuniga ko'ra toshning yerdan otilgan patdagi maksimal kinetik energiyasi yuqoriga ko'tarilganda maksimal potnsial energiyaga aylanadi.

$$E_{k.\max} = E_{p.\max} = mgh = 0,3 \cdot 10 \cdot 20 = 60J$$

Javob: *60 J*

Masala № 2. Bola dastlab $R=12m$ radiusli muz yarimsharning tepasida rasmdagi kabi o'tirgan edi. So'ngra u boshlang'ich tezliksiz pastga sirg'anib tusha boshladi. Yerdan qanday balandlikda bola muzdan uziladi? $g=9{,}8\ m/s^2$.



Berilgan:

$R=12m$

$g=9{,}8\ m/s^2$

$E_{k.\max}=?$

Yechilishi:

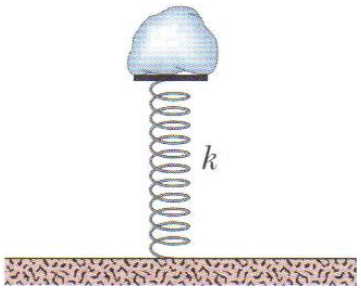
Energiyaning saqlanish qonuniga ko'ra bolaning yarimshar tepasidagi poensial energiyasi uzilish nuqtasidagi kinetik energiyasiga aylanadi.

$$E_{p.\max}=E_p+E_k,\ \rightarrow\ mgR=\frac{m\vartheta^2}{2}+mg\left(R-\Delta h\right),\ \rightarrow\ \vartheta^2=2g\Delta h$$

Bola muzdan ajralganda gorizontga nisbatan $\cos\alpha=\frac{R-\Delta h}{R}$ burchak hosil qiladi. Bunda sirtga normal bosim kuchi markazdan qochuvchi inersiya kuchiga miqdoran tenglshadi. $mg\cos\alpha=\frac{m\vartheta^2}{R},\ \rightarrow\ g\frac{R-\Delta h}{R}=\frac{2g\Delta h}{R},\ \rightarrow\ \Delta h=\frac{R}{3}$. Bu uzilish nuqtasining Yerdan balandligi $h=R-\Delta h=\frac{2}{3}R=8m$ bo'ladi.

Javob: *8 m*

Masala № 3. Massasi *8 kg* bo'lgan tosh prujinaning ustida rasmdagi kabi tinch turibdi. Bunda prujina *8 sm* ga siqilgan. Prujinani qo'shimcha ravishda yana *30 sm* ga siqildi va qo'yib yuborildi. Aniqlang: *a)* prujina bikrligini; *b)* qo'yib yuborish oldida prujina potensial energiyasini; *c)* tosh prujinadan uzilish onida qanday tezlikka erishishini; *d)* qo'yib yuborish nuqtasidan qancha maksimal balandlikka ko'tarilishini. $g=10\ m/s^2$.



Berilgan:

$m=8kg$

$\delta=8sm$

$x=30sm$

$a)k=?$

$b)W_p=?$

$c)h_{\max}=?$

Yechilishi:

a) Dastlab bikrlini aniqlaymiz. Bunda toshning og'irligi va prujinaning elastiklik kuchi tenglashguncha δ siqilish sodir bo'ladi.

$$mg=k\delta,\ \rightarrow\ k=\frac{mg}{\delta}=\frac{8\cdot10}{0{,}08}=1000\,N/m=1kN/m$$

b) Prujinani qo'shimcha ravishda yana *30 sm* ga siqilganda u jami $\Delta\ell=\delta+x=38sm$ ga siqiladi. Bunda potensial energiya

$W_{p2}=\frac{k\Delta\ell^2}{2}=\frac{1000\cdot0{,}38^2}{2}=72{,}2\ J$ bo'ladi.

c) Dastlab prujina tinch turganida u og'irlik kuchi bilan muvozanatda turgan bo'lsada, u siqilgan holda bo'lgani uchun prujina $W_{p1}=\frac{k\delta^2}{2}=\frac{1000\cdot 0,08^2}{2}=3,2\,J$ energiyaga ega bo'lgan. Prujina eng quyi nuqtadan toshning prujinadan uzilish nuatqasiga yetguncha prujina potensial energiyasi $\Delta W=W_{p2}-W_{p1}=72,2-3,2=69\,J$ ga kamayadi. Bu kamayish esa yerning tortish maydonida $E_p=mgx=8\cdot 9,8\cdot 0,3=23,52\ J$ potensial energiyaga hamda $E_k=\frac{m\vartheta^2}{2}=\frac{8\cdot\vartheta^2}{2}=4\cdot\vartheta^2$ kinetik energiyaga sarf bo'ladi. Demak,

$$69=23,52+4\cdot\vartheta^2,\ \rightarrow\ \vartheta^2=\frac{45,48}{4}=11,37,\ \rightarrow\ \vartheta=\sqrt{11,37}=3,37\,m/s$$

tezlikka erishar ekan.

d) Energiyaning saqlanish qonuniga ko'ra toshning qo'shimcha x=30 sm ga siqilgandagi potensial energiyasi tosh ajralish oldida kinetik energiyaga aylanadi, so'ng bu kinetik energiya biror h balandlika ko'tarilgandagi potensial energiyaga aylanadi. Energiya saqlanish qonunini ushbu ko'rinishda yozish mumkin:

$$E_{k.\max}=E_{p.\max},\ \rightarrow\ \frac{m\vartheta_{\max}^2}{2}=mgh,\ \rightarrow\ h=\frac{\vartheta^2}{2g}$$

Endi so'ralgan kattalikni aniqlaymiz.

$$h=\frac{\vartheta^2}{2g}=\frac{11,37}{2\cdot 9,81}\approx 0,58m=58\,sm;\ \rightarrow\ H=h+x=58+30=88\,sm$$

Javob: $a)k=1kN/m;\ b)W_p=72,2\,J;\quad c)3,37\ m/s;\quad d)\ 86,25\,sm$

16-amaliy mashg'ulot topshirig'i

16.1. Jism *12 m/s* tezlik bilan vertikal ravishda yuqoriga otildi. Necha metr balandlikda uning kinetik energiyasi potensial energiyasiga teng bo'ladi? **Javob:** *3,6 m*

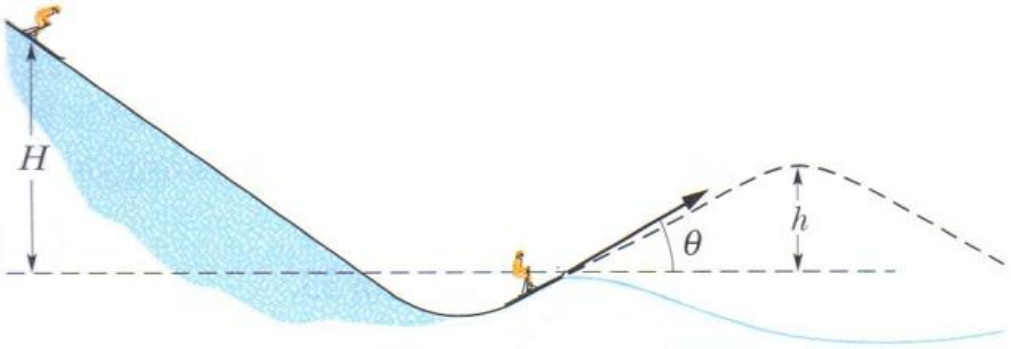
16.2. Jismning yerga urilish paytidagi tezligi *26 m/s* bo'lsa, u necha metr balandlikdan tushgan? $g=9,8\ m/s^2$. **Javob:** *34,5 m*

16.3. Ipga osilgan sharchani *5 sm* balandlikka og'dirib qo'yib yuborsak, muvozanat vaziyatidan o'tayotgandagi tezligi qanday (*m/s*) bo'ladi? $g=10\ m/s^2$ deb oling. J: *1 m/s*

16.4. Yuqoriga ϑ_0 boshlang'ich tezlik bilan otilgan jismning kinetik energiyasi qanday balandlikda uning potensial energiyasining yarmiga teng bo'ladi? Boshlang'ich tezlik *30 m/s* bo'lganda-chi? **Javob:** $\frac{\vartheta_0^2}{4g};\ 30\,m$

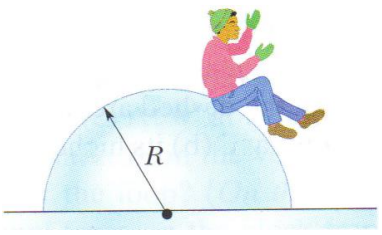
16.5. *20 m/s* tezlik bilan gorizontal otilgan *1 kg* massali jismning *4*-sekund oxiridagi kinetik energiyasi qanday? J: *20 kJ*

16.6. *70kg* massali chang‘ichi *H=22 m* balandlikdagi tramplindan tinch holatdan harakat boshladi va sakrash nuqtasidan $\theta = 28^0$ burchak ostida uziladi. Havo qarshiligi va muzning ishqalanishini hisobga olmang. Aniqlang: *a)* chang‘ichining uzilish nuqtasidan qancha *h* balandlika ko‘tarilishini; *b)* chang‘ichining massasi ortsa, ko‘tarilish balandligi qanday o‘zarishini. $g = 9{,}8\ m/s^2$. **Javob:** *h=4,85 m; ko‘tarilish balandligi massaga bog‘liq emas.*



16.7. Uzunligi *L* bo'lgan yengil cho'zilmas ipga bog'langan sharga gorizontal yo'nalishda qanday minimal tezlik berilganda, u vertikal tekislikda ip osilgan nuqta atrofida to'la aylanadi? **Javob:** $\sqrt{5gL}$

16.8. Bola dastlab $R = 12m$ radiusli muz yarimsharning tepasida rasmdagi kabi o‘tirgan edi. So‘ngra u boshlang‘ich tezliksiz pastga sirg‘anib tusha boshladi. Yerdan qanday balandlikda bola muzdan uziladi? $g = 9{,}8\ m/s^2$. **Javob:** 8m;

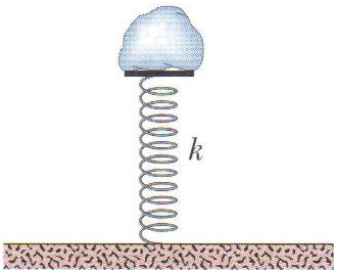


16.9. Massasi *m* bo'lgan jism ipga bog'lab vertikal tekislikda aylantirilmoqda. Yuqorigi nuqtadagiga qaraganda pastki nuqtada ipning taranglik kuchi qancha ortiq bo'ladi? Masala shartini jism o‘zgaruvchan va o‘zgarmas tezlik bilan aylanayotgan hollar uchun yeching. **Javob:** *6mg; 2mg*

16.10. Bikrligi *1000 N/m* bo'lgan prujinani *1 sm* ga siqish uchun *10 g* massali sharcha uning ustiga qanday balandlikdan erkin tushishi kerak (m)? J: *0,5 m*

16.11. Pruiinasi *4 sm* ga siqilgan to'pponchadan otilgan o'qning kinetik energiyasi *0,08 J* bo'lsa, prujinaning bikirligi qanday *(N/m)*? **Javob:** *100 N/m*

16.12. Massasi *8 kg* bo‘lgan tosh prujinaning ustida rasmdagi kabi tinch turibdi. Bunda prujina *8 sm* ga siqilgan. Prujinani qo‘shimcha ravishda yana *30 sm* ga siqildi va qo‘yib yuborildi. Aniqlang: *a)* prujina bikrligini; *b)* qo‘yib yuborish oldida prujina potensial energiyasini; *c)* tosh prujinadan uzilish onida qanday tezlikka erishishini; *d)* qo‘yib yuborish nuqtasidan qancha maksimal balandlikka ko‘tarilishini. $g = 10\ m/s^2$. **Javob:**



16.13. O'qning boshlang'ich tezligi *600 m/s*, uning massasi *10 g*. Agar trayektoriyaning eng yuqori nuqtasida o'qning kinetik energiyasi *450 J* ga teng bo'lsa, u miltiqning og'zidan gorizontga qanday burchak ostida uchib chiqqan? **Javob:** *60°*

16.14. Massasi *60 kg* bo'lgan sportchi tarang tortilgan to'rga *4 m* balandlikdan tushaai. Agar to'rning eng katta cho'zilishi *1 m* bo'lsa, uning sportchiga ta'sir kuchi ko'pi bilan qanday (*kN*) bo'ladi? **Javob:** *6 kN*

16.15.

17-MAVZU: Gravitatsion maydon potensial energiyasi va gravitatsion maydon potensiali. Energiyaning saqlanish va aylanish qonuni (h~R balandlikdan tushayotgan jism uchun).

Mavzuga oid muhim formulalar

$W = -G\frac{M\,m}{R}$	*Planeta sirtida gravitatsion maydon potensial energiyasi*
$W = -G\frac{M\,m}{r} = -G\frac{M\,m}{R+h}$	*Planeta sirtidan h balandlikda gravitatsion maydon potensial energiyasi*
$\varphi_0 = -G\frac{M_{Yer}}{R_{Yer}} = -62,6\left[\frac{MJ}{kg}\right]$	*Yer sirti uchun gravitatsion maydon potensiali*
$\varphi_h = \varphi_0\frac{R_{Yer}}{r} = \varphi_0\frac{R_{Yer}}{R_{Yer}+h}$	*Yer sirtidan h balandlik uchun gravitatsion maydon potensiali*
$A_{tash} = W_{p2} - W_{p1} = G\,M\,m\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $A_{grav} = W_{p1} - W_{p2} = G\,M\,m\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$	*Jismlar orasida masofani o'zgartishda tashqi kuchlar hamda gravitatsion maydon bajargan ish*
$A_{tash} = W_2 - W_1 = m\cdot(\varphi_2 - \varphi_1)$ $A_{grav} = W_1 - W_2 = m\cdot(\varphi_1 - \varphi_2)$	*Jismlar orasida masofani o'zgartishda tashqi kuchlar hamda gravitatsion maydon bajargan ish*
$A_{tash} = W_{um2} - W_{um1} = \frac{1}{2}G\,M\,m\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$	*Sun'iy yo'ldoshni bir orbitadan boshqasiga ko'chirishda tashqi kuchlar bajargan ish*
Jismlar sistemasidan iborat yopiq sistema uchun energiyaning saqlanish qonuni $W_{um} = W_{k.1} + W_{p.1} = W_{k.2} + W_{p.2} = \ldots = W_{k.N} + W_{p.N} = const$	
Yuqori (h~R) balandlikdan tushayotgan yoki katta ($\vartheta \sim \vartheta_I$) tezlikda otilgan jism uchun energiyaning saqlanish qonuni $W_{um} = \frac{m\vartheta_1^2}{2} - G\frac{M\,m}{r_1} = \frac{m\vartheta_2^2}{2} - G\frac{M\,m}{r_2} = \frac{m\vartheta_3^2}{2} - G\frac{M\,m}{r_3} = \ldots = \frac{m\vartheta_n^2}{2} - G\frac{M\,m}{r_n} = const$	

17-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Massasi *m=1 t* bo'lgan jismni Yer sirtidan $h_1 = R$ masofadan $h_2 = 4R$ masofagacha ko'chirish uchun qanday ish bajarish kerak?

Berilgan:	*Yechilishi:*
$h_1 = R$ $h_2 = 4R$ $m = 1000\,kg$ *A=?*	Bunda 1-orbita radiusi $r_1 = R + h_1 = 2R$ ga, 2-orbita radiusi esa $r_2 = R + h_2 = 5R$ ga teng bo'ladi. Jismni bir nuqtadan boshqasiga ko'chirganda bajarilgan ishni aniqlaymiz.

$$A_{tash} = W_{um2} - W_{um1} = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = g_0 R^2 m\left(\frac{1}{2R} - \frac{1}{5R}\right) = \frac{3}{10} mg_0 R =$$

$$= \frac{3}{10} \cdot 1000 \cdot 9{,}81 \cdot 6{,}37 \cdot 10^6 = 18{,}747 \cdot 10^9 \; J = 18{,}747 \; GJ$$

Javob: 18,747 *GJ*

Masala № 2. Yer sirtidan $h = R/3$ chuqurlikda gravitatsion maydon potensialini va gravitatsion maydon kuchlanganligini aniqlang. Yer sirti uchun $g_0 = 9{,}8 m/s^2$ va $\varphi_0 = -62{,}5 \; MJ/kg$.

Berilgan:

$h = R/3$

$g_0 = 9{,}8 m/s^2$

$\varphi_0 = -62{,}5 \frac{MJ}{kg}$

$g_h = ?, \; \varphi_h = ?$

Yechilishi:

Yer sirtidan *h* chuqurlikda gravitatsion maydon kuchlanganligi (ya'ni erkin tushish tezlanishi) $g_h = g_0 \frac{R-h}{R}$ formuladan, gravitatsion maydon potensiali esa $\varphi_h = -\frac{3}{2}\varphi_0 + \frac{1}{2}\varphi_0 \cdot \left(\frac{R-h}{R}\right)^2$ formuladan aniqlanadi. Shularga asosan, kuchlanganlik

$$g_h = g_0 \frac{R - R/3}{R} = \frac{2}{3} g_0 = 6{,}533 \; m/s^2$$

qiymatga, potensial esa

$$\varphi_h = -\frac{3}{2}\varphi_0 + \frac{1}{2}\varphi_0 \cdot \left(\frac{R - R/3}{R}\right)^2 = -\frac{3}{2}\varphi_0 + \frac{2}{9}\varphi_0 = -\frac{23}{18}\varphi_0 = -\frac{23}{18} \cdot 62{,}5 = -79{,}86 \frac{MJ}{kg}$$

qiymatga teng bo'ladi.

Javob: *294 J*

Masala № 3. Yer sirtidan $h_1 = R$ masofada aylanayotgan massasi *m=1 t* bo'lgan sun'iy yo'ldoshni $h_2 = 4R$ masofadagi orbitaga chiqarish uchun qanday ish bajarish kerak?

Berilgan:

$h_1 = R$

$h_2 = 4R$

$m = 1000 kg$

A=?

Yechilishi:

Bunda 1-orbita radiusi $r_1 = R + h_1 = 2R$ ga, 2-orbita radiusi esa $r_2 = R + h_2 = 5R$ ga teng bo'ladi. Sun'iy yo'ldoshning biror orbitadagi to'la energiyasi

$$W_{um} = W_p + W_k = W_p - \frac{1}{2} W_p = \frac{1}{2} W_p = -\frac{1}{2} G \frac{Mm}{r}$$

formuladan aniqlanadi. Sun'iy yo'ldosh bir orbitadan boshqasiga ko'chganda tashqi kuchlardan shu orbitalardagi to'la energiyalar farqiga teng bo'lgan ish bajarish talab etiladi.

$$A_{tash} = W_{um2} - W_{um1} = \frac{1}{2} G M m \left(\frac{1}{r_1} - \frac{1}{r_2} \right) = \frac{1}{2} g_0 R^2 m \left(\frac{1}{2R} - \frac{1}{5R} \right) = \frac{3}{20} m g_0 R =$$

$$= \frac{3}{20} \cdot 1000 \cdot 9{,}81 \cdot 6{,}37 \cdot 10^6 = 9{,}373 \cdot 10^9 \ J = 9{,}373 \ GJ$$

Javob: 9,373 *GJ*

17-amaliy mashg‘ulot topshirig‘i

17.1. Sayyora uchun ikkinchi kosmik tezlik *11,2 km/s*. Shu sayyoradan *12,2 km/s* tezlik bilan otilgan raketaning cheksizlikdagi tezligi qanday (*km/s*) bo'ladi? Sayyora atrofidagi fazoda boshqa sayyoralar yo'q deb hisoblang. **Javob:** *4,8 km/s*

17.2. Quyosh sistemasida daydib yurgan meteor tosh Yerning ta’sir zonasiga tushib qolganda uning tezligi $\vartheta_0 = 9\,km/s$ ga teng edi. Bu asteroid Yerning atmosfersiga qanday tezlikda kirib keladi? **Javob:** *14,37 km/s*

17.3. * Yer sirtidan 2-kosmik tezlikning yarmiga teng tezlik bilan otilgan jism qancha balandlikka ko‘tariladi? Yer radiusi $R = 6370\,km$. Atmosfera qobig‘ining qarshilik kuchini e’tiborga olmang. **Javob:** *h=R/3=2123 km*

17.4. * Massasi $m = 1000\,kg$ bo‘lgan aloqa stansiyasini Yer sirtidan *h=36 600 km* balandlikdagi orbitaga chiqarish uchun qanday ish bajarish kerak? Yer radiusini *6400 km* deb oling. **Javob:** $5{,}76 \cdot 10^{10}\ J$

17.5. * Yer sirtidan $h_1 = 4R$ balandlikdan tashlangan jismning $h_2 = R$ balandlikdagi tezligini aniqlang. **Javob:** 6120 *m / s*

17.6. Yer sirtidan *10 000 km* balandlikdagi massasi *3 t* bo‘lgan kosmik apparat doiraviy harakat qilmoqda. Bu apparatni Yerning tortish maydonidan chiqarib yuborish uchun qanday ish bajarilish kerak? **Javob:** *36,5 GJ*

17.7. * Yer sirtidan erkin tushish tezlanishining $h = 100\,km$ balandlikdagi qiymati qanday *H* chuqurlikdagi qiymatiga teng? Yer radiusi *R=6370 km*. Yer sirtida erkin tushish tezlanishi $g_0 = 9{,}81\ m/s^2$. **Javob:** $H = 195{,}4\,km$

17.8. * Yer sirtidan $h = 2R$ balandlikda gravitatsion maydon potensiali hamda gravitatsion maydon kuchlanganligini aniqlang. **Javob:** $\varphi_h = -20{,}8\ MJ/kg;\ \ g_h = 1{,}09\ m/s^2$

17.9. Yer sirtidan $h_1 = R$ masofada aylanayotgan massasi *m=1 t* bo‘lgan sun’iy yo‘ldoshni $h_2 = 4R$ masofadagi orbitaga chiqarish uchun qanday ish bajarish kerak? **Javob:**

17.10. **Yer sirtidagi *m* massali kosmik kemani kosmik kemani *r* radiusli orbitaga olib chiqish uchun bajarilishi kerak bo‘lgan ish formulasini keltirib chiqaring. Masalni *m=2 t* bo‘lgan hol uchun yeching. **Javob:** $A = GMm\left(\frac{1}{R} - \frac{1}{2r}\right)$; $A =$

17.11. Yer sirtidan $h = 2R$ balandlikda gravitatsion maydon potensiali hamda gravitatsion maydon kuchlanganligini aniqlang. **Javob:** $\varphi_h = -20{,}8\ MJ/kg;\ \ g_h = 1{,}09\ m/s^2$

17.12. *Yer sirtidan erkin tushish tezlanishining $h = 100\,km$ balandlikdagi qiymati qanday *H* chuqurlikdagi qiymatiga teng? Yer radiusi *R=6370 km*. Yer sirtida erkin tushish tezlanishi $g_0 = 9{,}81\ m/s^2$. **Javob:** $H = 195{,}4\,km$

17.13. *1 km/s* boshlang‘ich tezlik bilan tik yuqoriga otilgan jismning maksimal ko‘tarilish balandligining haqiqiy qiymati *g=9,81 m/s²=const* bo‘lgan holatdan necha metr balandroqq ko‘tariladi? **Javob:** *221 m*

17.14. **Yer markazidagi *m* massali toshning potensial formulasini kelriib chiqaring. Yerning massasi *M* ga, radiusi *R* ga teng. Yerni bir jinsli deb hisoblang. **Javob:** $W_{00} = -\frac{3}{2}G\frac{Mm}{R}$

17.15. **Yerning ixtiroriy ichki nuqtasida, ya’ni Yer markazidan *r (r<R)* masofada turgan *m* massali toshning potensial energiyasini hisoblab chiqaring. Yerning massasi *M* ga, radiusi *R* ga teng. Yerni bir jinsli deb hisoblang. **Javob:** $W = -\frac{3}{2}G\frac{Mm}{R} + \frac{1}{2}G\frac{Mm}{R}\cdot\left(\frac{r}{R}\right)^2$

17.16. **Yerning markazigacha quduq kovlangan deb faraz qilaylik. Massasi *1 kg* bo‘lgan jismni Yer markazidan $r_1 = R/3$ masofagacha, bu nuqtadan $r_2 = 2R/3$ masofaga va bu nuqtadan $r_3 = R$ masofaga ko‘chirishda bajarilgan ishlarni aniqlang. Ularning nisbatlarini aniqlang. Yerni bir jinsli deb hisoblang. **Javob:** $A_1 = 3{,}467\,MJ;\ \ A_2 = 10{,}4MJ;\ \ A_3 = 17{,}336MJ;\ \ A_1 : A_2 : A_3 = 1:3:5$

17.17. **Yerning markazigacha quduq kovlangan deb faraz qilaylik. Yer sirtidan qujuqga tosh tashlangan bo‘lsin. Bu toshning $h_1 = 1000\,km, h_2 = 2000\,km$ va $h_3 = R/2$ chuqurlikdagi erishgan tezliklarini aniqlang. Yerni bir jinsli deb hisoblang. **Javob:** $\vartheta_1 = 4250\,m/s;\ \vartheta_2 = 5750\,m/s;\ \vartheta_3 = 6842\,m/s$

18-MAVZU: Jism impulsi va uning vektorligi. Jismlar sistemasining umpulsi. Impuls vektorining o‘zgarishi. Kuch impulsi va uning yo‘nalishi.

Mavzuga oid muhim formulalar

$p = m\vartheta, \qquad \vec{p} = m\vec{\vartheta}$	*Jism impulsi va uning vektorligi*
$\vec{p} = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + ... + \vec{p}_n = \sum_{i=1}^{n} \vec{p}_i$ $\begin{cases} p_x = p_{1x} + p_{2x} + p_{3x} + ... p_{nx} = \sum_{i=1}^{n} p_{ix} \\ p_y = p_{1y} + p_{2y} + p_{3y} + ... p_{ny} = \sum_{i=1}^{n} p_{iy} \\ p_z = p_{1z} + p_{2z} + p_{3z} + ... p_{nz} = \sum_{i=1}^{n} p_{iz} \end{cases}$	*Jismlar sistemasining impulsining geometrik va analitik (koordinatalar orqali) ko‘rinishda berilishi*
$p = \sqrt{p_x^2 + p_y^2 + p_z^2}$ $\cos\alpha = \frac{p_x}{p}, \quad \cos\beta = \frac{p_y}{p}, \quad \cos\gamma = \frac{p_z}{p}$	*Jismlar sistemasini impulsining miqdori va yo‘nalishi (yo‘naltiruvchi kosinuslari)*
$m = \frac{p^2}{2E}, \qquad \vartheta = \frac{2E}{p}$	*Jismning impulsi va energiyasi ma’lum bo‘lganda massasi va tezligini anilash*
$\Delta\vec{p} = \vec{p}_2 - \vec{p}_1 \quad yoki \quad \Delta\vec{p} = m\left(\vec{\vartheta}_2 - \vec{\vartheta}_1\right) = m\Delta\vec{\vartheta}$ $\left\|\Delta\vec{p}\right\| = m\sqrt{\vartheta_1^2 + \vartheta_2^2 - 2\vartheta_1\vartheta_2\cos\gamma}$	*Jism impulsini o‘zgarish vektori va uning moduli*
$\Delta p = 2m\vartheta\cos\alpha$	*Devorga α burchak ostida absalyut elastik urilib qaytgan jismning devorga beradigan impulsi*
$\vec{I} = \vec{F}\cdot t \quad yoki \quad \vec{I} = \Delta\vec{p}$ $d\vec{I} = \vec{F}\cdot dt, \quad \rightarrow \quad \vec{I} = \int_0^t \vec{F}(t)\,dt$	*Kuch impulsi*
$\Delta\vartheta = \frac{I}{m}, \qquad \vartheta = \vartheta_0 + \Delta\vartheta$	*Kuch impulsi ma’lum bo‘lganda tezlik o‘zgarishi hamda jismning erishgan oxirgi tezligi*

18-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Massasi *2 kg* bo‘lgan tinch holatdagi jism *2 m/s²* tezlanish oldi. *2 s* dan so‘ng jism impulsi nimaga teng bo‘ladi (*kg·m/s*)?

Berilgan:	*Yechilishi:*
$m = 2\ kg$ $v_0 = 0$ *a=2 m/s²* *t=2 s* *p=?*	Jism tekis tezlanuvchan harkat qilyapti. Uning 2 s dan keyingi tezligini quyidagicha topamiz. $v = v_0 + at = at = 2 \cdot 2 = 4\ \text{m/s}$. Endi impulsini hisoblaymiz: $p = mv = 2 \cdot 4 = 8\ kg \cdot m/s$.

Javob: 8.

Masala № 2. Bir xil *m* massali ikkita avtomobil bir yo'nalishda v va 3 v tezlik bilan harakatlanmoqda. Birinchi avtomobil bilan bog'langan sanoq tizimida ikkinchi avtomobilning impulsi qanday?

Berilgan:	*Yechilishi:*
$m_1 = m_2 = m$ $v_1 = v$ $v_2 = 3v$ $p_{21} = ?$	Avtomobillar bir tomonga harakatlanyapti. Birinchi avtomobil bilan bog'langan sanoq sistemasiga nisbatan ikkinchi avtomobilning tezligi $v_{21} = v_2 - v_1 = 2v$ ga teng. Impulsi esa $p_{21} = m \cdot v_{21} = 2mv$ ga teng bo'ladi.

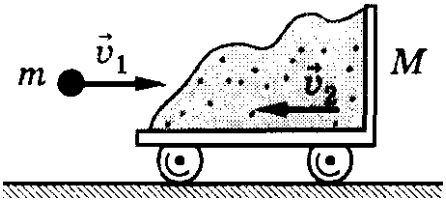
Javob: $2\text{m}v; 4mv$

Masala № 3. Rasmda yerdan biror balandlikda erkin turgan M massali aerostat pillapoyasida *m* massali sportchi turgani tasvirlangan. Agar u aerostatga nisbatan o'zgarmas ϑ tezlik bilan ko'tarila boshlasa, aerostat qaysi tomonga va qanday tezlik bilan harakatlanadi? Bunda sportchining yerga nisbatan tezligi nimaga teng?

Berilgan:	*Yechilishi:*
M m ϑ ϑ'=?	*m* massali sportchining tepaga yonalgan $m\vartheta$ impulsi (M+m) massaga pastga yo'nalgan $(M+m)\vartheta'$ impuls beradi. Bu impulslar miqdor jihatidan o'zaro tengdir. Bundan esa $$m\vartheta = (M+m)\vartheta', \ \rightarrow \ \vartheta' = \frac{m\vartheta}{M+m}$$ natija hosil bo'ladi.

Javob: *Pastga,* $\frac{m\vartheta}{M+m}$ *tezlik bilan;* $\frac{M\vartheta}{M+m}$

Masala № 4. $\vartheta_1 = 500\,m/s$ tezlik bilan uchayotgan $m = 30\,kg$ massali snaryad qarama-qarshi tomondan kelayotgan, massasi $M = 200\,kg$ bo'lgan aravadagi



qumga kirib qolib, aravani to'xtatdi. Aravachaning tezligi ϑ_2 qanday bo'lgan?

Berilgan:	*Yechilishi:*
$m = 30\ kg$ $M = 200\ kg$ $v' = 0$ $v_1 = 500\ m/s$ $v_2 = ?$	Bunda impulsning saqlanish qonuni $m\vartheta_1 - M\vartheta_2 = (m+M)\vartheta'$ ga ko'ra, $\vartheta_2 = \frac{m}{M}\vartheta_1 - \left(\frac{m}{M}+1\right)\vartheta' = \frac{30}{200}\cdot 500 - \left(\frac{30}{200}+1\right)\cdot 0 = 7{,}5\,m/s$ bo'ladi.

Javob: $\vartheta_2 = 7{,}5\,m/s$

18-amaliy mashg'ulot topshirig'i

18.1. Massasi *3 kg* bo'lgan tinch holatdagi jism *2 m/s²* tezlanish oldi. *5 s* dan so'ng jism impulsi nimaga teng bo'ladi? **Javob:** *75 kg·m/s*

18.2. Bir xil *m* massali ikkita avtomobil bir yo'nalishda ϑ va 3ϑ tezlik bilan harakatlanmoqda. Birinchi avtomobil bilan bog'langan sanoq tizimida ikkinchi avtomobilning impulsi qanday? Agar ular qarama-qarshi tomonga avvalgidek tezlik bilan harakatlanayotgan bo'lsa-chi? **Javob:** $2m\vartheta;\ -4m\vartheta$

18.3. Massasi *m* bo'lgan sharcha gorizontal sirtga erkin tushdi. Sirtga tegish vaqtidagi tezligi ϑ. Agar sharchaning tekislikka urilishi absolut elasik bo'lsa, sharcha impulsi o'zgarishi qanday bo'ladi? Urilish absolut noelasik bo'lsa-chi? **Javob:** $2m\vartheta;\ m\vartheta$

18.4. Massasi *2000 t* bo'lgan poyezd to'g'ri chiziqli harakatlanayotib tezligini *36* dan *72 km/soat* gacha oshirdi. Impulsning o'zgarishini toping. **Javob:** *2 ·10⁷ kg·m/s*

18.5. Moddiy nuqtaning harakati $x = 5-8t+4t^2$ tenglama bilan ifodalanadi. Uning massasini *2 kg* ga teng deb qabul qilib, vaqt hisobi boshlangandan keyin *2 s* va *4 s* vaqt oralig'ida impulsni toping. **Javob:** *16 kg·m/s; 48 kg·m/s*

18.6. Jismga biror kuch *6 s* davomida ta'sir qilib, uning impulsini *30 kg·m/s* ga o'zgartirdi. Ta'sir etuvchi kuchni aniqlang. **Javob:** *5 N*

18.7. *40 m/s* tezlik bilan yuqoriga tik otilgan *400 g* massali jism *35 m* balandlikdagi gorizontal to'siq bilan mutlaq elastik to'qnashib qaytdi. To'qnashishdagi kuch impulsini toping. **Javob:** *24 N·s*

18.8. $m = 200\,g$ massali shar polga $\vartheta = 5\,m/s$ tezlik bilan urildi va yerdan $h = 46\,sm$ balandlikka ko'tarildi. Sharning zarba vaqtidagi impuls o'zgarishini aniqlang. **Javob:** *1,6 kgm/s*

18.9. Suv oqimi o'ziga perpendikulyar bo'lgan vertikal devorga uriladi. Urilishdan so'ng devor bo'ylab oqib tushadi. Agar oqimning kesimi $5\,sm^2$, oqim tezligi esa $8\,m/s$ bo'lsa, u holda oqim devorga qanday kuch bilan ta'siqr qilishini aniqlang. **Javob:** *32 N*

18.10. Suv oqimi vertikal devor normaliga $\alpha = 60^0$ burchak ostida urilib, devordan tezligini yo‘qotmasdan qaytadi. Oqimning ko‘ndalang kesim yuzi $S = 6\,sm^2$ ga, tezligi $\vartheta = 12\,m/s$ ga teng. Oqim devorga qanday kuch bilan ta’siqr qilishini aniqlang. **Javob:** *86,4 N*

18.11. Massasi *50 g* bo‘lgan koptokcha devorga *45°* burchak ostida urildi va tezligining qiymatini o‘zgartirmay qaytdi. Zarbning o‘rtacha kuchi *21 N*, ta’sir vaqti *0,04 s* bo‘lsa, tezlikning moduli qanday? **Javob:** *12 m/s*

18.12. Massasi $5{,}3\cdot10^{-26}\,kg$ bo‘lgan molekula devorga tik holda *425 m/s* tezik bilan uriladi va xuddi shunday tezlik bilan orqaga qaytadi. Bunda devor qanday impuls oladi? Molekula impulsini o‘zgarish vektori qaysi tomonga yo‘nalgan? **Javob:** $4{,}5\cdot10^{-23}\,\frac{kg\cdot m}{s}$; *devordan tik golda molekula qaytadigan tomonga*

18.13. Sharcha devorga tik holda ϑ tezlik bilan uchib boryapti. Devor ham sharcha tomonga u tezlik bilan yaqinlashmoqda. Sharchaning devorga elastik urilib qaytgandan keyingi devorga nisbatan ϑ' tezligi hamda yerga nisbatan tezligi ϑ'' nimaga teng? **Javob:** $\vartheta' = \vartheta + u;\ \vartheta'' = \vartheta + 2u$

18.14. *1 m/s* tezlik bilan uzoqlashib ketayotgan po‘lat devorga *20 m/s* tezlik bilan koptok absalyut elastik urilib qaytgan bo‘lsa, u holda koptokning devorga va yerga nisbatan keyingi tezligini anilqang. Agar po‘lat devor va koptok bir-biriga tomon yaqinlashayotgan bo‘lganida edi koptokning devorga va yerga nisbatan keyingi tezligi qanday bo‘lar edi? **Javob:** *19 m/s; 18 m/s;21 m/s; 22 m/s*

18.15. *2 m/s* tezlik bilan uzoqlashib ketayotgan po‘lat devorga *20 m/s* tezlik bilan dumalayotgan shar urilib qaytgan bo‘lsa, u holda koptokning devorga va yerga nisbatan keyingi tezligini anilqang. Buda shar va devor urilishi uchun tiklanish koeffitsiyentini 0,8 ga teng deb oling. Agar po‘lat devor va shar bir-biriga tomon yaqinlashayotgan bo‘lganida edi koptokning devorga va yerga nisbatan keyingi tezligi qanday bo‘lar edi? **Javob:** *14,4 m/s; 12,4 m/s; 17,6 m/s; 19,6 m/s*

18.16. $\vartheta = 500\,m/s$ tezlik bilan harakatlanayotgan molekula unga yaqinlashayotgan porshenga elastik urilib qaytadi. Molekula tezligi va porshen normali orasidagi burchak 60^0 ni tashkil etadi. Porshenning tezligi $u = 20\,m/s$. Molekulaning porshenga urilgandan keyingi yerga nisbatan tezligi va yo‘nalishini aniqlang. **Javob:** $\vartheta' = 510{,}3\,m/s$; *porshen normali bilan* 58^0 *tashkil etadi*

18.17. Taekvondo musobaqasida sportchining qo‘lining tezligi raqibiga tegishidan oldin *13 m/s* tezlikgacha yetadi va $5{,}5\,ms$ lik to‘qnashuv davomida to‘xtaydi. Qo‘l mushtini bilakdan mustaqil va *0,7 kg* massaga ega deb hisoblab, zarba impulsini hamda o‘rtacha ta’sir kuchini aniqlang. **Javob:** $9{,}1\,\frac{kg\cdot m}{s}$; $1820\,N$

18.18. Massalari $m_1 = 2\,kg$ va $m_2 = 3\,kg$ bo‘lgan sharchalar gorizontal tekislikda mos holda $\vartheta_1 = 6\,m/s$ va $\vartheta_2 = 4\,m/s$ tezliklar bilan o‘zaro $\alpha = 90^0$ burchak tashkil etib harakatlanmoqdalar. Sharlar sistemasining impulsi p_{um} ni aniqlang. Agar $\alpha = 120^0$ bo‘lsa, yig‘indi impuls p_{um} nimaga teng bo‘ladi? **Javob:** $p_{um} = 17\frac{kg \cdot m}{s}$; $p_{um} = 12\frac{kg \cdot m}{s}$

18.19. $m_1 = 2\,g$ massali $\vec{\vartheta}_1 = 3\vec{i}$ tezlik bilan harakatlanayotgan zarra $m_2 = 3\,g$ massali $\vec{\vartheta}_2 = 2\vec{i} + 3\vec{j}$ tezlik bilan harakatlanayotgan boshqa zarraga absalyut noelastik uriladi va ular qo‘shilib bitta zarraga aylanadi. *a)* Hosil bo‘lgan zarraning tezlik vektori $\vec{\vartheta}'$ va uning moduli ϑ' nimaga teng [*m/s*]? *b)*Hosil bo‘lgan zarraning impuls vektori $\vec{p}'$ va uning moduli p' nimaga teng [*g·m/s*]? **Javob:** *a)* $\vec{\vartheta}' = 2,4\vec{i} + 1,8\vec{j}$; $\vartheta' = 3$; *b)* $\vec{p}_{um} = 12\vec{i} + 9\vec{j}$; $p_{um} = 15$

18.20. Tennis to'pi raketkaga *15 m/s* tezlik bilan urilib, *20 m/s* tezlik bilan qaytdi. Bu jarayonda to'pning kinetik energiyasi *10 J* ga o‘zgardi. To'p impulsi o'zgarishining moduli qanday? **Javob:** *4 kg·m/s*

19-MAVZU: Impuls vektorining saqlanish qonuni. Tiklanish koeffitsiyenti. Absalyut elastik va absalyut noelastik urilishlar.

Mavzuga oid muhim formulalar

To'qnashuvchi ikki jism uchun impulsning saqlanish qonuni: geometrik va analitik ko'rinishlarda

$$\vec{p}_1+\vec{p}_2=\vec{p}\,'_1+\vec{p}\,'_2 \quad yoki \quad m_1\vec{\vartheta}_1+m_2\vec{\vartheta}_2=m_1\vec{\vartheta}\,'_1+m_2\vec{\vartheta}\,'_2$$

$$\begin{cases} p_{1x}+p_{2x}=p'_{1x}+p'_{2x} \\ p_{1y}+p_{2y}=p'_{1y}+p'_{2y} \\ p_{1z}+p_{2z}=p'_{1z}+p'_{2z} \end{cases} yoki \begin{cases} m_1\vartheta_{1x}+m_2\vartheta_{2x}=m_1\vartheta'_{1x}+m_2\vartheta'_{2x} \\ m_1\vartheta_{1y}+m_2\vartheta_{2y}=m_1\vartheta'_{1y}+m_2\vartheta'_{2y} \\ m_1\vartheta_{1z}+m_2\vartheta_{2z}=m_1\vartheta'_{1z}+m_2\vartheta'_{2z} \end{cases}$$

To'qnashuvchi jismlar sistemsi uchun impulsning saqlanish qonuni: geometrik va analitik ko'rinishlarda

$$\sum_{i=1}^{k}\vec{p}_i=\sum_{i=1}^{k}\vec{p}\,'_i \quad yoki \quad \sum_{i=1}^{k}m_i\vec{\vartheta}_i=\sum_{i=1}^{k}m_i\vec{\vartheta}\,'_i$$

$$\begin{cases} \sum_{i=1}^{k}p_{i.x}=\sum_{i=1}^{k}p'_{i.x} \\ \sum_{i=1}^{k}p_{i.y}=\sum_{i=1}^{k}p'_{i.y} \\ \sum_{i=1}^{k}p_{i.z}=\sum_{i=1}^{k}p'_{i.z} \end{cases} yoki \begin{cases} \sum_{i=1}^{k}m_i\vartheta_{i.x}=\sum_{i=1}^{k}m_i\vartheta'_{i.x} \\ \sum_{i=1}^{k}m_i\vartheta_{i.y}=\sum_{i=1}^{k}m_i\vartheta'_{i.y} \\ \sum_{i=1}^{k}m_i\vartheta_{i.z}=\sum_{i=1}^{k}m_i\vartheta'_{i.z} \end{cases}$$

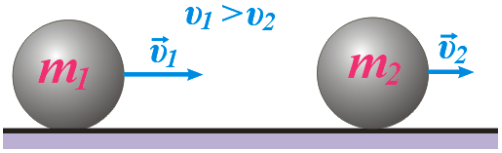
To'qnashuv paytida yo'qolganmexanik energiya

$$\Delta E=E_{um}-E'_{um}=\frac{1}{2}\left(m_1\vartheta_1^2+m_2\vartheta_2^2\right)-\frac{1}{2}\left(m_1\vartheta'^2_1+m_2\vartheta'^2_2\right)$$

$\alpha=\frac{\vartheta'}{\vartheta}$, yoki $\alpha=\sqrt{\frac{h}{H}}$	*Biror balandlikda sirtga tashlangan jism uchun tiklanish koeffitsiyenti*
$\alpha=\frac{\Delta\vec{\vartheta}'}{\Delta\vec{\vartheta}}=\frac{\vec{\vartheta}_2'-\vec{\vartheta}_1'}{\vec{\vartheta}_1-\vec{\vartheta}_2}$	*To'qnashuvchi ikki jism uchun tiklanish koeffitsiyentini (umumiy holda)*
$\begin{cases}\vec{\vartheta}'_1=\frac{m_1\vec{\vartheta}_1+m_2\vec{\vartheta}_2-\alpha m_2\left(\vec{\vartheta}_1-\vec{\vartheta}_2\right)}{m_1+m_2} \\ \vec{\vartheta}'_2=\frac{m_1\vec{\vartheta}_1+m_2\vec{\vartheta}_2+\alpha m_1\left(\vec{\vartheta}_1-\vec{\vartheta}_2\right)}{m_1+m_2}\end{cases}$	*Real jismlar uchun urilishdan keyingi tezliklari*

Bitta o'q bo'ylab harakatlanayotgan ikki real jismning to'qnashuvdan keyingi tezliklari

$$\begin{cases}\vartheta'_1=\frac{m_1\vartheta_1+m_2\vartheta_2-\alpha m_2\left(\vartheta_1-\vartheta_2\right)}{m_1+m_2} \\ \vartheta'_2=\frac{m_1\vartheta_1+m_2\vartheta_2+\alpha m_1\left(\vartheta_1-\vartheta_2\right)}{m_1+m_2}\end{cases}$$



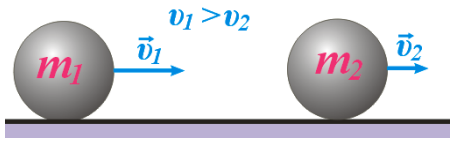
Absalyut noelastik to‘qnashuvchi ikki jism uchun impulsning saqlanish qonuni: geometrik va analitik ko‘rinishlarda

$$\vec{p}_1+\vec{p}_2=\vec{p}' \quad yoki \quad m_1\vec{\vartheta}_1+m_2\vec{\vartheta}_2=(m_1+m_2)\vec{\vartheta}'$$

$$\begin{cases} p_{1x}+p_{2x}=p'_x \\ p_{1y}+p_{2y}=p'_y \\ p_{1z}+p_{2z}=p'_z \end{cases} \quad yoki \quad \begin{cases} m_1\vartheta_{1x}+m_2\vartheta_{2x}=(m_1+m_2)\vartheta'_x \\ m_1\vartheta_{1y}+m_2\vartheta_{2y}=(m_1+m_2)\vartheta'_y \\ m_1\vartheta_{1z}+m_2\vartheta_{2z}=(m_1+m_2)\vartheta'_z \end{cases}$$

Bitta o‘q bo‘ylab harakatlanayotgan ikki jismning absalyut noelastik to‘qnashuvdan keyingi tezligi

$$\vartheta'=\frac{m_1\vartheta_1+m_2\vartheta_2}{m_1+m_2}$$



$$\Delta E=\frac{1}{2}\mu(\vartheta_1-\vartheta_2)^2, \quad \mu=\frac{m_1m_2}{m_1+m_2}$$

Bir sharcha boshqa sharchani quvib yetib unga absalyut noelastik urilgan hol uchun yo‘qolgan mexanik energiya

$$\Delta E=\frac{1}{2}\mu(\vartheta_1+\vartheta_2)^2, \quad \mu=\frac{m_1m_2}{m_1+m_2}$$

Bir sharcha ro‘paradan kelayotgan boshqa sharchaga absalyut noelastik urilgan hol uchun yo‘qolgan mexanik energiya

Jismlarning absalyut elastik urilish sharti

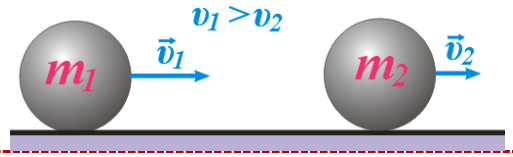
$$\begin{cases} \vec{p}_1+\vec{p}_2=\vec{p}'_1+\vec{p}'_2 \\ E_1+E_2=E'_1+E'_2 \end{cases} \quad yoki \quad \begin{cases} m_1\vec{\vartheta}_1+m_2\vec{\vartheta}_2=m_1\vec{\vartheta}'_1+m_2\vec{\vartheta}'_2 \\ \frac{m_1\vartheta_1^2}{2}+\frac{m_2\vartheta_2^2}{2}=\frac{m_1\vartheta_1'^2}{2}+\frac{m_2\vartheta_2'^2}{2} \end{cases}$$

$$\begin{cases} \vec{\vartheta}'_1=\frac{(m_1-m_2)\vec{\vartheta}_1+2m_2\vec{\vartheta}_2}{m_1+m_2} \\ \vec{\vartheta}'_2=\frac{(m_2-m_1)\vec{\vartheta}_2+2m_1\vec{\vartheta}_1}{m_1+m_2} \end{cases}$$

Absalyut elastik jismlar uchun urilishdan keyingi tezliklari

Bitta o‘q bo‘ylab harakatlanayotgan ikkita jismning absalyut elastik to‘qnashuvdan keyingi tezliklari

$$\begin{cases} \vartheta'_1=\frac{m_1\vartheta_1+m_2\vartheta_2-\alpha m_2(\vartheta_1-\vartheta_2)}{m_1+m_2} \\ \vartheta'_2=\frac{m_1\vartheta_1+m_2\vartheta_2+\alpha m_1(\vartheta_1-\vartheta_2)}{m_1+m_2} \end{cases}$$



19-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Massalari *6 kg* va *18 kg* bo‘lgan sharlar o‘zaro noelastik to‘qnashgandan so‘ng to‘xtab qolishlari uchun ularning to‘qnashuvgacha bo‘lgan tezliklari nisbati v_1/v_2 qanday bo‘lishi lozim?

Berilgan:	*Yechilishi:*
$m_1 = 6\ kg,\ m_2 = 18\ kg$ $\upsilon = 0$ $\frac{\upsilon_1}{\upsilon_2} = ?$	$m_1\overrightarrow{\upsilon_1} + m_2\overrightarrow{\upsilon_2} = (m_1 + m_2)\vec{\upsilon}$ $m_1\overrightarrow{\upsilon_1} - m_2\overrightarrow{\upsilon_2} = 0$ $m_1\overrightarrow{\upsilon_1} = m_2\overrightarrow{\upsilon_2}$ $\quad \frac{\upsilon_1}{\upsilon_2} = \frac{m_2}{m_1} = \frac{18}{6} = 3$

Javob: 3.

Masala № 2. Tezligi *0,3 m/s*, massasi *30 t* bo‘lgan vagon tezligi *0,2 m/s*, massasi *20 t* bo‘lgan vagonni quvib etdi va unga ulanib qoldi. Vagonlarning birgalikdagi tezligi qanday (*m/s*)?

Berilgan:	*Yechilishi:*
$\upsilon_1 = 0{,}3\ m/s$ $m_1 = 30\ t$ $\upsilon_2 = 0{,}2\ m/s$ $m_2 = 20\ t$ $\upsilon = ?$	Impulsning saqlanish qonuniga $m_1\overrightarrow{\upsilon_1} + m_2\overrightarrow{\upsilon_2} = (m_1 + m_2)\vec{\upsilon}$ $m_1\upsilon_1 + m_2\upsilon_2 = (m_1 + m_2)\upsilon$ $\upsilon = \frac{m_1\upsilon_2 + m_2\upsilon_2}{m_1 + m_2}$ $\upsilon = \frac{30\cdot10^3\cdot03 + 20\cdot10^3\cdot0.2}{30\cdot10^3 + 20\cdot10^3} = 0{,}26\frac{m}{s} = 26\ sm/s.$

Javob: *26 sm/s.*

Masala № 3. Ikkita titan sharlar bir-biriga tomon bir xil $\vartheta = 2\,m/s$ tezlik bilan harakatlanadi va markaziy absalyut elastik uriladi. Massasi $m_1 = 240\,g$ bo‘lgan birinchi shar to‘qnashuvdan so‘ng to‘xtab qoladi. Ikkinchi jismning massasini va urilishdan keyingi tezligini aniqlang.

Berilgan:	*Yechilishi:*
$\vartheta_1 = \vartheta, \vartheta_2 = -\vartheta,$ $\vartheta = 2\,m/s$ $m_1 = 240\,g$ $\vartheta'_1 = 0$ $m_2 = ?,\ \vartheta'_2 = ?$	Bunda impulsning saqlanish qonunini absalyut elastik urilish uchun chiqarilgan 1-jismni urilishdan keyingi tezligi formulasidan foydalanamiz. $\vartheta'_1 = \frac{(m_1 - m_2)\vartheta_1 - 2m_2\vartheta_2}{m_1 + m_2} = 0, \rightarrow (m_1 - m_2)\vartheta - 2m_2\vartheta = 0, \rightarrow$ $m_1 - m_2 - 2m_2 = 0, \rightarrow m_2 = \frac{m_1}{3} = 80\,g$ 1-jismni urilishdan keyingi tezligi esa quyidagicha bo‘ladi: $\vartheta'_2 = \frac{(m_1 - m_2)\vartheta_2 + 2m_1\vartheta_1}{m_1 + m_2} = \frac{3m_1 - m_2}{m_1 + m_2}\vartheta = \frac{3\cdot240 - 80}{240 + 80}\vartheta = 2\vartheta = 4\,m/s$

Javob: $m_2 = \frac{m_1}{3} = 80\,g;\ \vartheta_2 = 2\vartheta = 4\,m/s$

19-amaliy mashg‘ulot topshirig‘i

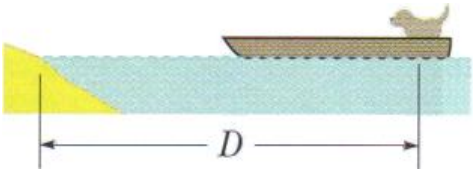
19.19. O‘q miltiqdan *865 m/s* tezlik bilan uchib chiqadi. Agar miltiqning massasi o‘qnikidan *470* marta katta bo‘lsa, u holda o‘q uchib chiqishda miltiqqa qanday tezlik beradi? **Javob:** *1,84 m/s*

19.20. Ikkita sportchi rolikli konkida bir-birining ro‘parasida turibdi. Birining massasi *75 kg*, ikkinchisi esa *70 kg*. Birinchisi *10 kg* toshni gorizontal holda *3 m/s* tezlik bilan ikkinchisiga otadi, ikkinchisi esa bu toshni ilib oladi. Birinchi sportchining toshni otgandan keyingi va ikkinchi sportchi uni ilib olgandan keyingi tezliklarni aniqlang. **Javob:** *0,4 m/s; 0,375 m/s*

19.21. Massasi m bo'lgan kishi *M* massali aravada tinch turibdi. Agar kishi arava ustida aravaga nisbatan ϑ nisbiy tezlik bilan harakatlansa, arava tezligi qanday bo'ladi? Bunda odamning yerga nisbatan tezligi qanday? Ishqalanishni hisobga olmang. **Javob:** $\frac{m\vartheta}{M+m}; \frac{M\vartheta}{M+m}$

19.22. Konkichi yukli chanani *5 m/s* tezlik bilan uchiryapti. Keyin esa chanani oldinga qarab itarib yubordi. Agar chananing keying tezligi *8 m/s* bo‘lib qolgan bo‘lsa, konkichining tezligi nimaga teng? Chananning massasi *90 kg*, konkichining massasi *60 kg*. **Javob:** *0,5 m/s*

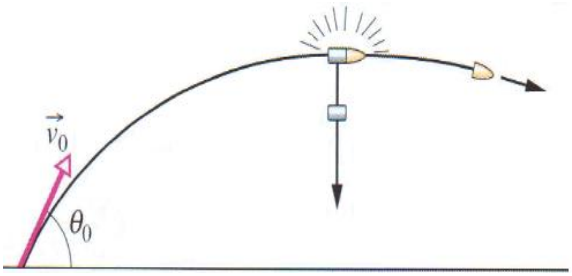
19.23. Rasmda kichkina qayiqchada yurayotgan kuchuk tasvirlangan. Qayiqchaning massasi *18 kg*, kuchukniki esa *4,5 kg*. Kuchuk qirg‘oqdan $D = 6m$ masofada turibdi. Kuchuk qayiqchaning quyruq qismidan boshiga qarab *2,5 m* masofaga yurib to‘xtagan bo‘lsa, qayiq qirg‘oqdan qancha uzoqlikda bo‘lib qoladi? **Javob:** *5,5 m*



19.24. Rasmda yerdan biror balandlikda erkin turgan *M* massali aerostat pillapoyasida *m* massali sportchi turgani tasvirlangan. Agar u aerostatga nisbatan o'zgarmas ϑ tezlik bilan ko'tarila boshlasa, aerostat qaysi tomonga va qanday tezlik bilan harakatlanadi? Bunda sportchining yerga nisbatan tezligi nimaga teng? **Javob:** *Pastga,* $\frac{m\vartheta}{M+m}$ *tezlik bilan;* $\frac{M\vartheta}{M+m}$

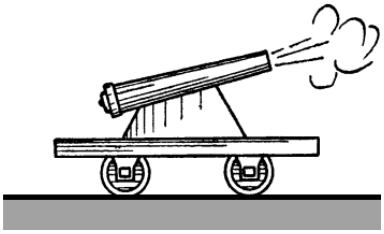
19.25. Massasi *M* bo'lgan qo'zg'almas atom yadrosi *m* massali zarrachani ϑ tezlik bilan chiqaradi. Yadroning o'zi qarama-qarshi tomonga harakatlanadi. Yadro tezligining moduli qanday? **Javob:** $\frac{m\vartheta}{M-m}$

19.26. Snaryad gorizontga nisbatan $\theta_0 = 60^0$ burchak ostida $\vartheta_0 = 20\,m/s$ boshlang‘ich tezlik bilan otildi. Trayektoriyaning yuqori qismida snaryad portlab teng ikki qismga bo‘linadi. Birinchi qism tik holda pastga tushadi. Ikkinchi kallak qism snaryad otilgan nuqtadan qancha masofaga tushadi? $g = 10\,m/s^2$. **Javob:** *103,9 m*



19.27. Massasi *12 kg* bo'lgan snaryad to'pdan *500 m/s* tezlik bilan uchib chiqdi. Agar to'pning massasi *1500 kg* bo'lsa, u orqaga necha metr masofaga siljiydi? To'pning yer bilan ishqalanish koeffitsiyenti *0,4* ga teng. **Javob:** *2 m*

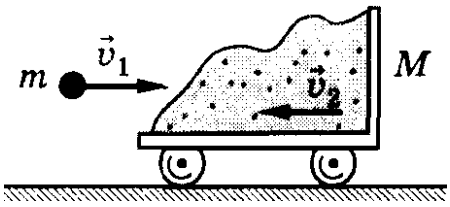
19.28. Massasi *750 t* bo'lgan kemada turib uning harakatiga qarshi yo'nalishda gorizontga 60^0 burchak ostida zambarak otildi. Agar massasi *30 kg* bo'lgan snaryad kemaga nisbatan *1 km/s* tezlik bilan uchib chiqqan bo'lsa, kemaning tezligi qancha o'zgaradi? **Javob:** *0,02 m/s*



19.29. Uzunligi $\ell = 9,2\,m$ bo‘lgan suvda tinch turgan platformaning ikki uchida bir-biriga qarab katta yoshli odam va kichik yoshli bola yugura boshladi. Odamning tezligi bolanikidan ikki marta katta. Odam platformaning bu uchiga yetib kelganda platforma qancha *s* masofaga va qaysi tomonga siljiydi? Platformaning massasi $m_1 = 600\,kg$, odamniki $m_2 = 60\,kg$ va bolaniki $m_3 = 30\,kg$ ga teng. **Javob:** $s = \dfrac{2m_2 - m_3}{m_1 + m_2 + m_3}\dfrac{\ell}{2} = 0,6\,m$

bola harakati bo‘yicha

19.30. $\vartheta_1 = 500\,m/s$ tezlik bilan uchayotgan $m = 30\,kg$ massali snaryad qarama-qarshi tomondan kelayotgan, massasi $M = 200\,kg$ bo'lgan aravadagi qumga kirib qolib, aravani to'xtatdi. Aravachaning tezligi ϑ_2 qanday bo’lgan? **Javob:** $\vartheta_2 = 7,5\,m/s$



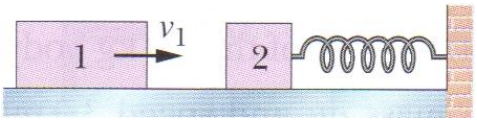
19.31. Tezligi *3 m/s*, massasi *30 t* bo‘lgan vagon tezligi *2 m/s*, massasi *20 t* bo‘lgan vagonni quvib yetdi va unga ulanib qoldi. Vagonlarning birgalikdagi tezligi qanday? Agar vagonlar bir-biriga tomon harakatlanayogan bo‘lsa-chi? **Javob:** *2,6 m/s; 1 m/s*

19.32. Ikki shar o‘rtasida absalyut noelastik to‘qnashuv sodir bo‘ladi. To‘qnashuv oldidan $m_1 = 3kg$ massali jism $\vartheta_1 = 20\,m/s$ tezlik bilan vertikal holda tik yuqoriga, $m_2 = 2\,kg$ massali jism esa $\vartheta_2 = 10\,m/s$ tezlik bilan vertikal holda tik pastga harakatlanayotgan

edi. To‘qnashuvdan keyin ular to‘qnashish nuqtasidan qancha balandlikka ko‘tariladi? $g = 9{,}8\ m/s^2$ deb oling. **Javob:** *3,26 m*

19.33. $m = 60\,g$ massali sharcha $\vartheta = 22\,m/s$ boshlang‘ich tezlik bilan $M = 240\,g$ massali tinch turgan prujinali qurolning stvoli ichiga otildi. Sharcha stvol ichida prujinaning maksimal siqilgan holatida tiqilib qoldi. Sharcha bilan stvol ichida ishqalanish yo‘q. Aniqlang: *a)* qurolning sharcha to‘xtagandan keyingi tezligini; *b)* sharcha kinetik energiyasining qanday qismi prujinaning siqilishiga sarflanishini. **Javob:** *4,4 m/s; 80%*

19.34. $m_2 = 1kg$ massali blok bikrligi *230 N/m* ga teng bo‘lgan siqilmagan prujinaga birikgan holda rasmdagi kabi silliq sirtda turibdi. Prujinaning ikkinchi uchi devorga mahkamlangan. $\vartheta_1 = 4\,m/s$ tezlik bilan kelayotgan $m_1 = 2\,kg$ massali blok 2-blok bilan to‘qnashadi va ular birlashib qoladi. Bloklar oniy to‘xtagan paytda prujina qanchaga siqilgan bo‘ladi? **Javob:** 20 sm

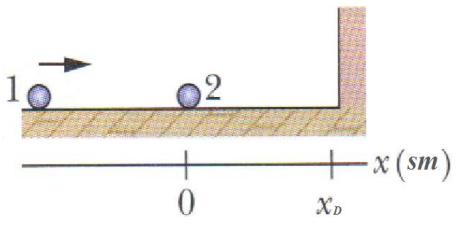


19.35. $\vartheta_1 = 7\,m/s$ tezlik bilan silliq polda harakatlanayotgan m_1 massali 1-blok tinch turgan $m_2 = 0{,}4m_1$ massali 2-blokka markaziy va absalyut elastik to‘qnashadi. To‘qnashuvdan keyin ikkala blok ham ishqalanish koeffitsiyenti $\mu = 0{,}2$ bo‘lgan dag‘al sohaga o‘tadi. *a)* Bu sohada ikkala blok qancha masofada to‘xtaydi? *b)* Bloklarning to‘xtash vaqtlari nimaga teng? $g = 10\ m/s^2$ deb oling. **Javob:** *a)* $2{,}25m;\ 25m;$ *b)* $1{,}5s;\ 5s$

19.36. Ikkita titan sharlar bir-biriga tomon bir xil $\vartheta = 2\,m/s$ tezlik bilan harakatlanadi va markaziy absalyut elastik uriladi. Massasi $m_1 = 240\,g$ bo‘lgan birinchi shar to‘qnashuvdan so‘ng to‘xtab qoladi. Ikkinchi jismning massasini va urilishdan keyingi tezligini aniqlang. Bunda tiklanish koeffitsiyenti nimaga teng bo‘ladi?

Javob: $m_2 = \dfrac{m_1}{3} = 80\,g;\ \vartheta_2 = 2\vartheta = 4\,m/s;\ \alpha = 1$

19.37. ** $m_1 = 0{,}3kg$ massali Ox o‘qi bo‘ylab o‘ng tomonga silliq sirtda *0,7 m/s* tezlik bilan harakatlanadi. $x = 0$ nuqtaga yetganda $m_2 = 0{,}4kg$ massali tinch turgan 2- jismga markaziy elastik to‘qnashadi. Keyin 2-jism $x_D = 60\,sm$ masofadagi devorga elastik urilib, undan tezlikni yo‘qotmasdan qaytadi. Ox o‘qida qaysi x nuqtada sharlar ikkinchi marta to‘qnashadi? **Javob:** $x = -24\,sm$



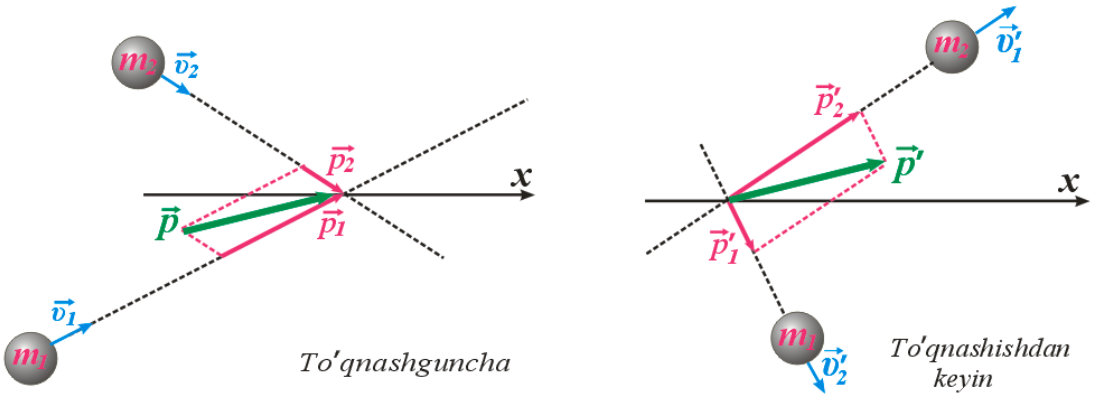
19.38. 3ϑ va ϑ tezlik bilan bir-birini quvib ketayotgan ikkita bir xil shar mutlaq noelastik to'qnashsa, sistemaning kinetik energiyasi necha marta kamayadi? **Javob:** *1,25 marta*

19.39. 3ϑ va ϑ tezlik bilan bir-biri tomon kelayotgan ikkita bir xil shar mutlaq noelastik to'qnashsa, sistemaning kinetik energiyasi necha marta kamayadi? **Javob:** *5 marta*

19.40. ϑ tezlik bilan harakatlanayotgan m massali shar tinch holatda turgan, massasi $2m$ bolgan shar bilan noelastik to'qnashdi. Bunda shar energiyasining qanday qismi ichki energiyaga aylandi? **Javob:** *2/3*

19.41. 3ϑ va ϑ tezlik bilan bir-birini quvib ketayotgan ikkita bir xil shar mutlaq elastik to'qnashdi. Birinchi sharning to'qnashishdan keyingi energiyasini aniqlang. **Javob:** $\frac{m\vartheta^2}{2}$

19.42. ** *Oxy* tekislikda rasmdagi kabi $\vartheta_1=4$ *m/s* va $\vartheta_2=2$ *m/s* tezliklar harakat qilayotgan massasi $m_1=400$ *g* va $m_2=600$ *g* bo‘lgan absalyut qattiq sharlar *Ox* o‘qi bilan mos holda $\alpha_1=53^0$ va $\alpha_2=37^0$ graduslar tashkil qilib to‘qnashadilar. Sharlarning to‘qnashishdan keyingi tezliklarini hamda bu tezlik vektorlarining *Ox* o‘qi bilan hosil qilgan burchaklarini aniqlang. **Javob:**



19.43. ** Mustahkam po‘latdan ($\alpha=0,6$) yasalgan ikkita bir xil sharlar bir-biriga tomon bir xil tezlik bian urilganda mexanik energiyaning qanday qismi ichki energiyaga aylanadi? **Javob:**

19.44. ** Fil suyagidan ($\alpha=0,9$) yasalgan ikkita shrning $m_1=800$ *g* va $m_2=500$ *g* ga teng. Birinchi shar ikkinchisini quvib yetib urilganda sharlar tezliklari qanday bo‘ladi? Bunda sharlar tezliklari $\vartheta_1=60$ *sm/s* va $\vartheta_2=40$ *sm/s* ga teng. Bunda mexnik energiyaning qanday qismi qoladi? **Javob:**

20-MAVZU: Massa markazi, massa markazi harakatining saqlanish qonuni. Siolkovskiy va Mesherskiy formulalari.

Mavzuga oid muhim formulalar

Massa markazini geometrik va analitik usulda aniqlash

$$\vec{r}_C = \frac{m_1\cdot\vec{r}_1 + m_2\cdot\vec{r}_2 + m_3\cdot\vec{r}_3 + \ldots + m_n\cdot\vec{r}_n}{m_1 + m_2 + m_3 + \ldots + m_n} = \frac{\sum m_i\cdot\vec{r}}{\sum m_i}$$

$$\begin{cases} x_C = \dfrac{m_1\cdot x_1 + m_2\cdot x_2 + m_3\cdot x_3 + \ldots + m_n\cdot x_n}{m_1 + m_2 + m_3 + \ldots + m_n} = \dfrac{\sum m_i\cdot x_i}{\sum m_i} \\ y_C = \dfrac{m_1\cdot y_1 + m_2\cdot y_2 + m_3\cdot y_3 + \ldots + m_n\cdot y_n}{m_1 + m_2 + m_3 + \ldots + m_n} = \dfrac{\sum m_i\cdot y_i}{\sum m_i} \\ z_C = \dfrac{m_1\cdot z_1 + m_2\cdot z_2 + m_3\cdot z_3 + \ldots + m_n\cdot z_n}{m_1 + m_2 + m_3 + \ldots + m_n} = \dfrac{\sum m_i\cdot z_i}{\sum m_i} \end{cases}$$

Massa markazini integrallash orqali topish qoidalari

$$\begin{cases} \vec{r}_C = \dfrac{\int\vec{r}\,dm}{\int dm}, \quad x_C = \dfrac{\int x\,dm}{\int dm}, \quad y_C = \dfrac{\int y\,dm}{\int dm}, \quad z_C = \dfrac{\int z\,dm}{\int dm} & -\ umumiy \\ \vec{r}_C = \dfrac{\int\vec{r}\,dV}{\int dV}, \quad x_C = \dfrac{\int x\,dV}{\int dV}, \quad y_C = \dfrac{\int y\,dV}{\int dV}, \quad z_C = \dfrac{\int z\,dV}{\int dV} & -\ hajmiy \\ \vec{r}_C = \dfrac{\int\vec{r}\,dS}{\int dS}, \quad x_C = \dfrac{\int x\,dS}{\int dS}, \quad y_C = \dfrac{\int y\,dS}{\int dS}, \quad z_C = \dfrac{\int z\,dS}{\int dS} & -\ sirtiy \\ \vec{r}_C = \dfrac{\int\vec{r}\,d\ell}{\int d\ell}, \quad x_C = \dfrac{\int x\,d\ell}{\int d\ell}, \quad y_C = \dfrac{\int y\,d\ell}{\int d\ell}, \quad z_C = \dfrac{\int z\,d\ell}{\int d\ell} & -\ chiziqli \end{cases}$$

$x_C = \dfrac{\sin\alpha}{\alpha}R$	*Markaziy burchagi 2α bo'lgan yoyning massa markazi*
$x_C = \dfrac{2}{3}\dfrac{\sin\alpha}{\alpha}R$	*Markaziy burchagi 2α bo'lgan sektorning massa markazi*
$z_C = \dfrac{1}{4}H$	*Konusni massa markazi (asosdan hisoblaganda)*
$z_C = \dfrac{3}{8}R$	*Asosi yerda yotgan yarimsharning massa markazi (asosdan hisoblaganda)*
$M\,\vec{a}_C = \vec{R}^{ex}$	*Massa markazining harakati haqidagi teorema*
$m\dfrac{d\vec{\vartheta}}{dt} = \vec{F} + \vec{\vartheta}_{nis}\dfrac{dm}{dt}$	*Mesherskiy formulasi*
$\vartheta = \vartheta_0 + \vartheta_{nis}\ln\dfrac{m_0}{m} = \vartheta_0 + \vartheta_{nis}\ln\left(1+\dfrac{m_y}{m_k}\right)$	*Sialkovskiy formulalari*

$\vartheta = \vartheta_0 + \vartheta_{nis} \ln z, \quad z = \frac{m_0}{m_k}$	

20-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Rasmda keltirilgan bir jinsli sterjenlar va aylanadan iborat sistemaning og‘irlik markazi topilsin.

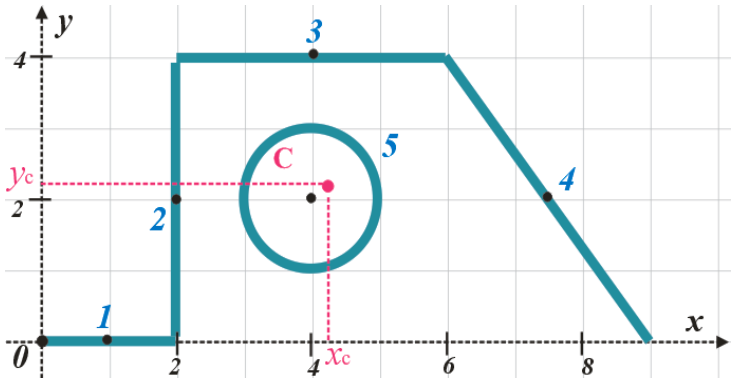
Berilgan:

$$\begin{cases} \ell_1 = 2 \\ x_1 = 1 \\ y_1 = 0 \end{cases}; \quad \begin{cases} \ell_2 = 4 \\ x_2 = 2 \\ y_2 = 2 \end{cases}; \quad \begin{cases} \ell_3 = 4 \\ x_3 = 4 \\ y_3 = 4 \end{cases};$$

$$\begin{cases} \ell_4 = 5 \\ x_4 = 7{,}5 \\ y_4 = 2 \end{cases}; \quad \begin{cases} \ell_5 = 6{,}28 \\ x_5 = 4 \\ y_5 = 2 \end{cases}$$

$$x_c = ?,\ y_c = ?$$

Yechish:



Og‘irlik markazining koordinatalarini topamiz.

$$x_C = \frac{\ell_1 \cdot x_1 + \ell_2 \cdot x_2 + \ell_3 \cdot x_3 + \ell_4 \cdot x_4 + \ell_5 \cdot x_5}{\ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5} = \frac{2 \cdot 1 + 4 \cdot 2 + 4 \cdot 4 + 5 \cdot 7{,}5 + 6{,}28 \cdot 4}{2 + 4 + 4 + 5 + 6{,}28} = \frac{88{,}62}{21{,}28} = 4{,}164$$

$$y_C = \frac{\ell_1 \cdot y_1 + \ell_2 \cdot y_2 + \ell_3 \cdot y_3 + \ell_4 \cdot y_4 + \ell_5 \cdot y_5}{\ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5} = \frac{2 \cdot 0 + 4 \cdot 2 + 4 \cdot 4 + 5 \cdot 2 + 6{,}28 \cdot 2}{2 + 4 + 4 + 5 + 6{,}28} = \frac{46{,}56}{21{,}28} = 2{,}188.$$

Javob: $x_c = 4{,}164;\ y_c = 2{,}188$

Masala № 2. Asosi *a* va markaziy balandligi *H* bo‘lgan uchburchakning og‘irlik markazini topish uchun quyidagi formula keltirib chiqarilsin.

$$y_C = \frac{1}{3}H$$

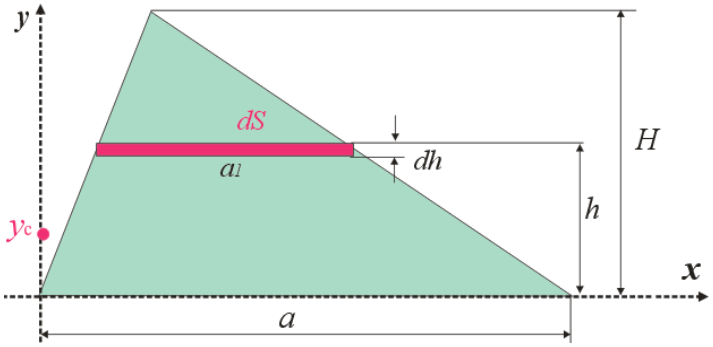
Berilgan:

a

H

$y_c = ?$

Yechilishi:



Uchburchak asosidan ixtiyoriy *h* masofada asosga parallel qilib bo‘yi a_1, eni *dh* bo‘lgan elementar yuzacha ajratamiz. Uchburchaklar o‘xshashligiga ko‘ra mos tomonlar nisbati o‘zaro teng bo‘lish kerak. Bundan elementar yuzachaning uzunligi a_1 ni topamiz.

$$\frac{a_1}{a}=\frac{H-h}{H};\ \rightarrow\ a_1=\frac{H-h}{H}a=a-\frac{a}{H}h$$

Elementar yuzacha $dS=a_1dh=\left(a-\frac{a}{H}h\right)dh$, uchburchak esa $S=\frac{1}{2}aH$ yuzaga ega. Integrallash natijasida og'irlik markazining *Oy* o'qidagi koordinatasini topamiz.

$$y_C=\frac{\int y\,dS}{\int dS}=\frac{\int_0^H h\cdot\left(a-\frac{a}{H}h\right)dh}{\int_0^H\left(a-\frac{a}{H}h\right)dh}=\frac{\int_0^H\left(ah-\frac{a}{H}h^2\right)dh}{\int_0^H\left(a-\frac{a}{H}h\right)dh}=\frac{\frac{1}{2}aH^2-\frac{a}{H}\cdot\frac{1}{3}H^3}{aH-\frac{a}{H}\cdot\frac{1}{2}H^2}=$$

$$=\frac{aH^2\left(\frac{1}{2}-\frac{1}{3}\right)}{\frac{1}{2}aH}=\frac{1}{3}H\ .$$

Javob: $y_C=\frac{1}{3}H$

Masala № 3. Rasmdan foydalanib, hamda integrallash orqali radiusi *R* va markaziy burchagi *2α* bo'lgan aylana yoyining og'irlik markazini topish uchun quyidagi formuladan keltirib chiqarilshi topilsin.

$$x_C=\frac{\sin\alpha}{\alpha}R$$

Markaziy *2α* burchak *90⁰* ga va *180⁰* ga teng bo'lgan xususiy hollar uchun og'irlik markazi egrilik markazidan qanday masofada bo'lishi aniqlansin.

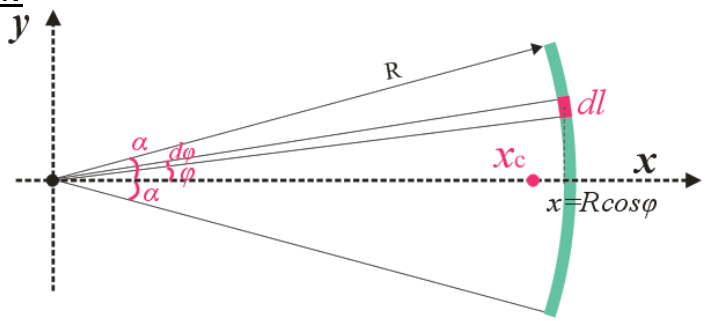
Berilgan:

$R,\ 2\alpha$

$\alpha_1=\frac{\pi}{4},\ \alpha_2=\frac{\pi}{2}$

$x_c=?,\ x_1=?,\ x_2=?$

Yechilishi:



Yoy uzunligi $\ell=2\alpha R$. Yoydan markaziy burchagi $d\varphi$ va uzunligi $d\ell=Rd\varphi$ bo'lgan elementar yoycha ajratamiz. Elementar yoyning og'irlik markazi $x=R\cos\varphi$. Integrallash natijasida yoyning og'irlik markazini topamiz. Simmetriyaga ega bo'lgani uchun yoyning og'irlik markazini faqat *Ox* o'qida topish yetarlidir.

$$x_C=\frac{\int x\,d\ell}{\int d\ell}=\frac{\int\limits_{-\alpha}^{\alpha}R\cos\varphi\cdot R\,d\varphi}{\int\limits_{-\alpha}^{\alpha}R\,d\varphi}=\frac{R^2\int\limits_{-\alpha}^{\alpha}\cos\varphi\,d\varphi}{R\int\limits_{-\alpha}^{\alpha}d\varphi}=R\frac{\sin\varphi\,|_{-\alpha}^{\alpha}}{\varphi\,|_{-\alpha}^{\alpha}}=R\frac{\sin\alpha-\sin(-\alpha)}{\alpha-(-\alpha)}=\frac{\sin\alpha}{\alpha}R.$$

Endi yuqoridagi formuladan foydalanib $\alpha_1=\frac{\pi}{4},\ \alpha_2=\frac{\pi}{2}$ burchaklar uchun og'irlik markazini hisoblab topamiz.

$$x_1=\frac{\sin\alpha_1}{\alpha_1}R=\frac{\sin\frac{\pi}{4}}{\frac{\pi}{4}}R=\frac{\frac{\sqrt{2}}{2}}{\frac{\pi}{4}}R=\frac{2\sqrt{2}}{\pi}R\approx 0,9R;\qquad x_2=\frac{\sin\alpha_2}{\alpha_2}R=\frac{\sin\frac{\pi}{2}}{\frac{\pi}{2}}R=\frac{2}{\pi}R\approx 0,6366R$$

Javob: $x_C=\frac{\sin\alpha}{\alpha}R;\ x_1=\frac{2\sqrt{2}}{\pi}R;\ x_2=\frac{2}{\pi}R$

Masala № 4. Rasmdan foydalanib, hamda integrallash orqali radiusi *R* va markaziy burchagi 2α bo'lgan doira sektorining og'irlik markazini topish uchun quyidagi formula keltirib chiqarilsin.

$$x_C=\frac{2}{3}\cdot\frac{\sin\alpha}{\alpha}R$$

Markaziy *2α* burchak *90⁰* ga va *180⁰* ga teng bo'lgan xususiy hollar uchun og'irlik markazi sektor uchidan qanday masofada bo'lishi aniqlansin.

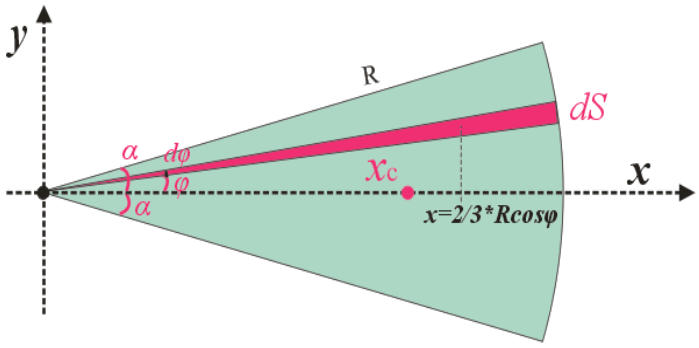
Berilgan:

$R,\ 2\alpha$

$\alpha_1=\frac{\pi}{4},\ \alpha_2=\frac{\pi}{2}$

$x_c=?,\ x_1=?,\ x_2=?$

Yechilishi:



Sektor yuzi $S=\alpha R^2$. Sektor ichidan markaziy burchagi $d\varphi$ va yuzi $dS=\frac{1}{2}R^2\,d\varphi$ bo'lgan elementar sektorcha ajratamiz. Elementar sektorning og'irlik markazi $x=\frac{2}{3}R\cos\varphi$. Integrallash natijasida yoyning og'irlik markazini topamiz. Simmetriyaga ega bo'lgani uchun sektorning og'irlik markazini faqat *Ox* o'qida topish yetarlidir.

$$x_C=\frac{\int x\,dS}{\int dS}=\frac{\int\limits_{-\alpha}^{\alpha}\frac{2}{3}R\cos\varphi\cdot\frac{1}{2}R^2\,d\varphi}{\int\limits_{-\alpha}^{\alpha}\frac{1}{2}R^2\,d\varphi}=\frac{\frac{1}{3}R^3\int\limits_{-\alpha}^{\alpha}\cos\varphi\,d\varphi}{\frac{1}{2}R^2\int\limits_{-\alpha}^{\alpha}d\varphi}=\frac{2}{3}R\frac{\sin\varphi|_{-\alpha}^{\alpha}}{\varphi|_{-\alpha}^{\alpha}}=$$

$$=\frac{2}{3}R\frac{\sin\alpha-\sin(-\alpha)}{\alpha-(-\alpha)}=\frac{2}{3}\cdot\frac{\sin\alpha}{\alpha}R.$$

Endi yuqoridagi formuladan foydalanib $\alpha_1=\frac{\pi}{4},\ \alpha_2=\frac{\pi}{2}$ burchaklar uchun og'irlik markazini hisoblab topamiz.

$$x_1=\frac{2}{3}\cdot\frac{\sin\alpha_1}{\alpha_1}R=\frac{2}{3}\cdot\frac{\sin\frac{\pi}{4}}{\frac{\pi}{4}}R=\frac{2}{3}\cdot\frac{\frac{\sqrt{2}}{2}}{\frac{\pi}{4}}R=\frac{4\sqrt{2}}{3\pi}R\approx 0,6R$$

$$x_2=\frac{2}{3}\cdot\frac{\sin\alpha_2}{\alpha_2}R=\frac{2}{3}\cdot\frac{\sin\frac{\pi}{2}}{\frac{\pi}{2}}R=\frac{2}{3}\cdot\frac{1}{\frac{\pi}{4}}R=\frac{8}{3\pi}R\approx 0,8488R$$

Javob: $x_C=\frac{2}{3}\cdot\frac{\sin\alpha}{\alpha}R;\ x_1=\frac{4\sqrt{2}}{3\pi}R;\ x_2=\frac{8}{3\pi}R$

Masala № 5. Asosining radiusi *R* va balandligi *H* bo'lgan konus og'irlik markazini topish uchun quyidagi formula keltirib chiqarilsin.

$$z_C=\frac{1}{4}H$$

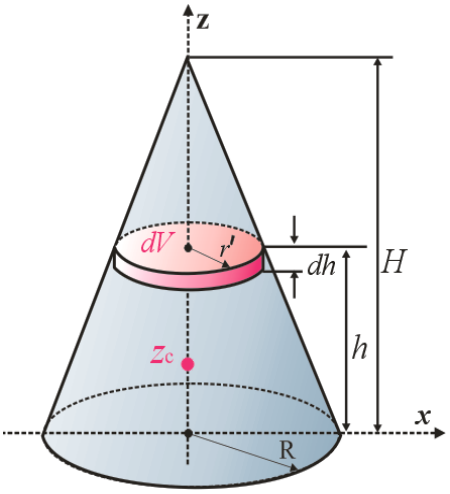
Berilgan:

R
H

$z_c=?$

Yechilishi:

Konus asosidan ixtiyoriy *h* masofada asosga parallel qilib radiusi *r′*, eni *dh* bo'lgan elementar slindrcha ajratamiz. Konusning o'q kesimida hosil bo'lgan uchburchaklar o'zaro o'xshashdir. Uchburchaklar o'xshashligiga ko'ra mos tomonlar nisbati o'zaro teng bo'lish kerak. Bundan elementar



slindrchaning radiusi r' ni topamiz.

$$\frac{r'}{R}=\frac{H-h}{H};\ \rightarrow\ r'=\frac{H-h}{H}R=R-\frac{R}{H}h$$

Elementar hajmcha $dV=\pi r'^2\,dh=\left(R-\frac{R}{H}h\right)^2 dh=\left(R^2-2\frac{R^2}{H}h+\frac{R^2}{H^2}h^2\right)dh$, konus hajmi esa $V=\frac{1}{3}\pi R^2 H$ hajmga ega.

Integrallash natijasida og‘irlik markazining *Oz* o‘qidagi koordinatasini topamiz.

$$y_C=\frac{\int y\,dV}{\int dV}=\frac{\int_0^H h\cdot\pi\left(R^2-2\frac{R^2}{H}h+\frac{R^2}{H^2}h^2\right)dh}{\int_0^H \pi\left(R^2-2\frac{R^2}{H}h+\frac{R^2}{H^2}h^2\right)dh}=\frac{\pi\cdot\int_0^H\left(R^2h-2\frac{R^2}{H}h^2+\frac{R^2}{H^2}h^3\right)dh}{\pi\cdot\int_0^H\left(R^2-2\frac{R^2}{H}h+\frac{R^2}{H^2}h^2\right)dh}=$$

$$=\frac{\frac{1}{2}R^2H^2-2\frac{R^2}{H}\cdot\frac{1}{3}H^3+\frac{R^2}{H^2}\cdot\frac{1}{4}H^4}{R^2H-2\frac{R^2}{H}\cdot\frac{1}{2}H^2+\frac{R^2}{H^2}\cdot\frac{1}{3}H^3}=\frac{R^2H^2\left(\frac{1}{2}-\frac{2}{3}+\frac{1}{4}\right)}{R^2H\left(1-1+\frac{1}{3}\right)}=\frac{\frac{1}{12}}{\frac{1}{3}}H=\frac{1}{4}H.$$

Javob: $z_c=\frac{1}{4}H$

Masala № 6. Yoqilg‘i bilan to‘la zapravka qilingan raketaning umumiy massasi *21000 kg* bo‘lib shundan *15000 kg* massa yoqilg‘i hissasiga to‘g‘ri keladi. Yonish paytida yoqilg‘i sarfi *190 kg/s* ga, yoqilg‘ining raketaga nisbatan otilib chiqish tezligi esa *2800 m/s* ga teng. Raketa tik holda yuqoriga ko‘tarilyapti deb quyidagilarni hisoblang: a) raketaga ta’sir qiluvchi reaktiv tortish kuchini; b) o‘t oldirish onidagi va yoqilg‘i yonib tugagan paytdagi raketaga ta’sir qiluvchi natijaviy kuchni; c) yoqilg‘i tugagandaerishgan tezlikni. Havonin qarshiligini hisobga olmang va erkin tushish tezlanishini o‘zgarmas g=9,81 m/s^2 deb hisoblang.

Berilgan:

M=21000 kg
M_y=15000 kg
ϑ_{nis}=2800 m/s
dm/dt=190 kg/s

a) F_{reak}=?
b) R_0=? , R=?
c) ϑ_{max}=?

Yechilishi:

a) Dastlab teaktiv kuchni topamiz.

$$F_{reak}=\vartheta_{nis}\frac{dm}{dt}=(2800m/s)\cdot(190kg/s)=5{,}32\cdot10^5N=532kN$$

b) tashqi kuch o’t oldirilgan onda

$$Mg=(21000kg)\cdot(9{,}8m/s^2)=205{,}8kN$$

ga, yoqilg‘i tugash onida esa

$$(M-m)g=(6000kg)\cdot(9{,}8m/s^2)=58{,}8kN$$

ga teng bo‘ladi. Bu paytlardagi raketaga ta’sir etuvchi natijaviy kuch esa

$$R_0=F_{reak}-Mg=532kN-205{,}8kN=326{,}2kN$$

$$R=F_{reak}-(M-m)g=532kN-58{,}8kN=473{,}2kN$$

c) Endi yoqilg‘i tugagan ondagi raketa erishgan maksimal tezlikni hisoblaymiz.

$$m\frac{d\vartheta}{dt}=F_{tash}+\vartheta_{nis}\frac{dm}{dt},\ \rightarrow\ d\vartheta=\frac{F_{tash}}{m}dt+\vartheta_{nis}\frac{dm}{m}=-g\,dt+\vartheta_{nis}\frac{dm}{m}$$

$$\int_{\vartheta_0}^{\vartheta}d\vartheta=-g\int_0^t dt+\vartheta_{nis}\int_M^{M-m_y}\frac{dm}{m},\ \rightarrow\ \vartheta-\vartheta_0=-gt+\vartheta_{nis}\ln\frac{M-m_y}{M},\ \rightarrow$$

$$\vartheta=\vartheta_0-gt+\vartheta_{nis}\ln\frac{M-m_y}{M}.$$

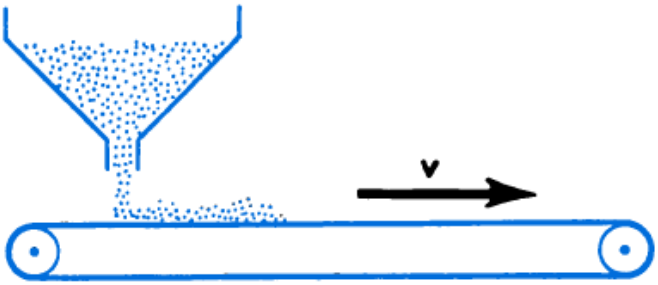
Yoqilg'i yonib tugash vaqti $t=\frac{15000}{190}=79\,s$ tezlik formulasiga qo'yib hisoblaymiz.

$$\vartheta_{\max}=\vartheta_0-gt+\vartheta_{nis}\ln\frac{M-m_y}{M}=0-(9{,}8\,m/s^2)\cdot(79\,s)+\left(-2800\,m/s\right)\cdot\ln\frac{21000\,kg-15000\,kg}{21000\,kg}=$$

$$=0-774{,}2\,m/s-(2800\,m/s)\cdot(-1{,}253)=-774{,}2\,m/s+3507{,}7\,m/s=2733{,}5\,m/s.$$

Javob: a) $F_{reak}=532\,kN$; b) $R_0=326{,}2\,kN$; $R=473{,}2\,kN$; c) $\vartheta_{\max}=2733{,}5\,m/s$

Masala № 7. Bunkerdan eltuvchi lentaga *7,5 kg/s* tezlik bilan shag'al to'kilmoqda. Lentaning *2,2 m/s* tezligini doimiy saqlash uchun qanday kuch kerak? Ishqalanish kuchini e'tiborga olmang.



Berilgan:	*Yechilishi:*
dm/dt=75 kg/s *dϑ/dt=0* *u=0* *ϑ=2,2 m/s*	Bunker tincg turgani uchun u=0 deymiz. Shag'alning to'kilish tezligi 75 kg/s. Lenta doimiy tezlik bilan siljigani uchun dϑ/dt=0 bo'ladi. $$m\frac{d\vec{\vartheta}}{dt}=\vec{F}+\left(\vec{\vartheta}-\vec{u}\right)\frac{dm}{dt}$$
a) F=?	Fformulaga ko'ra $$F=m\frac{d\vartheta}{dt}-(u-\vartheta)\frac{dm}{dt}=0+2{,}2\cdot75=165\,N$$

Demak, lenta doimiy tezlikbilan harakatlanish uchun tashqi kuch 165 N ga teng bo'lishi kerak ekan.

Javob: *F=165 N*

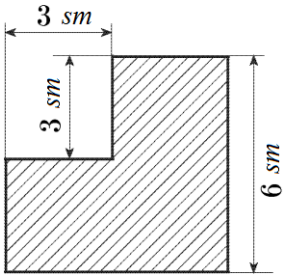
20-amaliy mashg'ulot topshirig'i

20.1. Bir jinsli valning bir uchidan 40 sm qirqib tashlandi. Bunda og'irlik markazi qayerga va qanchaga ko'chadi? **Javob:** *20 sm ikkinchi yelka tomonga*

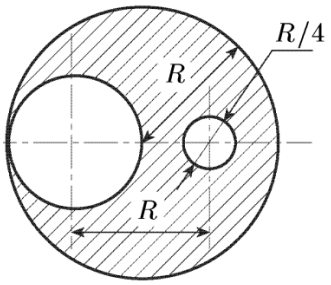
20.2. Slindrik metall tayoqchaning yarmi po‘latdan, yarmi alyuminiydan iborat. Agar butun metall tayoqchaning uzunligi *30 sm* bo‘lsa, uning og‘irlik markazi qayerda joylashgan? **Javob:**

20.3. Uzunligi $\ell = 1m$ bo‘lgan gorizontal g‘adir-budur doska ustiga balandligi H asos diametri D dan to‘rt marta katta bo‘lgan slindr qo‘yilgan. Doskaning bir chetini eng ko’pi bilan qancha h masofaga ko‘targanda slindr yiqilib ketmaydi? **Javob:** $h = \dfrac{\ell}{\sqrt{17}}$

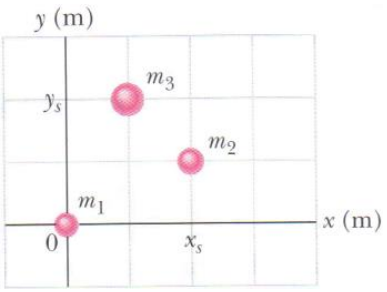
20.4. Rasmda ko‘rsatilgan shakldagi bir jinsli plastinka berilgan. Uning og‘irlik markazidan pastki tomongacha bo‘lgan x_C masofani va chap tomongacha bo‘lgan y_C masofani aniqlang. **Javob:** $x_C = 3{,}5\,sm;\ y_C = 2{,}5\,sm$



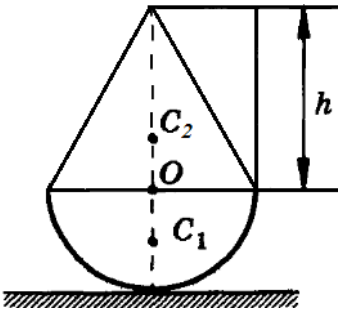
20.5. Ikkita doiraviy teshiklar ochilgan bir jinsli R radiusli diskning og‘irlik markazi disk markazidan necha santimetr o‘ng tomonda yotishini aniqlang. Ochilgan teshiklar radiuslari $R/2$ va $R/4$ ga teng bo‘lib, ularni holatlari rasmda tasvirlangan. **Javob:** $\dfrac{3}{22}R \approx 0{,}136R$



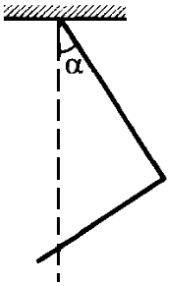
20.6. Uchta shar shaklidagi jismlar Oxy Dekart koordinatalar tekisligida rasmdagi kabi turibdi. Bunda sharlar massalari $m_1 = 2\,kg, m_2 = 4\,kg$ va $m_3 = 8\,kg$ ga teng. Sharlar sistemasining og‘irlik markazining koordinatalarini aniqlang [m]. 1 ta katakni *1 m* deb oling. **Javob:**



20.7. Konus va yarimshardan iborat bir jinsli jism silliq gorizontal sirtda rasmdagi kabi turibdi. h ning qanday eng katta qiymatigacha rasmdagi holat turg‘un muvozanatda bo‘ladi? R – yarimsharning radiusi, C_1 – yarimsharning og‘irlik markazi, C_2 – konusning og‘irlik markazi, $OC_1 = \dfrac{3}{8}R,\ OC_2 = \dfrac{1}{4}h$. **Javob:** $h \le \sqrt{3}R$

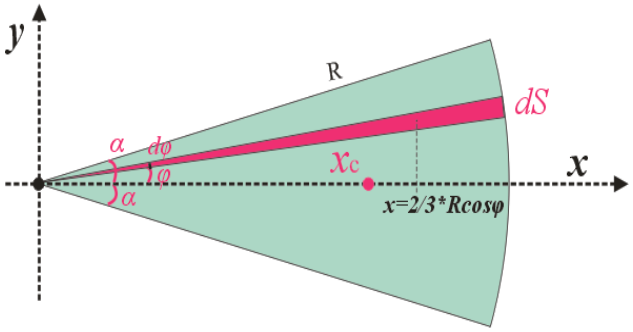


20.8. Og‘ir sterjen o‘rtasidan bukib to‘g‘ri burchak holiga keltirildi va bir uchidan rasmdagidek erkin osildi. Sterjenning yuqorigi yarmi vertikal bilan qanday burchak tashkil etadi? **Javob:** $\alpha = arctg\frac{1}{3} = 18,5^0$

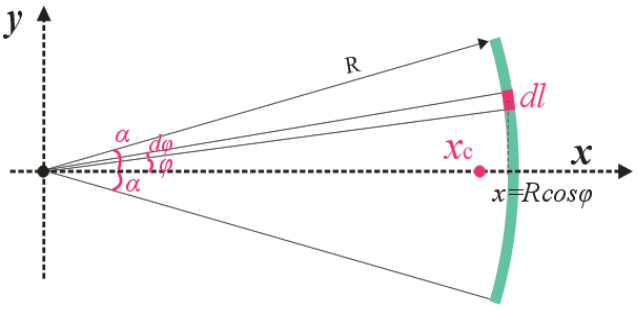


20.9. Slindrning ustiga konus o‘tqizilgan bo‘lsa, ularning og‘irlik markazi slindr pastki asosidan qanday masofada bo‘ladi. Slindr va konus balandliklari bir xil va *h* ga teng.
Javob: *11h/16*

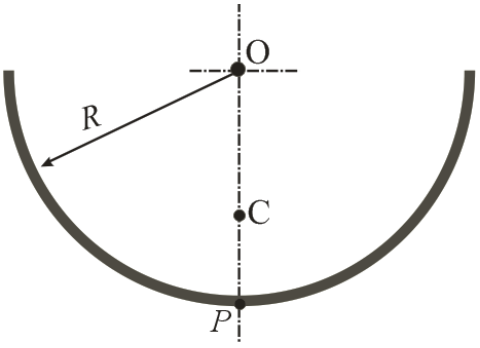
20.10. Integrallash orqali radiusi *R* va markaziy burchagi 2α bo‘lgan doira sektorining og‘irlik markazini topish uchun formula keltirib chiqaring. $\alpha = \frac{\pi}{3}; \alpha = \frac{\pi}{4};\quad \alpha = \frac{\pi}{2}; \alpha = \frac{2\pi}{3}$ qiymatlar uchun massalar markazining koordinatasini aniqlang. **Javob:** $x_C = \frac{2}{3}\cdot\frac{\sin\alpha}{\alpha}R;\ \frac{\sqrt{3}}{\pi}R;\ \frac{4\sqrt{2}}{3\pi}R;\ \frac{4}{3\pi}R;\ \frac{\sqrt{3}}{2\pi}R.$



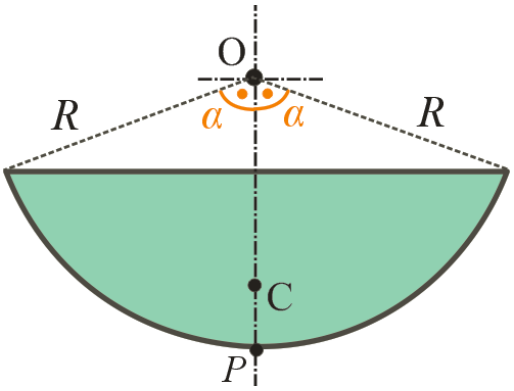
20.11. Integrallash orqali radiusi *R* va markaziy burchagi 2α bo‘lgan doira sektorining og‘irlik markazini topish uchun formula keltirib chiqaring. $\alpha = \frac{\pi}{3}; \alpha = \frac{\pi}{4};\quad \alpha = \frac{\pi}{2}; \alpha = \frac{2\pi}{3}$ qiymatlar uchun massalar markazining koordinatasini aniqlang. **Javob:** $x_C = \frac{\sin\alpha}{\alpha}R;\ \frac{3\sqrt{3}}{2\pi}R;\ \frac{2\sqrt{2}}{\pi}R;\ \frac{2}{\pi}R;\ \frac{3\sqrt{3}}{4\pi}R.$



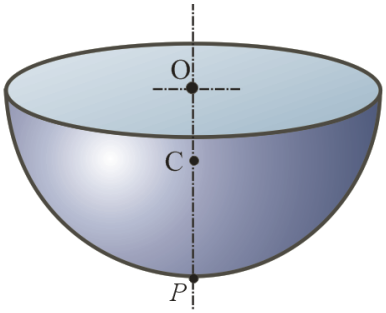
20.12. Rasmda yarim aylana shaklidagi yupqa devorli trubaning ko‘ndalang kesimi tasvirlangan. Bu trubaning massalar markazi *C* nuqta va *P* nuqta orasidagi masofa nimaga teng?
Javob: $PC = \frac{\pi - 2}{\pi}R$



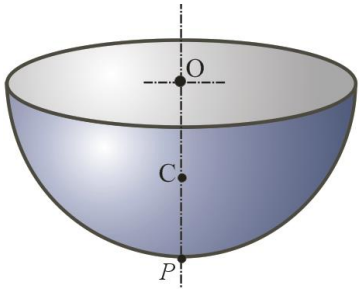
20.13. Rasmda markaziy burchagi 2α ga teng bo‘lgan R radiusli doira sektori berilgan. Bu segmentining massa markazi C nuqta va doira markazi O nuqta orasidagi masofa nimaga teng? $\alpha=\frac{\pi}{6};\alpha=\frac{\pi}{2}$ qiymatlar uchun hisob-lashlar bajaring. **Javob:** $OC=\frac{4}{3}\frac{\sin^3\alpha}{2\alpha-\sin 2\alpha}R;$ $OC=\frac{R}{2\pi-1};\ OC=\frac{4}{3\pi}R$



20.14. Rasmda R radiusli yarimshar tasvirlangan. Bu yarimsharning massalar markazi C nuqta sharning markazi O nuqtadan qanday masofada joylashgan? **Javob:** $OC=\frac{3}{8}R$



20.15. Rasmda R radiusli yarimsfera tasvirlangan. Bu yarimsferaning massalar markazi C nuqta sharning markazi O nuqtadan qanday masofada joylashgan? **Javob:** $OC=\frac{R}{2}$



20.16. $y=x^2$ funksiyani 0 dan a gacha bo‘lgan qismida funksiya va Ox o‘qi bilan chegaralangan qism yuzasining massalar markazini aniqlang. **Javob:** $x_C=\frac{3}{4}a;\ y_C=\frac{3}{5}a^2$

20.17. $y=\sqrt{x}$ funksiyaning 0 dan a gacha bo‘lgan qismini Ox o‘qi atrofida aylantirishdan hosil bo‘lgan fazoviy aylanish jismining massa markazi qayerda joylashgan? **Javob:** $x_C=\frac{2}{3}a$

20.18. Uch bosqichli raketa ilgarilanma harakat qiladi. Unga Yerning tortish kuchi va atmosfera qarshiligi ta’sir qilmaydi. Har bir bosqich uchun ajralish effektiv tezligi va Siolkovskiy soni bir xil bo‘lib, $\vartheta_e=2500$ *m/s*, $z=4$. Birinchi, ikkinchi va uchinchi bosqich oxirida raketa erishgan tezliklarni aniqlang. **Javob:** $\vartheta_1=3465$ *m/s;* $\vartheta_2=6930$ *m/s;* $\vartheta_3=10935$ *m/s.*

20.19. Raketaning 3ta yoqilg‘i baki bor. Raketaning sof massasi (yoqilg’i yuklanmagandagi massa) m ga, har bir bakda $3m$ ga teng yoqilg‘i bor. Yoqilg‘i

korpusga nisbatan *3 km/s* tezlikda otilib chiqadi. Har bir bak bo‘shaganda raketa qanday tezlikka erishadi? **Javob:** $\vartheta_1=1070$ *m/s*; $\vartheta_2=2749$ *m/s*; $\vartheta_3=6908$ *m/s*.

20.20. Samolyotning reaktiv dvigateliga har sekunnda *4,2 kg* yoqilg‘ini yoqish uchun 100 kg havo kiradi. Yongan maxsulaotlar sopladan samolyotga nisbatan *550 m/s* tezlik bilan chiqarib tashlanadi. Agar shu onda samolyot *270 m/s* tezlikda harakat qilayotgan bo‘lsa, samolyotning natijaviy tortish kuchi nimaga teng? Dvigatelning tezlashtiruvchi quvvatini ot kuchida hisoblang. **Javob:** *30,31 kN; 11134 ot kuchi*.

20.21. Yer sirtidan *6400 km* balandlikdagi va *1850 m/s* tezlikda uzoqlashayotgan raketa soplosidan (raketaga nisbatan) *1200 m/s* tezlikda gaz otilib chiqmoqda. Agar shu onda raketa massasi *25000 kg*, tezlanishi esa *1,7* m/s^2 bo‘lsa, gaz sarfi (*kg/s*) qancha bo‘lishi kerak? g=9,8 m/s^2. **Javob:** *86,5 kg/s*

20.22. *2500 kg* massali raketani harakat boshlanishida *3g* tezlanish bilan tezlatish kerak. Agar gaz sarfi *30 kg/s* bo‘lsa, gazning raketaga nisbatan otilib chiqish tezligi qanday bo‘lishi kerak? g=9,8 m/s^2. **Javob:** *3267 m/s*

21-MAVZU: Noinersial sanoq sistemasi. Inersiya kuchlari. Koriolis tezlanishi va Koriolis kuchi. Koriolis kuchining Yerdagi harakatlanayotgan jsmlarga ta'siri

Mavzuga oid muhim formulalar

$\vec{F}_{in} = -m\vec{a}$	*Inersiya kuchi*
$F_{qoch} = -ma_n$ $F_{qoch} = -\frac{m\vartheta^2}{R} = -m\omega^2 R$	*Markazdan qochuvchi inersiya kuchi*
$\vec{F}_{in} = \vec{F}_n + \vec{F}_\tau, \quad F_{in} = m\sqrt{a_n^2 + a_\tau^2}$ $F_{in} = m\sqrt{\varepsilon^2 + \omega^4} R$	*ISSga nisbatan egri chiziqli notekis harakat qilayotgan jismning umumiy inersiya kuchi*
$a = 2\vartheta\omega$	*Koriolis tezlanishi*
$\vec{F}_K = 2m\left[\vec{\vartheta}\vec{\omega}\right], \quad F_K = 2m\vartheta\omega\sin\alpha$	*Koriolis inersiya kuchi*
$S = \frac{2}{3}\Omega h\sqrt{\frac{2h}{g}}\cos\varphi$	*φ shimoliy kenglikda h balandlikdan boshlang'ich tezliksiz erkin tushayotgan jism uchun sharqqa og'ish masofasi*
$S = \frac{2}{3}\Omega\frac{\vartheta_0^3}{g^2}\cos\varphi$	*ϑ_0 boshlang'ich tezlik bilan tik yuqoriga otilgan jismning eng yuqoriga ko'tarilguncha qanday S masofaga g'arbga og'ish masofasi*
$\vec{a}_{umum} = \vec{a}_\tau + \vec{a}_n + \vec{a}_K$	*NSSga nisbatan egri chiziqli harakat qilayotgan jismning to'la tezlanishi*

21-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Kosmik raketa Yer sirtidan uchish vaqtida *20 m/s²* tezlanish bilan vertikal harakatlanadi, Agar kosmonavt uchuvchining massasi *80 kg* bo'lsa, kabinada uning og'irligi qancha bo'lishini toping. Uchuvchi qanday yuklanishni sezadi?

Berilgan:

$a = 20\ m/s^2$

m=80 kg

P=? n=?

Yechilishi:

Tezlanish yuqoriga yo'nalganda jismning og'irligi *P=m(g+a)* formuladan aniqlanadi. Shunga ko'ra og'irlik

P=80(10+20)=2400 N bo'ladi.

Yuklanishlar soni esa n=P/F_{og}' formuladan aniqlanadi. Shunga ko'ra yuklanishlar soni

n= 2400/800=3 bo'ladi.

Javob: *2,4 kN; 3*

Masala № 2. Arqon yordamida $m_1 = 100\,kg$ massali yukni yuqoriga $a = 2\ m/s^2$ tezlanish bilan ko'tarishga arqon chidaydi. Shu arqon bilan qanday m_2 massali yukni xuddi shunday tezlanish bilan pastga tushirish mumkin? $g = 10\ m/s^2$ deb oling.

Berilgan:

$m_1 = 100\,kg$

$a = 2\ m/s^2$

$P_1 = P_2$

---

m_2=?

Yechilishi:

Tezlanish yuqoriga yo'nalganda jismning og'irligi *P=m(g+a)* formuladan, tezlanish pastga yo'nalganda esa *P=m(g-a)* aniqlanadi. Shunga ko'ra og'irliklarni tenglashtirsak,

$$m_1(g+a) = m_2(g-a), \ \rightarrow \ m_2 = \frac{g+a}{g-a}m_1 = \frac{10+2}{10-2}\cdot 100 = 150\,kg$$

natija chiqadi.

Javob: $m_2 = \dfrac{g+a}{g-a}m_1 = 150\,kg$

Masala № 3. Massasi m bo'lgan jism ℓ uzunlikdagi chilvirga bog'langan. Shu jism vertikal tekislikda doimiy ϑ tezlik bilan aylanayotgan bo'lsa, chilvirning jism eng quyi va eng yuqori nuqtalarda bo'lgandagi taranglik kuchlari nisbati F_1/F_2 qanday bo'ladi?

Berilgan:

$a = 20\ m/s^2$

m=80 kg

P=? n=?

Yechilishi:

Trayektoriyaning eng yuqorigi nuqtasida jismning og'irligi $F_2 = m\left(g - \dfrac{\vartheta^2}{\ell}\right) = \dfrac{m}{\ell}\left(g\ell - \vartheta^2\right)$ formuladan, eng quyi nuqtasida esa

$F_1 = m\left(g + \dfrac{\vartheta^2}{\ell}\right) = \dfrac{m}{\ell}\left(g\ell + \vartheta^2\right)$ formuladan aniqlanadi. Ularning nisbati so'ralgan kattalikni beradi. $F_1 / F_2 = \dfrac{m}{\ell}\left(g\ell - \vartheta^2\right) : \dfrac{m}{\ell}\left(g\ell - \vartheta^2\right) = \left(\vartheta^2 + g\ell\right) / \left(\vartheta^2 - g\ell\right)$

Javob: $\left(\vartheta^2 + g\ell\right) / \left(\vartheta^2 - g\ell\right)$

Masala № 4. Toshkent shahri *41⁰* shimoliy kenglikda joylashgan. *a)* Bu kenglikdagi nuqtalarning markazga intilma tezlanishi nimaga teng? *b)* Bu tezlanishning gorizontal va vertikal tashkil etuvchilarini aniqlang. *c) 100 kg* massali jismning og'irligi necha nyuton bo'ladi va necha nyutonga yengillashadi? *d) 100 m* balandlikdan tashlangan jism yerga tushguncha janub tomonga necha santimetrga siljiydi? Berilgan kenglik uchun erkin tushish tezlanishini $g = 9{,}81\ m/s^2$ deb oling.

Berilgan:

$\varphi = 41^0$

m=100 kg

h=100 m

$a_\varphi = ?,$

$a_{\varphi.x} = ?,\ a_{\varphi.y} = ?$

$\Delta P = ?,\ \Delta x = ?$

Yechilishi:

Yerning barcha nuqtalari o'q atrofida bir xil burchak tezlik bilan aylanma harakat qiladi.

$$\omega = \frac{2\pi}{T} = \frac{2\pi\ rad}{86400\ s} = 7,2722 \cdot 10^{-5}\ \ [rad/s]$$

Aylanma harakat tufayli paydo bo'ladigan ekvatordagi nuqtalarning markazga intilma tezlanishi ushbu quyidagicha bo'ladi:

$$a_{ekvat} = \omega^2 R_{ekvat} = 0,03373\quad [m/s^2]$$

ko'rinishda bo'ladi.

a) Kengliklarda joylashgan nuqtalarning markazga intilma tezlanishlari

$$a_\varphi = \omega^2 r = \omega^2 R\cos\varphi = a_{ekvat}\cos\varphi = 0,03373 \cdot \cos 41^0 =$$

$$= 0,02546\ [m/s^2]$$

ga teng bo'ladi.

b) Bu tezlanishning vertikal tashkil etuvchisi $a_{\varphi.y} = a_\varphi \cdot \cos\varphi = 0,0192\ [m/s^2]$ ga, gorizontal tashkil etuvchisi esa $a_{\varphi.x} = a_\varphi \cdot \sin\varphi = 0,0167\ [m/s^2]$ ga teng bo'ladi.

c) Bu kenglikdagi jismning og'irligi $P = m\left(g - a_{\varphi.y}\right) = 100\left(9,81 - 0,0192\right) = 979\,N$ bo'ladi va bu jism $\Delta P = ma_{\varphi.y} = 100 \cdot 0,0192 = 1,92\,N$ ga yengillashadi.

d) *h=100 m* balandlikdan erkin tashlangan jism $t = \sqrt{\frac{2h}{g - a_{\varphi.y}}}$ formulaga ko'ra $t = \sqrt{\frac{200}{9,81 - 0,0192}} \approx 4,52\,s$ vaqtda yerga tushadi. Bu vaqtda esa bu jism gorizontal yo'nalishda janub tomonga qarab $\Delta x = \frac{a_{\varphi.x}t^2}{2} = \frac{0,0167 \cdot 4,52^2}{2} \approx 0,1706\,m = 17,06\,sm$ masofaga siljiydi.

Javob: $a)\ a_\varphi = 0,02546\ m/s^2;\ \ b)\ a_{\varphi.y} = 0,0192\ m/s^2,\ a_{\varphi.x} = 0,0167\ m/s^2;$
$c)\ P = 979\,N,\ \Delta P = 1,92\,N;\ \ d)\ \Delta x = 17,06\,sm$

21-amaliy mashg'ulot topshirig'i

21.1. m massali sharcha aravachaga o'rnatilgan ustunga osilgan. Aravacha gorizontal yo'nalishda a tezlanish bilan harakatlanadi. Sharcha ipi bilan vertikal orasidagi α burchakni va ipning T taranglik kuchini toping. **Javob:**

$\alpha = arctg\frac{a}{g};\ T = m\sqrt{g^2 + a^2}$

21.2. $m_1 = 240\,kg$ massali yukka dosh bera oladigan tros yordamida $m_2 = 200\,kg$ massali yukni qanday a_1 tezlanish bilan ko'tarish mumkin? $m_3 = 300\,kg$ massali yukni qanday

a_2 tezlanish bilan tushirish mumkin? $g = 10\ m/s^2$ deb oling. Javob:

$a_1 = \frac{m_1 - m_2}{m_2} g = 2\ m/s^2;\ a_2 = \frac{m_3 - m_1}{m_3} g = 2\ m/s^2$

21.3. *50 kg* massali bola uzunligi *5 m* bo‘lgan arg‘imchoqda uchmoqda. Muvozanat vaziyatidan *5 m/s* tezlik bilan o‘tayotganda, u o‘rindiqqa qanday kuch bilan ta’sir qiladi? **Javob:** *750 N*

21.4. Massasi *m* bo‘lgan jism ℓ uzunlikdagi chilvirga bog‘langan. Shu jism vertikal tekislikda doimiy ϑ tezlik bilan aylanayotgan bo‘lsa, chilvirning jism eng quyi va eng yuqori nuqtalarda bo‘lgandagi taranglik kuchlari nisbati F_1/F_2 qanday bo‘ladi? **Javob:** $\left(\vartheta^2 + g\ell\right)/\left(\vartheta^2 - g\ell\right)$

21.5. Velosiped poygasi uchun qilingan yo'lakda radiusi *40 m* bo'lgan burilish bor. Shu joyda yo'lak gorizontga nisbatan *40°* burchak ostida qiya qilingan. Bunday qiyalik qanday tezlikda yurishga mo'ljaliangan? **Javob:** *18,3 m/s*

21.6. Elektropoyezd *s=200 m* yo‘lni o‘tib to‘xtagan, vagonga osilgan shovun esa 5^0 ga og‘gan bo‘lsa, poyezdning tormozlanish boshidagi tezligi qanday bo‘lgan? Tormozlanishni tekis sekilanuvchan deb oling. **Javob:** *18,7 m/s*

21.7. Avtomobil yo‘lning radiusi *R=40 m* bo‘lgan egrilangan qismida $\ell = A + Bt + Ct^2$ qonun bo‘yicha harakatlanmoqda. Bu yerda $A = 5m;\ B = 12\,m/s;\ C = -0,5\ m/s^2$ ga teng. Haydovchining massasi *80 kg* ga teng. Vaqtning *t=4 s* vaqt onidagi haytovchi tomonidan o‘rindiqa ta’sir qiladigan tangensial, normal va to‘la inersiya kuchlarini hisoblang. **Javob:** $F_n = 200\,N;\ F_t = 80\,N;\ F_{um} = 215,4\,N$

21.8. Radiusi $R = 10\ sm$ bo‘lgan diskning burilish burchagi $\varphi = 4 + 3t + t^2\ [rad]$ qonun bo‘yicha o‘zgaradi. Diskning chetiga *10 g* massali kichkina tanga yopishtirib qo‘yilgan? *t=3s* vaqt onida tanganing diskka ta’sir qiladigan tangensial va normal inersiya kuchlarini aniqlang. Bunda umumiy inersiya kuchi disk radiusi bilan qanday burchak tashkil etadi? **Javob:** $F_n = 81mN;\ F_t = 2mN;\ \mu \approx 1,4^0$

21.9. Avtomobil yo‘lning *R=100 m* radiusli egrilangan qismida *20 m/s* tezlik bilan harakatlanayotgan edi. Haydovchi to‘satdan tormozni bosdi va avtomobil *2 m/s²* sekinlanish bilan sekinlasha boshladi. Tormoz boshlanish onida va tormoz bosilgandan *3 sek* dan keyin haydovchi harakat yo‘nalishiga nisbatan necha gradus egrilik tashqarisi tomonga og‘ishini aniqlang. **Javob:**

21.10. Ekvatorda yotgan *10 kg* massali jismning og‘irligi qutbdagidan qanchaga kamroq? **Javob:** *338 mN*

21.11. Koriolis kuchi markazdan qochuvchi kuchni muvozonatlashi uchun ekvatordagi jism qanday tezlikda va qaysi yo‘nalishda harakatlanishi kerak? **Javob:** $\vartheta = \frac{\omega R}{2} = 232\,m/s$ tezlik bilan g‘arb tomonga harakatlanishi kerak.

21.12. Massasi *m* bo‘lgan sharqdan g‘arbga tomon ϑ tezlik bilan harakatlanayotgan jism harakatining yo‘nalishi qarama-qarshi tomonga o‘zgarganda Yer sirtiga

bo‘lgan bosim kuchi qanchaga o‘zgarishini aniqlang. Yerning sutkalik burchak tezligi ω_0 ga teng. **Javob:** $\Delta F = 2F_K = 4m\vartheta\omega_0$ *ga kamayadi*.

21.13. 100 t massali poyezd 45^0 shimoliy kenglikda shimol tomonga *72 km/soat* tezlikda harakatlanmoqda. Koriolis inersiya kuchi nimaga teng. Bunda qaysi rels ko‘proq yeyiladi? **Javob:** *205 N; o‘ng rels ko‘proq yeyiladi*

21.14. Daryodagi suvning hajmiy sarfi (daryo ko‘ndalang yuzasidan birlik vaqtda oqib o‘tadigan suv hajmi) Q ga $\left(Q = \frac{\Delta V}{\Delta t}\right)$, suvning zichligi ρ ga teng. Daryoning ℓ uzunlikdagi qismidagi suvga ta’sir qiluvchi Koriolis kuchini aniqlang. Daryo φ ga teng shimoliy kenglikda joylashgan bo‘lib, aniq meridian bo‘ylab oqmoqda. **Javob:** $F_K = 2\omega Q\rho\ell\sin\varphi$

21.15. $^{**}\varphi = 60^0$ shimoliy kenglikda jism Yerga *h=200 m* balandlikdan erkin tushmoqda. Yerning aylanishi natijasida vujudga keladigan Koriolis kuchi ta’sirida jism qanchaga va qaysi tomonga og‘ishini aniqlang. Yerning sutkalik burchak tezligi ω_0 ga teng. **Javob:** $\Delta s = \frac{2}{3}\omega_0 h\sqrt{\frac{2h}{g}}\cos\varphi = 3{,}1sm$ *sharq tomonga og‘adi*.

21.16. **Geografik kengligi $\varphi = 41^0$ bo‘lgan Toshkent shahridagi nuqtadan tik yuqoriga qarab miltiqdan o‘q uzildi. Biroz vaqtdan keyin o‘q Yerga qaytib tushdi. Agar o‘qning boshlang‘ich tezligi $\vartheta_0 = 200\,m/s$ bo‘lsa, o‘q otilish nuqtasidan qancha masofaga va qaysi tomonga siljib tushadi? Yerning sutkalik burchak tezligi ω_0 ga teng. Havoning qarshiligini e’tiborga olmang. **Javob:** $\Delta s = \frac{1}{3}\omega_0\frac{\vartheta_0^3}{g^2}\cos\varphi = 1{,}524\,m$ *g‘arb tomonga og‘adi*.

21.17. **Termiz shahri $\varphi = 37^0$ shimoliy kenglikda joylashgan. Bu joyda yer sirtidan *h=200 m* balandlikdagi nuqtadan Yer markazi tomonga ϑ_0*=30 m/s* tezlik bilan tosh otildi. Bu tosh yerga tushguncha qancha masofaga sharq tomonga siljiydi? **Javob:** *4sm*

22-MAVZU: Inersiya momenti. Shteyner teoremasi. Turli jismlarning inersiya momentlarini hisoblash. Impuls momenti.

Mavzuga oid muhim formulalar

$I = mr^2$	*Nuqtavij jismning inersiya momenti*
$I = m_1 r_1^2 + m_2 r_2^2 + ... + m_n r_n^2 = \sum_{i=1}^{n} m_i r_i^2$	*Chekli elementlardan iborat nuqtaviy jismlar sistemasining inersiya momenti*
$I = \sum_{i=1}^{\infty} m_i r_i^2 = \int r^2 dm$	*Ckeksiz ko'p elementlardan iborat sistema (tutash jism) ning inersiya momenti*
$I = I_0 + Md^2$	*Parallel o'qlar haqidagi teorema – Shteyner teoremasi*
$I_x + I_y + I_z = 2I_0, \quad I_{xy} + I_{yz} + I_{xz} = I_0,$ $I_{xy} + I_{yz} + I_{xz} = \frac{I_x + I_y + I_z}{2}$	*Perpendikulyar o'qlar haqidagi teorema*
$I = \frac{1}{12} M\ell^2, \quad I = \frac{1}{3} M\ell^2$	*Sterjenning o'rtasidan hamda bir uchidan o'tgan perpendikulyar o'qqa nisbatan inersiya momenti*
$I = \frac{1}{2} MR^2$	*Disk yoki slindrning o'qiga nisbatan inersiya momenti*
$I = \frac{1}{2} MR^2$	*Ingichka xalqa yoki yupqa devorli slindrik trubaning o'qiga nisbatan inersiya momenti*
$I_0 = \frac{3}{5} MR^2, \quad I_z = \frac{2}{5} MR^2$	*Sharning markaziga nisbatan hamda diametridan o'tgan o'qqa nisbatan inersiya momenti*
$I_0 = MR^2, \quad I_z = \frac{2}{3} MR^2$	*Sharning markaziga nisbatan hamda diametridan o'tgan o'qqa nisbatan inersiya momenti*
$\vec{L} = \vec{r} \times \vec{p} = m\vec{r} \times \vec{\vartheta}$ $L = mr\vartheta \sin\varphi$	*Nuqtaviy jism impuls momentining yo'nalishi va miqdori*
$\vec{L}_{nat} = \vec{L}_1 + \vec{L}_2 + \vec{L}_3 + ... + \vec{L}_n = \sum_{i=1}^{n} \vec{L}_i$ $\vec{L} = mr^2\vec{\omega} = I\vec{\omega}$	*Nuqtalar sistemasining inersiya monenti*
$\vec{L} = \vec{r} \times \vec{p} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ x & y & z \\ p_x & p_y & p_z \end{vmatrix} = m \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ x & y & z \\ \vartheta_x & \vartheta_y & \vartheta_z \end{vmatrix}$ $L_x = y \cdot p_z - z \cdot p_y, \; L_y = z \cdot p_x - x \cdot p_z, \; L_z = x \cdot p_y - y \cdot p_x$ $\vec{L} = L_x \cdot \vec{i} + L_y \cdot \vec{j} + L_z \cdot \vec{k}$	*Impuls momentini koordinatalar orqali berilishi*

22-amaliy mashg‘ulot uchun dars ishlanmasi

Masala №1. Fizik tebrangich uzunligi $\ell = 120\,sm$ va massasi $m_1=2\ kg$ bo‘lgan uchlaridan biriga massasi $m_2=1\ kg$ va radiusi $R=30\ sm$ bo‘lgan disk mahkamlangan sterjendan iborat. Shu tebrangichni O nuqtadan o‘tuvchi gorizontal o‘qqa nisbatan inersiya momenti aniqlansin. O nuqta sterjenning yuqorigi uchidan $40\ sm$ masofada joylashgan.

Berilgan:

$\ell = 120\,sm$

$m_1 = 2\,kg$

$m_2 = 1kg$

$R = 30\,sm$

$I = ?$

Yechilishi:

Avval sterjanning O nuqtaga nisbatan inersiya momentini hisoblaymiz.

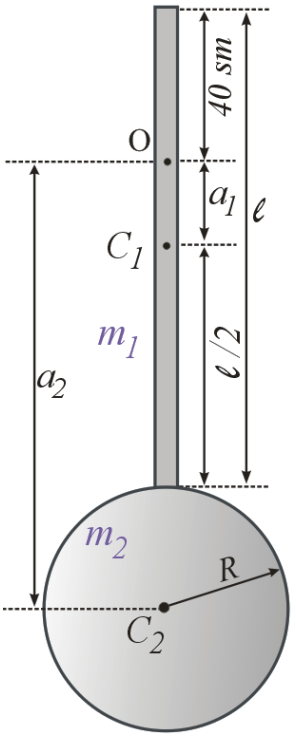
$$I_1 = \frac{1}{12}m_1\ell^2 + m_1a_1^2 = \frac{1}{12}\cdot 2\cdot 1,2^2 + 2\cdot 0,2^2 = 0,24 + 0,08 = 0,32\,kg\cdot m^2$$

Endi diskning O nuqtaga nisbatan inersiya momentini hisoblaymiz.

$$I_2 = \frac{1}{2}m_2R^2 + m_2a_2^2 = \frac{1}{2}\cdot 1\cdot 0,3^2 + 1\cdot 1,1^2 = 0,045 + 1,21 = 1,255\ kg\cdot m^2$$

Endi esa fizik tebrangichning O nuqtaga nisbatan inersiya momentini hisoblaymiz.

$$I = I_1 + I_2 = 0,32 + 1,255 = 1,575\ kg\cdot m^2$$



Javob: $I = 1,575\ kg\cdot m^2$

Masala № 2. Massasi $M=9\ kg$ va radiusi $R=30\ sm$ bo‘lgan bir jinsli diskning radiusi o‘rtasidan $r=10\ sm$ radiusli doira kesib olib tashlangan. Hosil bo‘lgan jismni teshikning P nuqtasidan osildi. Shu jismni P nuqtadan o‘tvchi o‘qqa nisbatan inersiya momenti aniqlansin.

Berilgan:

$M=9\ kg$

$R=30\ sm$

$r=10\ sm$

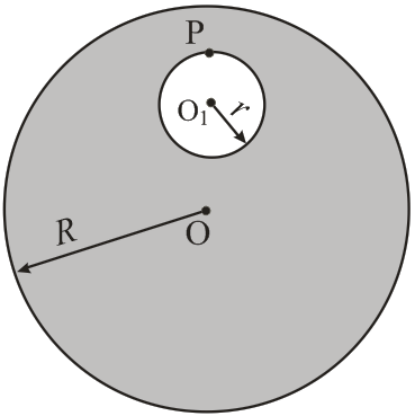
$M_1 = ?$

$M_2 = ?$

Yechilishi:

Dastlab butun jismni P nuqtaga nisbatan inersiya momentini hisoblaymiz.

$$I_1 = \frac{1}{2}MR^2 + M\left(\frac{R}{2}+r\right)^2 = \frac{1}{2}\cdot 9\cdot 0,09 + 9\cdot(0,15+0,1)^2 = 0,405 + 0,5625 = 0,9675\,kg\cdot m^2$$



Endi kesib olingan qismning P nuqtaga nisbatan inersiya momentini hisoblaymiz.

$$I_2 = \frac{1}{2}mr^2 + mr^2 = \frac{3}{2}mr^2 = \frac{3}{2}\cdot 1\cdot 10^{-2} = 0,015\,kg\cdot m^2$$

Endi natijaviy inersiya momentni hisoblaymiz.

$$I = I_1 - I_2 = 0,6975 - 0,015 = 0,6825\ kg \cdot m^2$$

Javob: *0,6825 kg·m²*

Masala № 3. Rasmda radiusi *r* bo‘lgan *m* massali bir jinsli yarim shar tasvirlangan. Bu slindrning *O* nuqta va *T* nuqtadan o‘tgan gorizontal o‘qga nisbatan inersiya momentini aniqlang. Bu slindrni ozgina turtib yuborilsa *P* nuqtadan o‘tgan o‘q atrofida tebrana boshlaydi. Bu o‘qga nisbatan inersiya momenti nimaga teng? J: $I_O = \frac{1}{2}mr^2;\ I_T = \left(\frac{1}{2} + \frac{16}{9\pi^2}\right)mr^2;\ I_P = \left(\frac{3}{2} - \frac{8}{3\pi}\right)mr^2$.

Berilgan:

m

r

$I_O = ?$

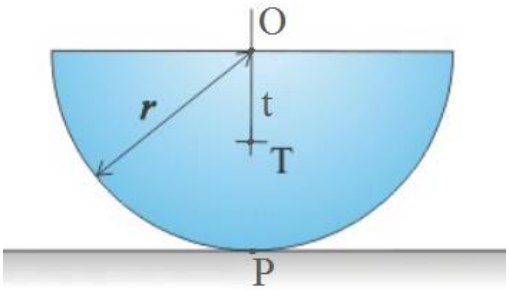
$I_T = ?$

$I_P = ?$

Yechilishi:

Dastlab O nuqtadan o‘tgan o‘qqa nisbatan inersiya momentni aniqlaymiz.

$$2I_O = \frac{2}{5}\cdot(2m)R^2,\ \rightarrow\ I_O = \frac{2}{5}mR^2$$



Yarimsharning massa markazi *O* nuqtadan $t = OT = \frac{3}{8}R$ masofada joylashgan. T nuqtaga nisbatan yarimsharning inersiya mometni Shteyner teoremasiga ko‘ra aniqlanadi.

$$I_T = I_O - mt^2 = \frac{2}{5}mR^2 - m\cdot\left(\frac{3}{8}R\right)^2 = \frac{2}{5}mR^2 - \frac{9}{64}mR^2 = \frac{19}{320}mR^2$$

Endi T nuqtaga nisbatan inersiya momentni topamiz.

$$I_P = I_T + m(R-t)^2 = \frac{19}{320}mR^2 + m\cdot\left(\frac{5}{8}R\right)^2 = \frac{19}{320}mR^2 + \frac{25}{64}mR^2 = \frac{144}{320}mR^2 = 0,45mR^2$$

Javob: $I_O = \frac{2}{5}mR^2;\ I_T = \frac{19}{320}mR^2;\ I_P = 0,45mR^2$

22-amaliy mashg‘ulot topshirig‘i

22.1. *M* massali radiusi *R* bo‘lgan bir jinsli diskning markazidan o‘tuvchi o‘qiga nisbatan inersiya momentini hamda inersiya radiusini hisoblang. Shi diskning diametridan o‘tgan o‘qqa nisbatan inersiya momenti va inersiya radiusi nimaga teng?

J: $I = \frac{1}{2}MR^2;\ \rho = \frac{R}{\sqrt{2}} = 0,707R;\ \ I = \frac{1}{2}MR^2;\ \rho = 0,5R$

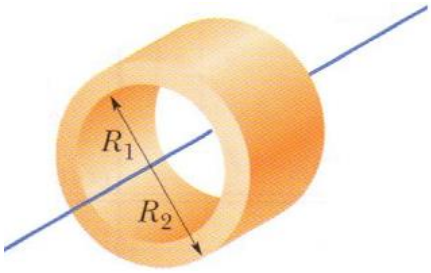
22.2. Uzunligi $\ell = 60\,sm$ va massasi *m=100 g* bo‘lgan ingichka bir jinsli tayochaning unga tik va tayoqcha uchlaridan biridan *a=20 sm* masofadagi nuqtasidan o‘tuvchi o‘qqa nisbatan inersiya momenti *I* aniqlansin. J: $4\cdot10^{-3}\ kg\cdot m^2$

22.3. Masssi $m=50\ g$ va radiusi $r=10\ sm$ bo‘lgan xalqaning [alqaga urinma bo‘lgan o‘qqa nisbatan inersiya momentin I ni aniqlang. J: $I=\frac{3}{2}mr^2=7{,}5\cdot10^{-4}\,kg\cdot m^2$

22.4. Diskning diametri $d=20\ sm$, massasi $m=800\ g$. Disk radiusining o‘rtasidan disk tekisligiga tik holda o‘tuvchi o‘qqa nisbatan inersiya momentin I ni aniqlang. J: $I=\frac{3}{16}md^2=6\cdot10^{-3}\,kg\cdot m^2$

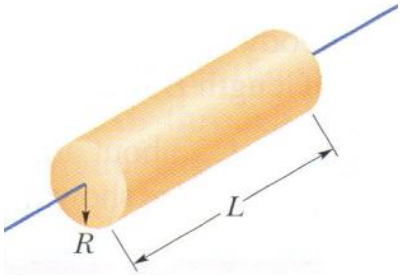
22.5. Ichki radiusi R_1 va tashqi radiusi R_2 bo‘lgan bir jinsli M massali xalqaning o‘qiga nisbatan inersiya momenti nimaga teng? $R_1=0{,}5R$, $R_2=R$ bo‘lganda inersiya radiusi nimaga teng bo‘ladi?

J: $I=\frac{1}{2}M\left(R_1^2+R_2^2\right);\ \rho=\sqrt{\frac{5}{8}}R=0{,}79R$

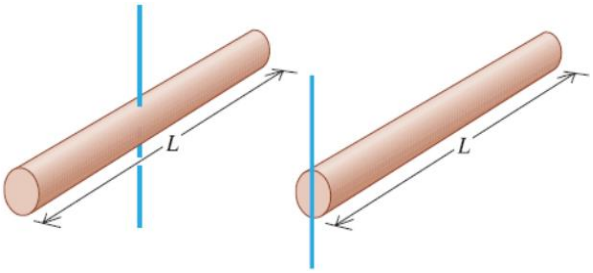


22.6. Uzunligi L ga teng bo‘lgan M massali yo‘g‘on slindrik sterjenning o‘qiga nisbatan inersiya momentini hisoblash formulasini keltirib chiqaring. Inersiya radiusi nimaga teng?

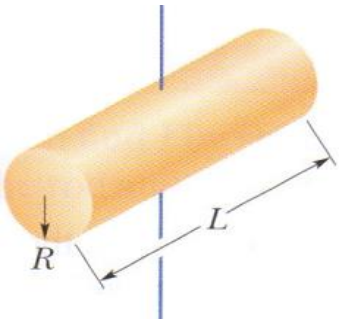
J: $I=\frac{1}{2}MR^2;\ \rho=\frac{R}{\sqrt{2}}=0{,}707R$



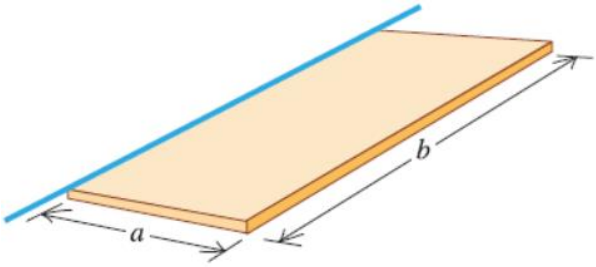
22.7. Ingichka va uzun L uzunlikdagi M massali slindrik sterjenning markazidan hamda bir chetidan sterjenga perpendikulyar holda o‘tgan o‘qqa nisbatan inersiya momentlarini hisoblash formulalarini keltirib chiqaring. J: $\frac{1}{12}ML^2;\ \frac{1}{3}ML^2$



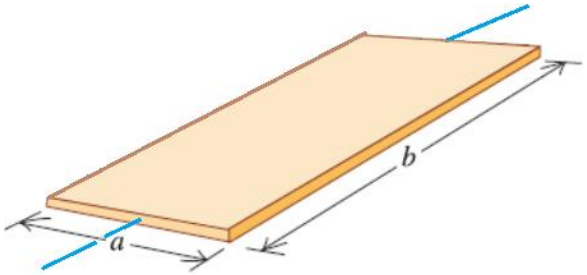
22.8. *Uzunligi L ga teng bo‘lgan M massali yo‘g‘on slindr o‘rtasidan slindr o‘qiga tik holda o‘tgan o‘qga nisbatan inersiya momentini hisoblash formulasini aniqlang. J: $I=\frac{1}{4}MR^2+\frac{1}{12}ML^2$



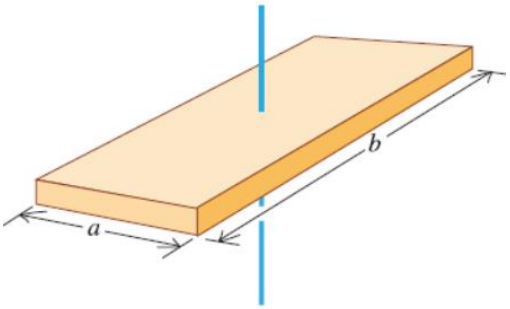
22.9. Rasmda tomonlari a va b bo‘lgan bir jinsli to‘g‘ti to‘rtburchak shaklidagi plastina tasvirlangan. Bu plastinanaing b tomonidan o‘tuvchi o‘qqa nisbatan inersiya momentini aniqlang. J: $I=\frac{1}{3}Ma^2$



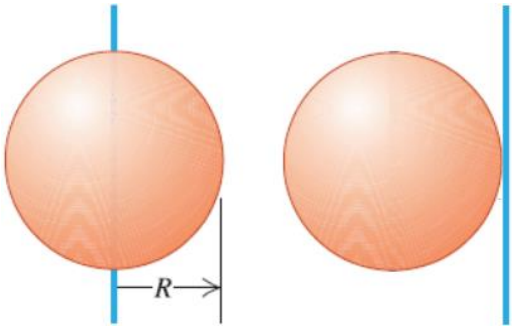
22.10. Rasmda tomonlari *a* va *b* bo‘lgan bir jinsli to‘g‘ti to‘rtburchak shaklidagi plastina tasvirlangan. Bu plastinanaing *a* qirrasi o‘rtasidan *b* tomonga parallel holda o‘tuvchi o‘qqa nisbatan inersiya momentini aniqlang. J: $I = \frac{1}{12}Ma^2$



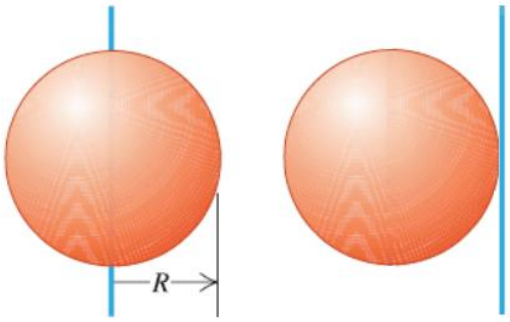
22.11. *Rasmda tomonlari *a* va *b* bo‘lgan bir jinsli to‘g‘ti to‘rtburchak shaklidagi plastina tasvirlangan. Bu plastinanaing markazidan plastina tekisligiga tik holda o‘tuvchi o‘qqa nisbatan inersiya momentini aniqlang. J: $I = \frac{1}{12}M\left(a^2 + b^2\right)$



22.12. Rasmda bir jinsli yupqa devorli massasi *M* ga teng bo‘lgan sfera berilgan. Bu sferaning markazi O nuqtaga nisbatan hamda diametridan o‘tuvchi o‘qqa nisbatan inersiya momentlarini aniqlang. Sferaga urinuvchi o‘qqa nisbatan inersiya momenti qanday? J: $MR^2; \frac{2}{3}MR^2; \frac{5}{3}MR^2$

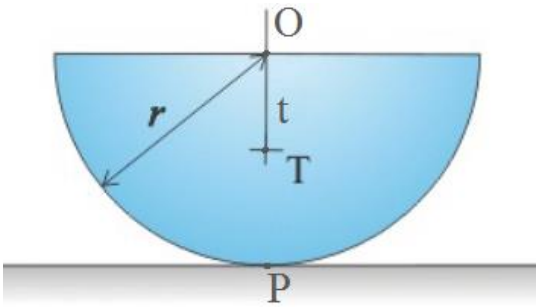


22.13. Rasmda bir jinsli massasi *M* ga teng bo‘lgan shar berilgan. Bu sharning markazi *O* nuqtaga nisbatan hamda diametridan o‘tuvchi o‘qqa nisbatan inersiya momentlarini aniqlang. Shar-ga urinuvchi o‘qqa nisbatan inersiya momenti qanday? J: $\frac{3}{5}MR^2; \frac{2}{5}MR^2; \frac{7}{5}MR^2$



22.14. **Rasmda radiusi *r* bo‘lgan *m* massali bir jinsli yarim slindr tasvirlangan. Bu slindrning *O* nuqta va *T* nuqtadan o‘tgan gorizontal o‘qga nisbatan inersiya momentini aniqlang. Bu slindrni ozgina turtib yuborilsa *P* nuqtadan o‘tgan o‘q atrofida tebrana boshlaydi. Bu o‘qga nisbatan inersiya momenti nimaga teng? J:

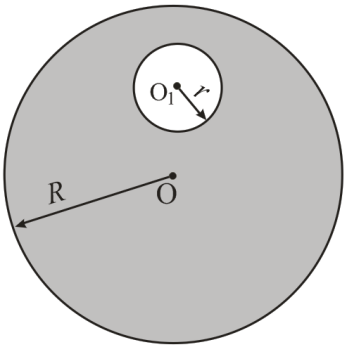
$I_O = \frac{1}{2}mr^2; I_T = \left(\frac{1}{2} + \frac{16}{9\pi^2}\right)mr^2; I_P = \left(\frac{3}{2} - \frac{8}{3\pi}\right)mr^2$



22.15. **Yuqoridagi masala shartini yarimshar uchun yeching. J:

22.16. **22.11-masala shartini qozon shaklidagi yupqa devorli yarimsfera uchun yeching. J:

22.17. Massasi *M=9 kg* va radiusi *R=30 sm* bo‘lgan bir jinsli diskning radiusi o‘rtasidan *r=10 sm* radiusli doira kesib olib tashlangan. Hosil bo‘lgan jismninng disk markazi *O* nuqtadan o‘tvchi o‘qqa nisbatan inersiya momenti aniqlansin. Inersiya radiusi nimaga teng? J: $I_O \approx 0,4 kg \cdot m^2;\ \rho = 10 sm$



22.18. Yer sharining aylanish o‘qiga nisbatan inersiya momentini hamda impuls momentini aniqlang. Yer radiusi *R=6370 km*, massasi $M=5,97\cdot10^{24}$ *kg*. J: $I = 9,69 \cdot 10^{37}\ kg \cdot m^2;\ L = 7,04 \cdot 10^{33}\ kg \cdot m^2 / s$

22.19. Yer sharining Quyosh atrofida aylanishidagi inersiya momentini hamda impuls momentini aniqlang. Yerdan Quyoshgacha masofa $r=1,5\cdot10^{11}$ *m*, Yer massasi $M=5,97\cdot10^{24}$ *kg*. Bunda Yerni nuqtaviy jism deb oling. J: $I = 1,343 \cdot 10^{47}\ kg \cdot m^2;\ L = 2,674 \cdot 10^{40}\ kg \cdot m^2 / s$

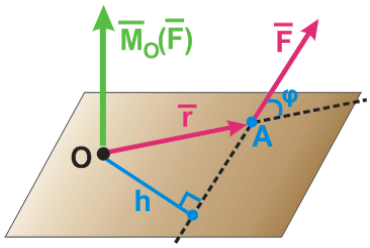
22.20. Yerning Quyosh atrofida aylanishidagi inersiya momenti o‘z o‘qi atrofida aylanishidagi inersiya momentidan necha marta katta? Bunda impuls momentlar necha marta farq qiladi? J: $1,375\cdot10^9$ *marta;* $3,755\cdot10^6$ *marta*

22.21. Oyning Yer atrofida aylanishidagi inersiya momenti va impuls momenti nimaga teng? Oyning sinodik davri *27 sutka 6 soat*ga teng. Yerdan Oygacha masofa *384000 km*. Oyning massasi $7,37\cdot10^{22}$ *kg*. Yer atrofida aylanishida Oyni nuqtaviy deb oling. J: $I = 1,087 \cdot 10^{40}\ kg \cdot m^2;\ L = 2,9 \cdot 10^{34}\ kg \cdot m^2 / s$

22.22. Mars sayyorasining o‘z o‘qi atrofidag aytlanishidagi inersiya momenrini hamda impuls momentini aniqlang. Mars sayyorasining radiusi *R=3400 km*, massasi $M=6,42\cdot10^{23}$ *kg*. Bu sayyora o‘z o‘qi atrofida *24 soat 37 min* da bir marta aylanadi. J: $I = 2,97 \cdot 10^{36}\ kg \cdot m^2;\ L = 2,105 \cdot 10^{32}\ kg \cdot m^2 / s$

23-MAVZU: Burobchi moment. Aylanma harakat dinamikasining asosiy tenglamasi. Aylanma harakat kinetik energiyasi. Dumalayotgan jismning to‘la energiyasi. Impuls momentining saqlanish qonuni.

Mavzuga oid muhim formulalar

$M_O(\vec{F}_i) = \pm F \cdot h$	*Kuchning moment markaziga nisbatan momenti*
Kuchning momentining vektorligi $\begin{cases} \vec{M}_O(\vec{F}) = \vec{r} \times \vec{F} \\ \lvert \vec{M}_O(\vec{F}) \rvert = \lvert \vec{r} \rvert \cdot \lvert \vec{F} \rvert \cdot \sin\varphi \end{cases}$ $\vec{M}_O(\vec{F}) = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ x & y & z \\ F_x & F_y & F_z \end{vmatrix}$ 	
$A = \int_0^{\varphi} M(\varphi)\, d\varphi$	*Kuch mometining bajargan ishi*
$N = M \cdot \omega$	*Kuch mometining quvvati*
$E_{k.ayl} = \dfrac{I\omega^2}{2}$	*Aylanma harakat kinetik energiyasi*
$E_k = E_{k.ilg} + E_{k.ayl} = \dfrac{m\vartheta^2}{2} + \dfrac{I\omega^2}{2}$	*Umumiy kinetik energiya*
$E_k = \dfrac{1}{2}mR^2\omega^2 + \dfrac{1}{2}I\omega^2$	*Dumalayotgan jismning gardishidagi chiziqli tezligi $\vartheta = \omega R$ ekanini e’tiborga olingan holda, uning kinetik energiyasi*
$\vec{M} = \vec{r} \times \dfrac{d\vec{p}}{dt} = \dfrac{1}{dt}(\vec{r} \times d\vec{p}) = \dfrac{d\vec{L}}{dt}$ $\vec{M} = \dfrac{d(I\vec{\omega})}{dt} = I\dfrac{d\vec{\omega}}{dt} = I\vec{\varepsilon}$	*Aylanma harakat dinamikasining asosiy tenglamasi*
$\vec{L}_1 = \vec{L}_2 \quad yoki \quad I_1\vec{\omega}_1 = I_2\vec{\omega}_2$	*Impuls momentining saqlanish qonuni*
$L = m \cdot \vec{r} \times \vec{\vartheta} = mr\vartheta\sin\varphi = const$ $r_1\vartheta_1\sin\varphi_1 = r_2\vartheta_2\sin\varphi_2$	*Markaziy kuch maydonida harakatlanayotgan jism uchun impuls momentining saqlanish qonuni*

23-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Jism *O* nuqtadan o‘tuvchi o‘qqa mahkamlangan. Jismga uning *A*, *B*, *C* nuqtalariga uchta kuch ta’siq etadi. $F_A = 12\,N,\ F_B = 14\,N,\ F_C = 23\,N$. Kuchlarning qo‘yilish nuqtalaridan moment markazi O nuqtagacha masofalar $OA = 80\,sm,\ OB = 40\,sm, OC = 30\,sm$ ga teng. Bunda kuchlarning ta’sir etish

burchaklari ham rasmdagi kabi mos holda $\alpha = 135^0$, $\beta = 160^0$, $\gamma = 90^0$ ga teng. Jismga ta'sir etuvchi natijaviy kuch momenyi nimaga teng?

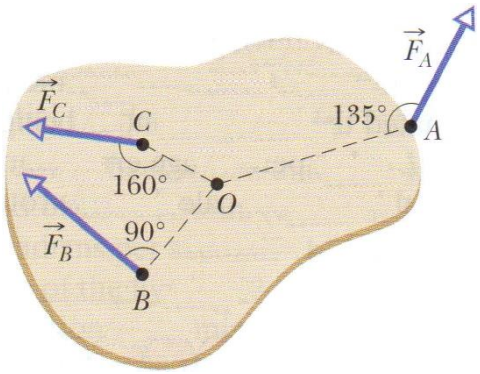
Berilgan:

$F_A = 12\,N$, $F_B = 14\,N$,
$F_C = 23\,N$, $OA = 80\,sm$,
$OB = 40\,sm$, $OC = 30\,sm$

$M_{nat} = ?$

Yechilishi:

Kuchlarning momentlari $M = Fr\sin\varphi$ formulaga ko'ra aiqlanadi.



$$M_A = F_A \cdot OA \cdot \sin 135^0 =$$

$$= 12 \cdot 0{,}8 \cdot \frac{\sqrt{2}}{2} = 6{,}788\ Nm$$

$$M_B = -F_B \cdot OB \cdot \sin 90^0 = -14 \cdot 0{,}4 \cdot 1 = -5{,}6\ Nm$$

$$M_C = F_C \cdot OC \cdot \sin 160^0 = 23 \cdot 0{,}3 \cdot 0{,}588 = 4{,}056\ Nm$$

Endi natijaviy kuch momentini aniqlaymiz.

$$M_{nat} = M_A + M_B + M_C = 6{,}788 - 5{,}6 + 4{,}056 = 5{,}244\ Nm.$$

Javob: $M_{nat} = 5{,}244\ Nm$

Masala № 2. Vertikal o'qqa o'rnatilgan sharga ip o'ralgan va ipning boshqa uchiga *m* massali jism *r* radiusli shkiv orqali osib qo'yilgan. Sharning radiusi *R* ga teng. Jism og'irligidan yuzaga kelgan shar va shkiv o'qlaridagi kuch momentlari topilsin.

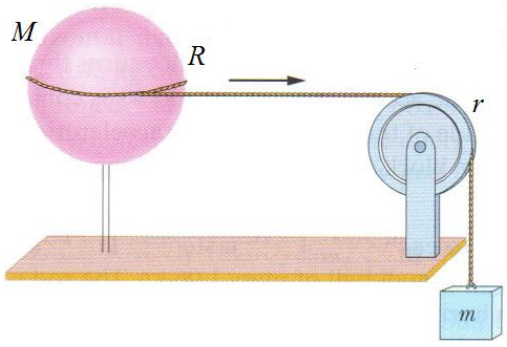
Berilgan:

m
R
r

$M_1 = ?$
$M_2 = ?$

Yechilishi:

Jismning og'irligi *P=mg* ga teng. Bu kuch ip bo'ylab yo'nalgan shunga teng miqdordagi *T=P=mg* taranglik kuchini hosil qiladi. Bu taranglik kuchi esa shar o'qiga nisbatan $M_1 = TR = mgR$ ga teng, shkiv o'qiga nisbatan $M_2 = Tr = mgr$ ga teng moment beradi.



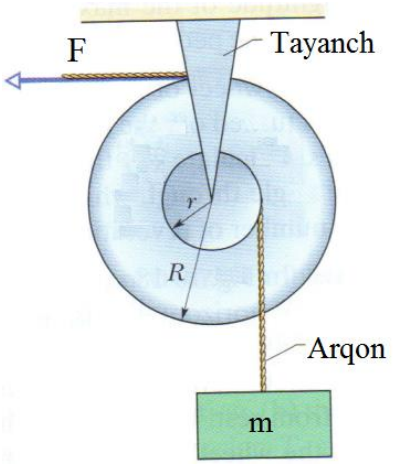
Javob: $M_1 = mgR$, $M_2 = mgr$

Masala № 3. Tayanchda bitta o'qda radiuslari *R=25 sm* va *r=10 sm* bo'lgan shkivlar mahkamlangan. Kichik shkivga o'ralgan arqonning bir uchiga *m=8 kg* massali yuk osilgan. Katta shkivga o'ralgan arqonning uchiga qo'yilgan *F* kuch ta'sirida yuk tekis ko'tarilmoqda. Bunda yukdan va *F* kuchdan shkivlar o'qida yuzaga keladigan kuch momentlari nimaga teng? *F* kuchning qiymati nimaga teng? $g = 10\ m/s^2$.

Berilgan:
m=8 kg
R=25 sm
r=10 sm

$M_1 = ?$
$M_2 = ?$
$F = ?$

Yechilishi:



Osilgan yukning og'irligi *P=mg* ga teng. Bu kuch ip bo'ylab yo'nalgan shunga teng miqdordagi *T=P=mg* taranglik kuchini hosil qiladi. Bu taranglik kuchi esa shkiv o'qiga nisbatan $M_1 = -Tr = -mgr = -8\ Nm$ ga teng manfiy kuch momentini hosil qiladi. Shkivlar tekis aylanayotgani uchun F kuch yukning momentiga teng miqdordagi, lekin qarama-qarshi yo'nalgan $M_2 = -M_1 = 8\ Nm$ ga teng musbat momentni hosil qiladi. Endi *F* kuchni aniqlaymiz. $M_2 = FR, \ \rightarrow \ F = \frac{M_2}{R} = \frac{8\ Nm}{0,25m} = 32\,N$.

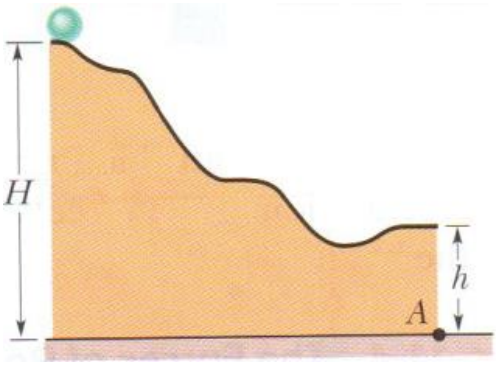
Javob: $M_1 = -8\ Nm, M_2 = 8\ Nm, F = 32\,N$

Masala № 4. Qattiq shar *H=6 m* balandlikdan tinch holatdan boshlab rasmdagi kabi sirpanishsiz dumalaydi? Shar trayektoriyaning *h=2 m* balandlikdagi gorizontal qismiga kelganda sirtdan uziladi. Shar *A* nuqtadan qancha masofaga borib tushadi. $g = 9,81\ m/s^2$

Berilgan:
H=6 m
h=2 m
$g = 9,81\ m/s^2$

$\ell = ?$

Yechilishi:



Yuqorida mavzufda dumalayotgan jism kinetik energiyasi aylanma va ilgarilanma harakatlar kinetik energiyalari yig'indisidan iborat ekanligini aytib o'tilgan edi. Shunga ko'ra

$$E_k = E_{k.ilg} + E_{k.ayl} = \frac{M\vartheta^2}{2} + \frac{I\omega^2}{2} = \frac{1}{2}MR^2\omega^2 + \frac{1}{5}MR^2\omega^2 = \frac{7}{10}MR^2\omega^2 = \frac{7}{10}M\vartheta^2$$

natija hosil bo'ladi. h balandlikdan yuqoridagi mg(H-h) potensila energiya kinetik energiyaga tenglashtirilishidan uzilish tezligi aniqlanadi.

$$E_p = E_k, \ \rightarrow \ Mg(H-h) = \frac{7}{10}M\vartheta^2, \ \rightarrow \ \vartheta = \sqrt{\frac{10}{7}g(H-h)} = \sqrt{\frac{10}{7}\cdot 9,81\cdot 4} = 7,49\ m/s.$$

Endi uchish masofasini aniqlaymiz.

$$\ell = \sqrt{\frac{2h}{g}}\vartheta = \sqrt{\frac{2\cdot 2}{9,81}}\cdot 7,49 = 4,78m.$$

Javob: 4,78 m

Masala № 5. Ishqalanishsiz aylanadigan *R=5 sm* radiusli shkivga massalari $m_1 = 460\,g$ va $m_2 = 500\,g$ yuklar osilgan. Bloklar qo'yib yuborilganda 2-blok arqonldagi sirg'anishsiz *5 s* vaqtda *75 sm* pastga tushadi. Quyidagilrni anilang: a) bloklarning tezlanishini hamda shkivning burchak tezlanishini; b) ipning uchlaridagi T_1 va T_2 taranglik kuchlarini; c) shkivning inersiya momentini. $g = 9{,}81\ m/s^2$.

Berilgan:

$m_1 = 460\,g$

$m_2 = 500\,g$

R=5 sm

t=5 s

h=75 sm

$g = 9{,}81\ m/s^2$

$a) a = ?; \varepsilon = ?$

$b) T_1 = ?, T_2 = ?$

$c) I = ?$

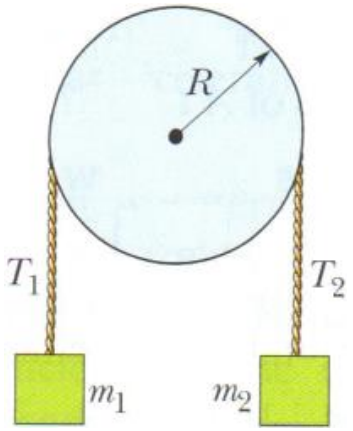
Yechilishi:

a) Tezlanishni aniqlaymiz.

$$a = \frac{2h}{t^2} = \frac{2 \cdot 0{,}75}{5^2} = \frac{1{,}5}{25} = 0{,}06\ m/s^2$$

Burchak tezlanishni aniqlaymiz.

$$a = \varepsilon R, \rightarrow \varepsilon = \frac{a}{R} = \frac{0{,}06}{0{,}05} = 1{,}2\ rad/s^2$$



b) ipning uchlaridagi taranglik kuchlarini aniqlaymiz.

$$T_1 = m_1(g + a) = 0{,}46(9{,}81 + 0{,}06) = 4{,}54\,N$$

$$T_2 = m_2(g - a) = 0{,}5(9{,}81 - 0{,}06) = 4{,}875\,N$$

c) shkivning inersiya momentini aniqlaymiz.

$$T_2 - T_1 = I\varepsilon, \rightarrow I = \frac{T_2 - T}{\varepsilon} = \frac{4{,}875 - 4{,}54}{1{,}2} = \frac{0{,}335}{1{,}2} = 0{,}279\ kg \cdot m^2$$

Javob: $a) a = 0{,}06\ m/s^2, \varepsilon = 1{,}2\ rad/s^2; b) T_1 = 4{,}54\,N,\ T_2 = 4{,}875\,N; c) I = 0{,}279\ kg \cdot m^2$

Masala № 6. Uzunligi $\ell = 1{,}5m$ va massasi *M=10 kg* bo'lgan tayoqcha yuqori uchidan o'tuvchi qo'zg'almas o'q atrofida aylana oladi. Tayoqchaning o'rtasiga massasi *m=10 g* bo'lgan o'q gorizontal yo'nalishda *ϑ=500 m/s* tezlikda uchib kelib tayoqchaga qadalib qoladi. Urilishdan keyin tayoqcha qanday α burchakka og'adi?

Berilgan:

$\ell = 1{,}5m$

M=10 kg

m=10 g

ϑ=500 m/s

$\alpha = ?$

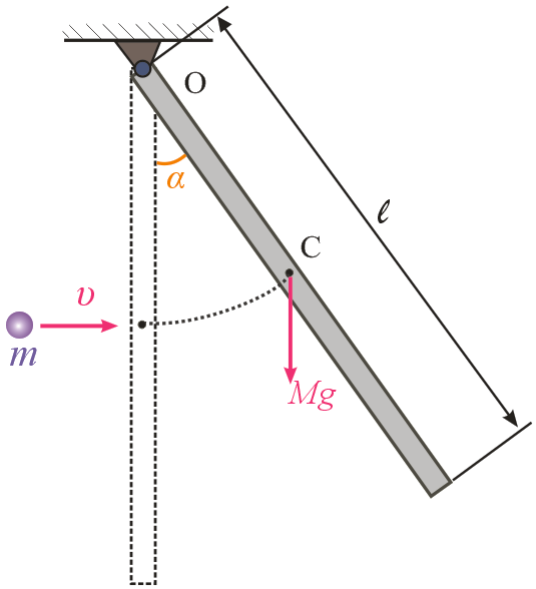
Yechilishi:

Impuls momentining saqlanish qonunidan o'q tayoqchaga kirib qolgan ondagi (zarb onidagi) tayoqcha olgan burchak tezlikni topamiz.

$$m\vartheta\frac{\ell}{2} = \left(\frac{1}{3}M\ell^2 + \frac{1}{4}m\ell^2\right)\omega \approx \frac{1}{3}M\ell^2\omega$$

$$\omega = \frac{3m\vartheta}{2M\ell} = \frac{3 \cdot 10^{-2} \cdot 500}{2 \cdot 10 \cdot 1{,}5} = 0{,}5\ rad/s$$

Endi esa energiyaning saqlanish qonunini qo 'llaymiz,



ya’ni, zarb onida tayoq olgan aylanma kinetik energiya tayoq massa markazi ko‘tarilishda olgan potensial energiyaga teng bo‘ladi.

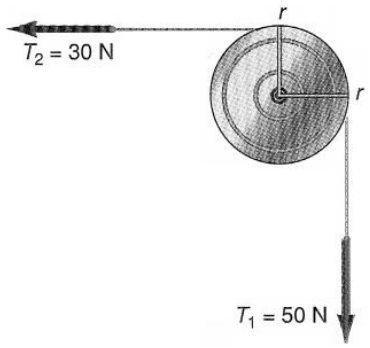
$$E_K = E_P, \rightarrow \frac{I\omega^2}{2} = Mg\ell(1-\cos\alpha), \rightarrow \cos\alpha = 1-\frac{I\omega^2}{Mg\ell} = 1-\frac{\omega^2}{Mg\ell}\cdot\frac{M\ell^2}{3} = 1-\frac{\omega^2\ell}{3g} =$$

$$= 1-\frac{0,25\cdot 1,5}{3\cdot 9,81} = 0,987, \quad \rightarrow \quad \alpha = \arccos 0,987 = 9,33^0 = 9^0 20'$$

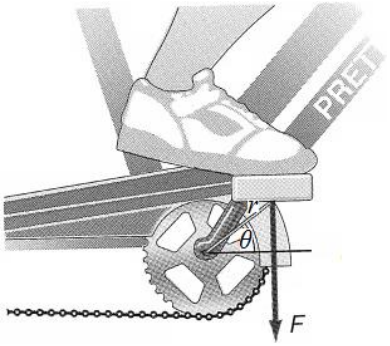
Javob: $\alpha = 9^0 20'$

23-amaliy mashg‘ulot topshirig‘i

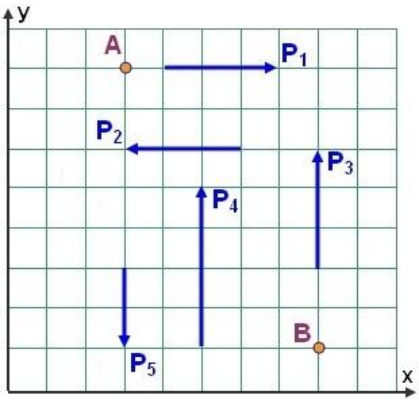
23.1. Rasmdagi shkivga ta’sir etuvchi natijaviy burovchi momentni aniqlang. Shkivning radiusi $r = 25\,sm$ ga, ipdagi taranglik kuchlari $T_1 = 50\,N, T_2 = 30\,N$ ga teng. **Javob:** *4 N·m*



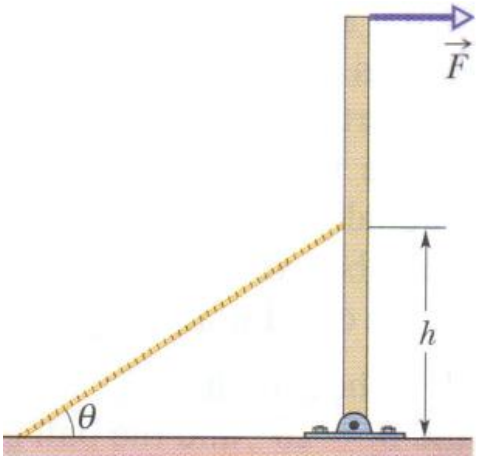
23.2. Rasmda poygachini oyog‘i va velosipedni zabjirli uzatmasi tasvirlangan. Bunda pedal radiusi $r = 20\,sm$ ga, pedalni gorizont bilan hosil qilgan burchagi $\theta = 37^0$ ga va pedalga qo‘yilgan kuch $F = 150\,N$ ga teng. Uzatmada paydo bo‘ladigan burovchi momentni aniqlang. **Javob:** *24 N·m*



23.3. Rasmda *Oxy* tekisligida yotuvchi kuchlar sistemasi berilgan. Mashtabni 1 ta katakni uzunlik uchun *10 sm* deb, kuch uchun esa *10 N* deb oling. Kuchlar sistemasining *Oxy* tekislikdan ixtiyoriy olingan *A* va *B* nuqtalariga nisbatan kuch momentini aniqlang [*N·m*]. **Javob:** $M_A = 17\,Nm; M_B = -8\,Nm$

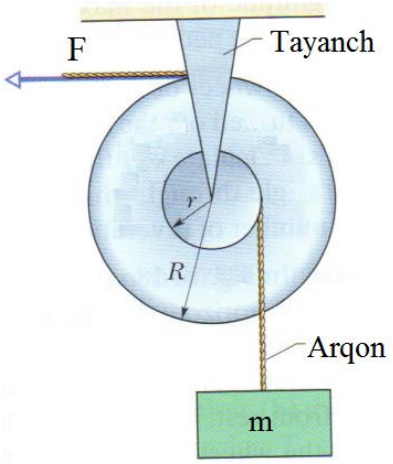


23.4. Uzunligi $L=3,2\ m$ va og‘irligi $P=60\ N$ bo‘lgan sharnirga birikkan balka Vertikal holga keltirildi. Balkaning tepa uchiga gorizontal holda $F=50\ N$ kuch qo‘yilgan. Balkaning yerdan $h=2\ m$ balandlikdagi nuqtasiga ip bog‘langan bo‘lib, bu arqonning ikkinchi uchi yerga $\theta = 25^0$ burchak ostida magkamlangan. F kuch hosil qilgan burovchi momentni, ipning taranglik kuchini hamda sharnirdagi reaksiya kuchini aniqlang.



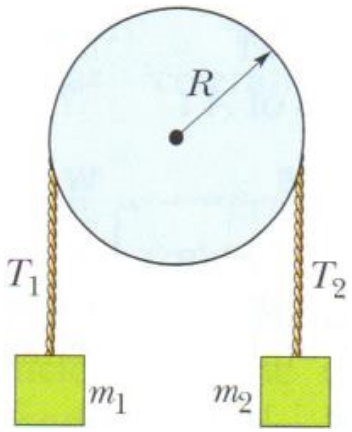
Javob: $M(F)=160\ N\cdot m;\ T=88,27\ N;\ R=101,82\ N$

23.5. Tayanchda bitta o‘qda radiuslari $R=25\ sm$ va $r=10\ sm$ bo‘lgan shkivlar mahkamlangan. Kichik shkivga o‘ralgan arqonning bir uchiga $m=8\ kg$ massali yuk osilgan. Katta shkivga o‘ralgan arqonning uchiga qo‘yilgan F kuch ta’sirida yuk tekis ko‘tarilmoqda. Bunda yukdan va F kuchdan shkivlar o‘qida yuzaga keladigan kuch momentlari nimaga teng? F kuchning qiymati nimaga teng? $g = 10\ m/s^2$.



Javob: $M_1 = -8\ Nm,\ M_2 = 8\ Nm,\ F = 32\ N$

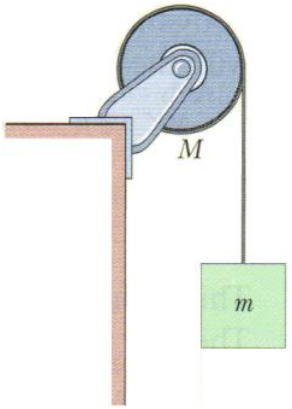
23.6. Rasmda m amassali va R radiusli shkiv orqali o‘tkazilgan cho‘zilmas yengil arqon uchlariga m_1 va m_2 massali yuklar osilgani tasvirlangan. Yuklar qanday tezlanish bilan harakatlanadilar? Ipning uchlaridagi taranglik kuchlari T_1 va T_2 nimaga teng? Shkivni bir jinsli disk deb oling.



Javob: $a = \dfrac{m_2 - m_1}{m_2 + m/2 + m_1} g;$

$$T_1 = \frac{2m_2 + m/2}{m_1 + m/2 + m_2} m_1 g;\ T_1 = \frac{2m_1 + m/2}{m_1 + m/2 + m_2} m_2 g$$

23.7. Rasmda M amassali va R radiusli shkivga aylantirib o‘ralgan cho‘zilmas yengil ip uchiga m massali yuk osilgan. Yukning tushish tezlanishi qanday? Arqondagi taranglik kuch-chi? Yuk ha balandlikdan tushganda qanday tezlikka erishadi? Shkivni bir jinsli disk deb oling.



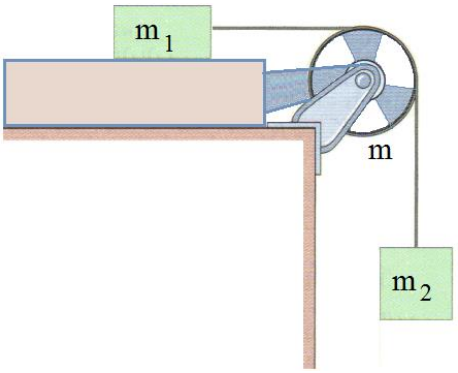
Javob: $a = \dfrac{m}{m + M/2} g;\ T = \dfrac{M}{M + 2m} mg;\ \vartheta = 2\sqrt{\dfrac{m}{2m + M} gh}\ .$

23.8. Uzunligi $\ell = 50\,sm$ va massasi *m=400 g* bo‘lgan ingichka bir jinsli tayoqcha o‘rtasidan tayoqchaga tik ravishda o‘tadigan o‘q atrofida $\varepsilon = 3 rad/s^2$ burchak tezlanish bilan aylanadi. Aylantiruvchi moment *M* aniqlansin. **Javob:** *0,025 Nm*

23.9. *R= 5 sm* radiusli shkivga cho‘zilmas yengil ip o‘ralgan. Ipning bir uchiga *m=0,4 kg* massali yuk osilib qo‘yib yuborilganda *t=3 s* da *s=1,8 m* masofa o‘tdi. Shkivni bir jinsli disk deb hisoblab, uning inersiya momenti *I* ni aniqlang. *g=9,8 m/s*^{2}. **Javob:** *0,0235 kg·m*^{2}

23.10. Massasi *m=100* kg va radiusi *R=5 sm* bo‘lgan val *ν=8 Gs* chastota bilan aylanmoqda. Valning sirtiga *F=40 N* kuchga ega tormoz dastasining bosilishi natijasida *t=10 s* dan keyin val to‘xtadi. Ishqalanish koeffitsiyenti μ nimaga teng? valni yaxlit slindr deb oling. **Javob:** μ*=0,314*

23.11. Massalari m_1*=0,25 kg* va m_2*=0,15 kg* bo‘lgan ikkita jism *m=0,1 kg* massali shkiv orqali o‘tkazilgan ingichka ip bilan bog‘langan. Yuklar qanday tezlanish bilan harakatlanadi? Ipning uchlaridagi taranglik kuchlari T_1 va T_2 qanday? m_1 jismning stol ustida sirpangandagi ishqalanish koeffitsiyenti μ*=0,2* ga teng. Shkivni bir jinsli va uning massasini xalqa gardishida yotibdi deb hisoblang. *g=10 m/s*^{2}. **Javob:**

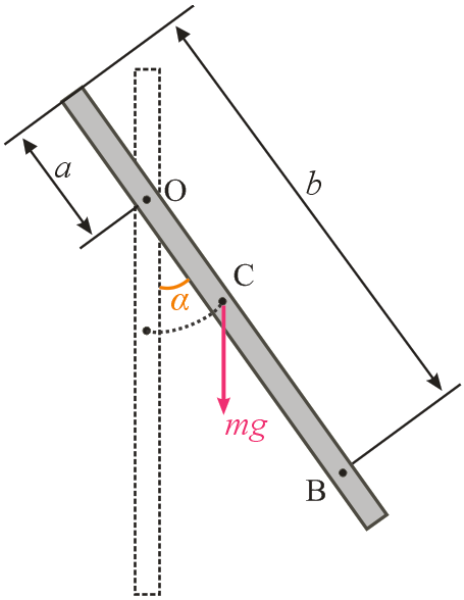


$$a = \frac{m_2 - \mu m_1}{m_1 + m + m_2} g = 2\,m/s^2; \quad T_1 = \frac{\mu m + (1+\mu) m_2}{m_1 + m + m_2} m_1 g = 1N;$$

$$T_2 = \frac{m + (1+\mu) m_1}{m_1 + m + m_2} m_2 g = 1{,}5\,N.$$

23.12. Massasi *m=10 kg* va radiusi *R=20 sm* bo‘lgan shar o‘z markazidan o‘tuvchi o‘q atrofida aylanadi. Sharning aylanishh tenglamasi $\varphi = A + Bt^2 + Ct^3$ ko‘rinishga ega, bunda *B=4 rad/s*^{2}, *C=-1rad/s*^{3}. Sharga ta’sir etayotgan kuch momentining o‘zgarish qonunij topilsin. Vaqtning *t=2 s* onidagi kuch momenti aniqlansin. **Javob:** $M = \frac{4}{5} mR^2 (B + 3Ct) = -0{,}64\,N \cdot m$

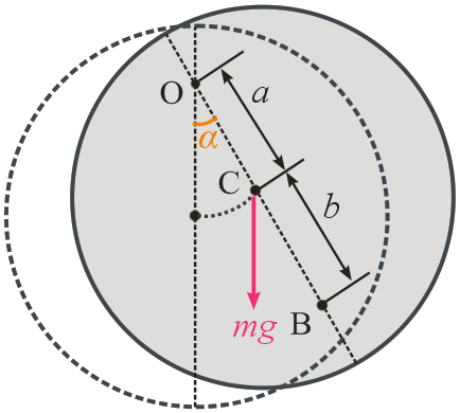
23.13. Uzunligi $\ell = 1m$ bo‘lgan ingichka va bir jinsli tayoqcha tayoqchadagi O nuqtadan o‘tuvchi gorizontal o‘q atrofida erkin aylana oladi. Tayoqchani vertikaldan α burchakka og‘dirib qo‘yib yuborildi. Tayoqchadagi B nuqtaning vaqtning boshlang‘ich onidagi burchak tezlanishi ε va tangensial tezlanishi a_t aniqlansin. Hisoblash quyidagi hollar uchun bajarilsin: 1) $a = 0, b = \frac{2}{3}\ell, \alpha = \frac{\pi}{2}$; 2) $a = \frac{\ell}{3}, b = \ell, \alpha = \frac{\pi}{3}$.



Javob: 1) $\varepsilon = \frac{3g}{2\ell} = 14,7\,rad/s^2;\ a_t = g = 9,8\,m/s^2;$

$\varepsilon = \frac{3g}{2\ell}\sin\alpha = 12,7\,rad/s^2;\ a_t = g\sin\alpha = 8,49\,m/s^2$

23.14. Radiusi $R=10$ *sm* bo‘lganbir jinsli disk disk tekisligiga tik va undagi O nuqtadan o‘tuvchi gorizontal o‘q atrofida erkin aylana oladi. Diskni α burchakka og‘dirib qo‘yib yuborildi. Diskdagi B nuqtaning vaqtning boshlang‘ich onidagi burchak tezlanishi ε va tangensial tezlanishi a_t aniqlansin. Hisoblash quyidagi hollar uchun bajarilsin: 1) $a = R, b = \frac{R}{2}, \alpha = \frac{\pi}{2}$; 2) $a = \frac{R}{2}, b = R, \alpha = \frac{\pi}{6}$. **Javob:**



1) $\varepsilon = 65,3\frac{rad}{s^2};\ a_t = 9,8\frac{m}{s^2};$ 2) $\varepsilon = 32,7\frac{rad}{s^2};\ a_t = 4,9\frac{m}{s^2}$

23.15. Inersiya momenti *245* $kg\cdot m^2$ ga teng bo‘lgan maxovik g‘ildirak *20 Gs* chastota bilan aylanmoqda. Aylantiruvchi momentning ta’siri to‘xtatilgandan so‘ng *1 min* vaqt o‘tgach g‘ildirak to‘xtaydi. 1) Ishqalanish kuchining momenti, 2) aylantiruvchi moment ta’siri to‘xtatilgandan to to‘xtaguncha aylanishlar soni topilsin. **Javob:** 1) $M_{ishq} = 513\ N\cdot m;$ 2) $N = 1200\,ayl$

23.16. Avtomobilning *1800 ayl/min* castota bilan aylanayotgan tirsakli vali *100 ot kuchi* ga teng quvvatni motordan g‘ildirak o‘qlariga uzatadi. Bunda tirsakli val qanday kattalikdagi M burovchi momentni uzatmoqda? **Javob:** $M=390\ N\cdot m$

23.17. Jukovskiy kursisida turgan odam gorizontal tekisligi yo‘nalishida $\vartheta = 20\,m/s$ tezlik bilan uchib kelayotgan massasi $m=0,4$ *kg* bo‘lgan to‘pni qo‘li bilan tutub oladi. To‘pning trayektoriyasi kursi aylanayotgan vertikal o‘qdan $r=0,8$ *m* masofadan o‘tadi. Agar odam va kursining yig‘indi inersiya momenti $I=60$ $kg\cdot m^2$ bo‘lsa, Jukovskiy kursisi to‘pni ushlagan kishi bilan birgalikda qanday ω burchak tezlik bilan aylana boshlaydi. **Javob:** *1,02 rad/s*

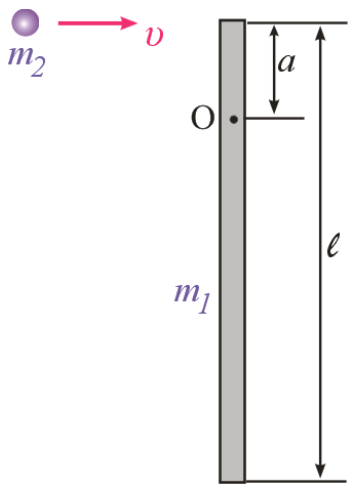
23.18. *Radiusi *R=2 m* bo‘lgan disk shaklidagi gorizontal platformaning chekkasida $m_1 = 80\,kg$ massali odam turibdi. Platformaning massasi $m_2 = 240\,kg$. Platforma o‘zining markazidan o‘tuvchi vertikal o‘q atrofida aylana oladi. Agar odam uning chekkasi bo‘ylab platformaga nisbatan $\vartheta = 2\,m/s$ tezlik bilan yursa, platforma qanday ω burchak tezlik bilan aylana boshlaydi. Ishqalanish hisobga olinmasin.

Javob: $\omega = \dfrac{2m_1\vartheta}{(2m_1 + m_2)R} = 0,4\,rad/s$

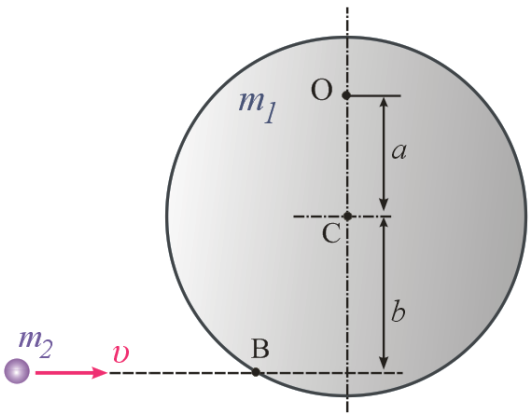
23.19. Oldingi masalada odam platformani 1 marta dastlabki turgan nuqtasiga qaytib kelsa, platforma qanday φ burchakka buriladi? **Javob:** $\varphi = \dfrac{4\pi m_1}{2m_1 + m_2} = \dfrac{2\pi}{3}$

23.20. Radiusi *R=1 m* bo‘lgan disk ko‘rinishidagi platforma inersiya bo‘yicha $n_1 = 6\,\text{min}^{-1}$ chastota bilan aylanadi. Platformaning chekkasida massasi *m=80 kg* bo‘lgan odam turibdi. Agar odam platformaning markaziga o‘tsa, u qanday n_2 chastota bilan aylanadi? Odamni moddiy nuqta deb oling. Platformaning inersiya momenti *I=120 kg·m²*. **Javob:** $n_2 = \dfrac{I + mR^2}{I} n_1 = 10\,\text{min}^{-1}$

23.21. **Massasi m_1=0,2 kg va uzunligi $\ell = 1m$ bo‘lgan bir jinsli ingichka tayoqcha *O* nuqtadan o‘tuvchi gorizontal o‘q atrofida erkin aylana oladi. $\vartheta = 10\,m/s$ tezlik bilan gorizontal uchib kelayotgan m_2=10 g massali plastilin sharcha tayoqchaning B nuqtasiga tegib yopishib qoladi. Zarb onida tayoqchaning burchak tezligi ω va tayoqcha pastki uchiniing chiziqli tezligi *u* aniqlansin. Hisoblash quyidagi hollar uchun bajarilsin: 1)*a=l/2; 2)a=l/3;a=l/4*. **Javob:**



23.22. **Massasi m_1=0,2 kg va radiusi *R=20 sm* bo‘lgan bir jinsli disk tekisligiga tik va *C* nuqtadan o‘tuvchi gorizontal z o‘q atrofida erkin aylana oladi. $\vartheta = 10\,m/s$ tezlik bilan gorizontal uchib kelayotgan m_2=10 g massali plastilin sharcha disk yasovchisining *B* nuqtasiga tegib yopishib qoladi. Vaqtning boshlang‘ich onida diskning burchak tezligi ω va diskdagi *O* nuqtaning chiziqli tezligi u aniqlansin. Hisoblash ishlari *a* va *b* larning quyidagi qiymatlari uchun bajarilsin. *1) a=b=R; 2) a=R/2, b=R; 3) a=2R/3, b=R/2*.



Javob:

23.23. Uzunligi $\ell_1 = 1m$ bo‘lgan ipning uchiga bog‘langan $m=100\ g$ massali sharcha gorizontal tekislikda sirpangancha $\nu_1=1Gs$ chastota bilan aylanmoqda. Ip qisqartirilib, sharcha aylanish o‘qiga $\ell_2 = 0,5m$ masofagacha yaqinlashdi. Bunda sharcha qanday ν_2 chastota bilan aylanadi? Ipni qisqartishda tashqi kuch qanday A ish bajaradi? Sharchaning tekislikka ishqalanishini e’tiborga olmang. **Javob:**

$$n_2 = \left(\frac{\ell_1}{\ell_2}\right)^2 n_1 = 4Gs;\ A = 5,92\,J$$

23.24. G‘ildirak $\varphi = A + Bt + Ct^2$ tenglama bilan ifodalanuvchi qonun bo‘yicha aylanmoqda. Bunda $A=2rad$, $B=16\ rad/s$, $C=2\ rad/s^2$. G‘ildirakning inersiya momenti $I=50\ kg\cdot m^2$. Aylantiruvchi moment M va quvvat N ning o‘zgarish qonuni topilsin. Vaqtning $t=3\ s$ onida quvvat nimaga teng? **Javob:** $M=200\ N\cdot m=const$; $N = 3,2 + 0,8t\ \ kW$

23.25. Aylanayotgan g‘ildirakning kinetik energiyasi $K=1\ kJ$. O‘zgarmas tormozlovchi moment ta’sirida g‘ildirak tekis sekinlanuvchan aylana boshlaydi va $k=80$ marta aylanib to‘xtaydi. Tormozlovchi kuch momenti M aniqlansin. **Javob:** $M=1,99\ Nm$

23.26. $m=4\ kg$ massali dumaloq jism gorizontal sirt bo‘ylab sirpenishsiz dumalamoqda. Slindr o‘qining chiziqli tezligi $\vartheta = 1m/s$. Dumaloq jismning to‘la kinetik energiyasi K aniqlansin. Dumaloq jism: 1) slindr; 2) xalqa; 3) shar bo‘lgan hollar uchun hisoblashlarni bajaring. **Javob:** 1) $K = \frac{3}{4}m\vartheta^2 = 3J;$ 2) $K = m\vartheta^2 = 4J;$ 3) $K = \frac{7}{10}m\vartheta^2 = 2,8J$.

23.27. h balandlikdagi qiya sirtdan ishqalanishsiz sirpanib tushgan jism qiyalik etagida ϑ tezlikka erishgan bo‘lsa, bu qiyalikdan dumalab tushgan jismning markazi qanday zhiziqli tezlikka erishadi? Dumaloq jism: 1) slindr; 2) xalqa; 3) shar bo‘lgan hollar uchun hisoblashlarni bajaring. **Javob:** 1) $\sqrt{\frac{2}{3}}\vartheta \approx 0,816\vartheta;$ 2) $\frac{\sqrt{2}}{2}\vartheta \approx 0,707\vartheta;$ 3) $\sqrt{\frac{5}{7}}\vartheta \approx 0,845\vartheta.$

23.28. Uzunligi $\ell_1 = 1m$ bo‘lgan ingichka to‘g‘ri tayoqcha o‘zining uchidan o‘tuvchi gorizontal tekislikdagi o‘qqa mahkamlangan. Tayoqchani muvozonat holatidan $\varphi=60^0$ burchakka og‘dirib qo‘yib yuborildi. Tayoqchaning quyi uchining muvozonat holatidan o‘tayotgan paytdagi chiziqli tezligi ϑ aniqlansin. J: $3,84\ m/s$

23.29. Inersiya momenti I, massasi m va radiusi R bo‘lgan dumaloq jism gorizontal sirtda ishqalanishsiz dumalamoqda. Bu jismning to‘la kinetik energiyasi K ning

qanday qismi ilgarilanma harakat $\left(\frac{K_{ilg}}{K}\right)$ va qanday qismi aylanma harakat $\left(\frac{K_{ayl}}{K}\right)$ hissasiga to‘g‘ri keladi? **Javob:** $\frac{K_{ilg}}{K}=\frac{mR^2}{I+mR^2}$; $\frac{K_{ayl}}{K}=\frac{I}{I+mR^2}$.

23.30. Yuqoridagi masala shartida dumalayotgan jismni: 1) disk; 2) xalqa; 3) shar deb olib, hisoblashlarni bajaring. **Javob:** 1) $\frac{K_{ilg}}{K}=\frac{2}{3}$; $\frac{K_{ayl}}{K}=\frac{1}{3}$; 2) $\frac{K_{ilg}}{K}=\frac{1}{2}$; $\frac{K_{ayl}}{K}=\frac{1}{2}$; 3) $\frac{K_{ilg}}{K}=\frac{7}{10}$; $\frac{K_{ayl}}{K}=\frac{3}{10}$.

23.31. Agar dumalovchi jismning o‘z o‘qiga nisbatan inersiya momenti $I_0=\delta MR^2$ ga teng. Bu holda dumalovchi jismni *h* balandlikdagi qiyalik tepasidan qiyalik bo‘ylab dumalatib yuborildi. Qiyalik etgida dumalovchi jism erishgan tezlik va tezlanish aniqlansin. **Javob:** $\vartheta=\sqrt{\frac{2gh}{\delta+1}}$; $a=\frac{g\sin\alpha}{\delta+1}$

23.32. Oldingi masala shartini dumalovchi jism: 1) xalqa; 2) disk; 3) sfera; 4) shar bo‘lgan hollar uchun yeching. **Javob:** 1) $\vartheta=\sqrt{gh}$; $a=\frac{1}{2}g\sin\alpha$; 2) $\vartheta=2\sqrt{\frac{gh}{3}}$; $a=\frac{2}{3}g\sin\alpha$; 3) $\vartheta=\sqrt{\frac{6gh}{5}}$; $a=\frac{3}{5}g\sin\alpha$; 4) $\vartheta=\sqrt{\frac{10gh}{7}}$; $a=\frac{5}{7}g\sin\alpha$

24-MAVZU: Lorens almashtirishlaridan kelib chiqadigan natijalar. Bir vaqtlilikning nisbiyligi. Vaqt oralig‘ining, uzunlikning va massaning nisbiyligi. Relyativistik mexanikada tezliklarni qo‘shish qoidasi

Mavzuga oid muhim formulalar

Lorents almashtirishlari

$$K' \to K \ da\ , \qquad x = \frac{x' + \vartheta_0 t'}{\sqrt{1-\frac{\vartheta_0^2}{c^2}}}, \qquad y = y', \qquad z = z', \qquad t = \frac{t' + \frac{\vartheta_0}{c^2}x'}{\sqrt{1-\frac{\vartheta_0^2}{c^2}}}$$

$$K \to K' \ da\ , \qquad x' = \frac{x - \vartheta_0 t}{\sqrt{1-\frac{\vartheta_0^2}{c^2}}}, \qquad y' = y, \qquad z' = z, \qquad t' = \frac{t - \frac{\vartheta_0}{c^2}x}{\sqrt{1-\frac{\vartheta_0^2}{c^2}}}$$

Bir vaqtlilikning nisbiyligi

$$\Delta t = t_2 - t_1 = \frac{\frac{\vartheta_0}{c^2}\cdot(x_2' - x_1')}{\sqrt{1-\left(\frac{\vartheta_0}{c}\right)^2}}, \qquad \Delta t' = \frac{\vartheta_0}{c^2}(x_2' - x_1')$$

Vaqt oralig‘ining nisbiyligi

$$\tau = \frac{\tau_0}{\sqrt{1-(\vartheta_0/c)^2}} = \frac{\tau_0}{\sqrt{1-\beta^2}}, \qquad \vartheta_0 = \sqrt{1-\left(\frac{\tau_0}{\tau}\right)^2}\,c$$

Uzunlikning nisiyligi

$$\ell = \ell_0\sqrt{1-(\vartheta_0/c)^2} = \ell_0\sqrt{1-\beta^2}, \qquad \vartheta_0 = \sqrt{1-\left(\frac{\ell}{\ell_0}\right)^2}\,c$$

Massa va zichlikning nisiyligi

$$m = \frac{m_0}{\sqrt{1-(\vartheta_0/c)^2}} = \frac{m_0}{\sqrt{1-\beta^2}}, \qquad \vartheta_0 = \sqrt{1-\left(\frac{m_0}{m}\right)^2}\,c$$

$$\rho = \frac{\rho_0}{1-(\vartheta_0/c)^2} = \frac{\rho_0}{1-\beta^2}, \qquad \vartheta_0 = \sqrt{1-\frac{\rho_0}{\rho}}\,c$$

$\vartheta = \dfrac{\vartheta_0 + \vartheta'}{1+\dfrac{\vartheta_0\vartheta'}{c^2}}$	*Relyativistik tezliklarni qo‘shish qoidasi*
$\vartheta = \dfrac{\vartheta_0 - \vartheta'}{1-\dfrac{\vartheta_0\vartheta'}{c^2}}$	*Nisbiy relyativistik tezlik*

24-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Tinch holatdagi uzunligi *1 m* bo‘lgan chizg‘ich biror sanoq tizimida *0,6c* tezlik bilan harakatlansa, shu tizimaa uning uzunligi qanday (*cm*) bo‘ladi?

Berilgan:	*Yechish:*
$l_0 = 1m$ $\upsilon = 0{,}6c$ l =?	Maxsus nisbiylik nazariyasi qonunlariga ko‘ra jismning uzunligi xarakat tezligiga teskari mutonosib yani tezligi ortishi bilan uning uzunligi qisqaradi. Bu bog‘lanish $l = l_0\sqrt{1-\frac{\upsilon^2}{c^2}}$ ko‘rinishida. Bundan $l = 1\sqrt{1-\frac{0{,}36c^2}{c^2}} = 0{,}8\ m = 80\ sm$ ekanligi kelib chiqadi.

Javob: 80 sm

Masala № 2. Agar Yerda *70 yil* o‘tsa, Yerga nisbatan *0,99c* tezlik bilan harakatlanayotgan yulduzlararo uchuvchi kemada necha yil o‘tadi? c=3·10^{8}m/s.

Berilgan:	*Yechish:*
$t_0 = 70yil;$ $\upsilon = 0{,}99c;$ t =?	Nisbiylik nazariyasi qonunlariga binoan vaqt ham nisbiy tushuncha bo‘lib u ham xarakat tezligiga bo‘gliq yani yorug‘lik tezligiga yaqin tezlik bilan xarakatlanyotgan sistemada vaqtning o‘tishi tinch turgan sistemaga nisbatan sekinroq o‘tadi. Shunga binoan harakatdagi sistemadagi vaqt tinch turgan sistemedagi vaqt bilan quydagicha bog‘langan $t = t_0\sqrt{1-\frac{\upsilon^2}{c^2}}$ bundan $t = 70 \cdot 0{,}141 \approx 10$ yil

Javob: 10 yil

Masala № 3. Jism qanday tezlik bilan harakatlanganaa, uning massasi tinchlikdagi massasidan ikki marta ortadi?

Berilgan:	*Yechish:*
$\frac{m}{m_0} = 2$ V=?	Nisbiylik nazariyasi qonunlariga ko‘ra jimning harakatdagi massasi uning tinchlikdagi massasi bilan quydagicha bog‘langan $m = \frac{m_0}{\sqrt{1-\frac{\upsilon^2}{c^2}}}$ bundan $\upsilon = c\sqrt{1-\left(\frac{m_0}{m}\right)^2} = \frac{\sqrt{3}c}{2}$

Javob: *0,87 c*

Masala № 4. Yerdan ikkita kosmik kema Yerga nisbatan har biri *0,5c* tezlik bilan qarama-qarshi tomonga uchirildi. Birinchi kemaning ikkincnisiga nisbatan tezligi qanday?

Berilgan:

$v_1 = 0{,}5c;$

$v_2 = 0{,}5c;$

$v_n = ?$

Yechish:

Tezliklarni qo‘shishning relyativistik qonuniga ko‘ra $v_n = \frac{v_1+v_2}{1+\frac{v_1 v_2}{c^2}} = 0{,}8c$ ekanligi kelib chiqadi.

Javob: 0,8 c

Masala № 5. Lorens faktorining *3, 5, 10* ga teng qiymatlarida *K′* sanoq sistemasining tezligi qanday bo‘lganini aniqlang.

Berilgan:

$\gamma_1=3$

$\gamma_2=5$

$\gamma_3=10$

$\vartheta = ?$

Yechish:

So‘ralgan kattalikni Lorens faktori formulasiga ko‘ra aniqlaymiz.

$$\gamma = \sqrt{\frac{1}{1-(\vartheta/c)^2}}, \rightarrow \frac{1}{\gamma^2} = 1-(\vartheta/c)^2, \rightarrow (\vartheta/c)^2 = \frac{\gamma^2-1}{\gamma^2}, \rightarrow$$

$$\rightarrow \vartheta = \frac{\sqrt{\gamma^2-1}}{\gamma}c$$

Endi Lorens faktorining turli qiymatlari uchun so‘ralgan tezlik qiymatlarini aniqlaymiz.

$$\vartheta_1 = \frac{\sqrt{\gamma_1^2-1}}{\gamma_1}c = \frac{\sqrt{3^2-1}}{3}c = \frac{2\sqrt{2}}{3}c \approx 0{,}9428c; \quad \vartheta_2 = \frac{\sqrt{\gamma_2^2-1}}{\gamma_2}c = \frac{\sqrt{5^2-1}}{5}c = \frac{2\sqrt{6}}{5}c \approx 0{,}9798c;$$

$$\vartheta_3 = \frac{\sqrt{\gamma_3^2-1}}{\gamma_3}c = \frac{\sqrt{10^2-1}}{10}c = \frac{\sqrt{99}}{10}c \approx 0{,}995c$$

Javob: $\vartheta_1 \approx 0{,}9428c;\ \vartheta_2 \approx 0{,}9798c;\ \vartheta_3 \approx 0{,}995c$

Masala № 6. Galaktika Yerdan *0,825 c* tezlik bilan uzoqlashayapti deb taxmin qiling. Bu galaktika o‘zidan uzunligi *0,525 m* bo‘lgan radioto‘lqinlar chqaradi. Yerdagi kuzatuvhci bu to‘lqinni qanday uzunlikda qabul qiladi?

Berilgan:

$\lambda_0 = 0{,}525m$

$v = 0{,}825c$

$\lambda = ?$

Yechish:

So‘ralgan kattalikni Doppler effektiga ko‘ra aniqlaymiz.

$$\lambda = \lambda_0\sqrt{\frac{1+\vartheta/c}{1-\vartheta/c}} = 0{,}525\cdot\sqrt{\frac{1+0{,}825}{1-0{,}825}} = 0{,}525\cdot\sqrt{\frac{1825}{175}} = 1{,}695m \approx 1{,}7m$$

Demak bunda to‘lqin uzunligi 3,29 marta uzayar ekan.

Javob: $\lambda = 1{,}7\ m$

24-amaliy mashg‘ulot topshirig‘i

24.1. Elektronning tezligi *180000 km/s*. Uning massasi tinch holatdagi massasidan necha marta katta? Yoruglikning bo‘shliqdagi tezligi *300000 km/s*. **Javob:** *1,25 marta*

24.2. Jism *0,89c* tezlik bilan harakatlanmoqda. Bunda uning zichligi qanday o‘zgaradi? **Javob:** *1,26 marta*

24.3. Tezligi *0,6c* bo‘lgan zarrachaning kinetik energiyasi uning tinchlikdagi energiyasidan necha marta kichik boladi? **Javob:** *4 marta*

24.4. Bikrligi *20 kN/m* bo‘lgan prujinani *30 sm* ga cho‘zganda, uning massasi qancnaga ortadi? **Javob:** $10^{-14}\,kg$

24.5. Massasi *20 kg* bo‘lgan azot o‘zgarmas bosimda *0* dan *200°C* gacha qizdirildi. Bunda azotning massasi qanchaga oshgan? Azotning o‘zgarmas bosimdagi solishtirma issiqiik sig‘imi *1,05kJ/(kg·K)*. **Javob:** $4{,}667\cdot10^{-12}\,kg$ *ortadi*

24.6. Ikki zarracha bir-biriga qarab Yerga nisbatan $\vartheta_1 = 0{,}5c$ va $\vartheta_2 = 0{,}8c$ tazlik bilan harakatlanmoqda. Ikkinchi zarra bilan bog‘langan sanoq sistemasida birinchi zarraning tezligi namaga teng? **Javob:** $\frac{13}{14}c$

24.7. Tinch turgan chizg‘ichning uzunligi $\ell_0 = 1m$. *0,6 c* tezlik bilan bo‘ylama yo‘nalishda harakatlanayotgan chizg‘ichning uzunligi qancha bo‘ladi? **Javob:** *0,8m*

24.8. Yerga nisbatan $\vartheta = 0{,}98c$ tezlik bilan harakatlanayotgan kosmik zarrachaning Yer soati bilan o‘lchangan umri t uning xususiy umri t_0 dan necha marta ortiq? **Javob:** *5 marta*

24.9. Yerga nisbatan $\vartheta = 0{,}33c$ tezlik bilan harakatlanayotgan zvezdolyotda $\tau_0 = 50$ yil vaqt o‘tdi. Yerda necha yil vaqt o‘tgan? **Javob:** *53 yil*

24.10. $\vartheta = 2{,}4\cdot10^8\,m/s$ tezlik bilan harakatlanayotgan protonning massasi qanday? Protonning tinchlikdagi massasi m_0=1 m.a.b. deb hisoblang. **Javob:** *1,67 m.a.b.*

24.11. Harakatdagi jismning bo‘ylama o‘lchami *n* marta qisqarishi uchun u qanday tezlikka erishsish kerak? **Javob:** $\vartheta = \frac{\sqrt{n^2-1}}{n}c$

24.12. Kosmik nurlar tarkibidagi mezonlar yorug‘lik tezligining 95% tezligida harakatlansa, mezon o‘lchaminig bo‘ylama qisqarishi qanday? **Javob:** *68,6%*

24.13. Beqaror zarracha yorug‘lik tazligining 99%ini tashkil etadi. Uning yashash vaqti Yerdagi kuzutuvchiga nigohida necha marta uzayadi? **Javob:** *7,1 marta*

24.14. Yerga tomon ϑ tezlik bilan harakatlanaayotgan yulduz tomonidan nurlangan yorug‘lik Yerga $c+\vartheta$ tezlik bilan emas, balki c tezlik bilan yaqinlashishini isbot qiling.

24.15. Tezlatkich radioaktiv yadroga $1{,}2\cdot10^8\,m/s$ tezlik beradi. Tezlatkichdan chiqish paytida yadro o‘z yo‘nalishida tezlatkichga nisbatan $2{,}25\cdot10^8\,m/s$ tezlikka ega bo‘lgan elektron chiqaradi. Elektronning yadroga nisbatan tezligini aniqlang. **Javob:** $1{,}5\cdot10^8\,m/s$

24.16. ϑ=0,999c tezlik bilan harakatlanayotgan elektronning relyativistik massasi uning tinchlikdagi massasidan necha marta katta bo‘ladi? **Javob:** *22,37 marta*

24.17.

25-MAVZU: Relyativistik dinamikaning asosiy tenglamasi. Relyativistik kinetik energiya. Massa va energiya orasidagi bog‘lanish. Energiya va impuls orasidagi bog‘lanish.

Mavzuga oid muhim formulalar

$m=\gamma m_0=\dfrac{m_0}{\sqrt{1-\left(\dfrac{\vartheta_0}{c}\right)^2}}$	*Relyativistik massa*
$p=\dfrac{m_0\vartheta}{\sqrt{1-(\vartheta/c)^2}},\quad \vartheta=\dfrac{pc}{\sqrt{p^2+(m_0c)^2}}$	*Relyativistik impuls, bunda tezlikni topish*
$F=\dfrac{dp}{dt}=\dfrac{d}{dt}\left(\dfrac{m_0\vartheta}{\sqrt{1-\left(\dfrac{\vartheta}{c}\right)^2}}\right)$	*Relyativistik dinamikaning asosiy tenglamasi*
$E_K=m_0c^2(\gamma-1)=m_0c^2\left(\dfrac{1}{\sqrt{1-\left(\dfrac{\vartheta_0}{c}\right)^2}}-1\right)$	*Relyativistik kinetik energiya*
$E=mc^2\quad$ *yoki* $\quad\Delta E=\Delta mc^2$	*Massa va energiya orasidagi bog‘lanish*
$E=\sqrt{(m_0c^2)^2+(pc)^2}$	*Energiya va impuls orasidagi bog‘lanish*
Relyativistik Doppler effekti *(yorug‘lik manbasi kuzatuvchidan uzoqlashayotgan holat)* $\lambda=\lambda_0\sqrt{\dfrac{1+\vartheta/c}{1-\vartheta/c}}=\lambda_0\sqrt{\dfrac{1+\beta}{1-\beta}},\qquad \nu=\nu_0\sqrt{\dfrac{1-\vartheta/c}{1+\vartheta/c}}=\nu_0\sqrt{\dfrac{1-\beta}{1+\beta}}$ *(yorug‘lik manbasi kuzatuvchiga yaqinlashayotgan holat)* $\lambda=\lambda_0\sqrt{\dfrac{1-\vartheta/c}{1+\vartheta/c}}=\lambda_0\sqrt{\dfrac{1-\beta}{1+\beta}},\qquad \nu=\nu_0\sqrt{\dfrac{1+\vartheta/c}{1-\vartheta/c}}=\nu_0\sqrt{\dfrac{1+\beta}{1-\beta}}$	

25-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Quyosh nurlari yil davomida Yerga *5,4·10²⁴ J* energiya olib keladi. Agar Yer bu energiyani fazoga nurlamaganida *10 yil* davomida uning massasi necha kg ortgan bo‘lar edi?

Berilgan: *Yechish:*

$E=5{,}4\cdot10^{24}$ J

$\Delta m=?$

Nisbiylik prinsipiga ko‘ra massa energiyaga ekvivalent kattalik bo‘lib, jismlar energiya yutish bilan massasi ortadi va aksincha. Ular orasida $E=\Delta mc^2$ bog‘lanish mavjud. Bunda Δm massaning o‘zgarishi. Demak, 1 yil davomida Yer massasi $\Delta m=\frac{E}{c^2}\approx 6\cdot10^7$ kg ga ortar ekan. 10 yilda esa $6\cdot10^8$kg ga ortgan bo‘lar edi.

Javob: *$6\cdot10^8$kg*

Masala № 2. Elektronning kinetik energiyasi *E_K=2 MeV*. Klassik va relyativistik formulalardan foydalanib elektronning tezligini aniqlang.

Berilgan: *Yechish:*

E_K=2 MeV

$m_e=9{,}1\cdot10^{-31}$ kg

$\vartheta=?$

Kinetik energiyani SI sistemasiga o‘tkazamiz.

$$E_K=2MeV=2\cdot10^6eV=2\cdot10^6\cdot\left(1{,}6\cdot10^{-19}\ J\right)=3{,}2\cdot10^{-13}\ J$$

Dastlab, kinetik energiyaning klassik formulasidan foydalanib tezlikni aniqlaymiz.

$$E_K=\frac{m_e\vartheta^2}{2},\ \rightarrow\ \vartheta_{klas}=\sqrt{\frac{2E_K}{m_e}}=\sqrt{\frac{2\cdot3{,}2\cdot10^{-13}}{9{,}1\cdot10^{-31}}}=8{,}39\cdot10^8\frac{m}{s}$$

Bu tezlik yorug‘lik tezligidan ham kattaroqdir. Shuning uchun ham masala shartida klassik formuladan foydalanish noto‘g‘ridir. Endi kinetik energiyaning relyativistik formulasidan foydalanib tezlikni aniqlaydigan formulani keltirib chiqaramiz.

$$E_K=m_ec^2\left(\frac{1}{\sqrt{1-(\vartheta/c)^2}}-1\right),\ \rightarrow\ \frac{1}{\sqrt{1-(\vartheta/c)^2}}=1+\frac{E_K}{m_ec^2},\ \rightarrow\ 1-(\vartheta/c)^2=\frac{1}{\left(1+\frac{E_K}{m_ec^2}\right)^2},\ \rightarrow$$

$$\rightarrow\left(\frac{\vartheta}{c}\right)^2=1-\frac{1}{\left(1+\frac{E_K}{m_ec^2}\right)^2},\ \rightarrow\ \vartheta=\sqrt{1-\frac{1}{\left(1+\frac{E_K}{m_ec^2}\right)^2}}\cdot c$$

$$\vartheta_{rel}=\sqrt{1-\frac{1}{\left(1+\frac{E_K}{m_ec^2}\right)^2}}\cdot c=\sqrt{1-\frac{1}{\left(1+\frac{3{,}2\cdot10^{-13}}{9{,}1\cdot10^{-31}\cdot9\cdot10^{16}}\right)^2}}\cdot3\cdot10^8\approx2{,}937\cdot10^8\frac{m}{s}$$

Javob: *$\vartheta=2{,}937\cdot10^8$ m/s*

Masala № 3. Galaktika Yerdan *0,825 c* tezlik bilan uzoqlashayapti deb taxmin qiling. Bu galaktika o‘zidan uzunligi *0,525 m* bo‘lgan radioto‘lqinlar chqaradi. Yerdagi kuzatuvhci bu to‘lqinni qanday uzunlikda qabul qiladi?

Berilgan:

$\lambda_0 = 0{,}525m$

$v = 0{,}825c$

$\lambda = ?$

Yechish:

So‘ralgan kattalikni Doppler effektiga ko‘ra aniqlaymiz.

$$\lambda = \lambda_0\sqrt{\frac{1+\vartheta/c}{1-\vartheta/c}} = 0{,}525\cdot\sqrt{\frac{1+0{,}825}{1-0{,}825}} = 0{,}525\cdot\sqrt{\frac{1825}{175}} = 1{,}695m \approx 1{,}7m$$

Demak bunda to‘lqin uzunligi 3,29 marta uzayar ekan.

Javob: *λ=1,7 m*

25-amaliy mashg‘ulot topshirig‘i

25.1. Agar harakatlanayotgan elementar zarraning kinetik energiyasi tinchlikdagi energiyasidan *7* marta katta bo‘lsa, uning massasi tinchlikdagi massasidan necha marta katta bo‘ladi? **Javob:** *8 marta*

25.2. *0,5c* tezlik bilan harakatlanayotgan zarraning kinetik energiyasi tinchlikdagi energiyasining necha foizini tashkil etadi? **Javob:** *15,6 %*

25.3. Massasi *20 kg* bo‘lgan azot o‘zgarmas bosimda *0* dan *200°C* gacha qizdirildi. Bunda azotning massasi qanchaga oshgan? Azotning o‘zgarmas bosimdagi solishtirma issiqiik sig‘imi *1,05kJ/(kg·K)*. **Javob:** $4{,}667\cdot10^{-12}\,kg$ *ortadi*

25.4. Tezlatkich radioaktiv yadroga $1{,}2\cdot10^8 m/s$ tezlik beradi. Tezlatkichdan chiqish paytida yadro o‘z yo‘nalishida tezlatkichga nisbatan $2{,}25\cdot10^8 m/s$ tezlikka ega bo‘lgan elektron chiqaradi. Elektronning yadroga nisbatan tezligini aniqlang. **Javob:** $1{,}5\cdot10^8\,m/s$

25.5. *ϑ=0,99c* tezlik bilan harakatlanayotgan elektronning relyativistik massasi uning tinchlikdagi massasidan necha marta katta bo‘ladi? **Javob:** *22,37 marta*

25.6. Harakatdagi jismning relyativistik massasi uning tinchlikdagi massasiga nisbatan 20% ga ortdi. Bunda uning uzunligi necha marta qisqargann? **Javob:** *1,2 marta*

25.7. Elektron $2\cdot10^8\,m/s$ tezlik bilan harakatlanmoqda. Elektronning kinetik energiyasini klassik va relyativistik formulalar bo‘yicha hisoblab, natijalarni taqqoslang. **Javob:** $E_k^{klas} = 114keV;\ E_k^{rel} = 175keV$

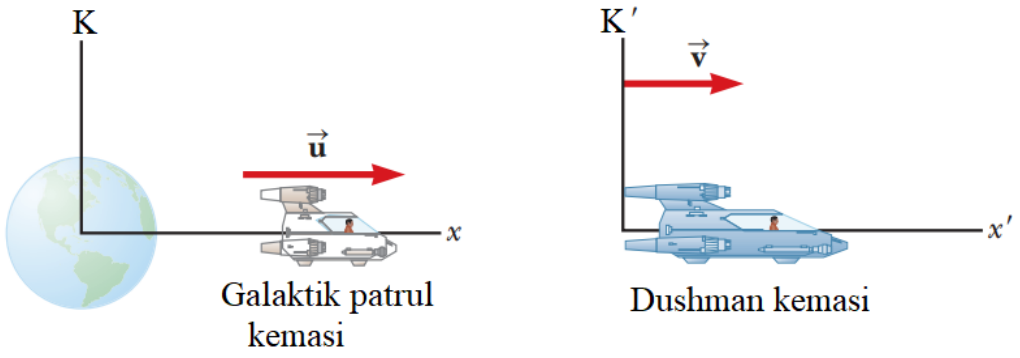
25.8. Energiyaning *1J* o‘zgarishi massaning qanday o‘zgarishiga olib keladi? **Javob:** $1{,}11\cdot10^{-17}\,kg$

25.9. Massa elektronning tinch holdagi massasichalik o‘zgarishi uchun energiya qanday o‘zgarish kerak? **Javob:** $8{,}2\cdot10^{-14}\,J$

25.10. Neytron zarrasi kuzatuvchiga nisbatan tinch bo‘lganda *900 s* vaqt yashaydi, so‘ngra parachalanib ketadi. Agar neytron biror tezlikda harakatlanayotgan bo‘lsa, kuzatuvchi nazdida bu zarra *2065 s* vaqt yashaydi. Neytron qanday tezlikda harakatlanmoqda? **Javob:** *0,9c*

25.11. Agar relyativistik effektlar *1 %* dan oshmaslik kerak bo‘lsa, u holda Lorens faktori $\gamma=1{,}01$ bo‘lshi kerak. Qanday nisbiy tezlikda $\gamma=1{,}01$ bo‘ladi? Relyativistik effektlar *3 %* dan oshmaslik uchun nisbiy tezlik qanday bo‘lishi kerak? **Javob:** *42 000 km/s*; *71900 km/s*

25.12. Dushman kosmik kemasi Yerdan *0,8c* tezlik bilan uzoqlashmoqda. Galaktik patrul kemasi esa uni Yerga nisbatan *0,9c* tezlik bilan quvmoqda (pastdagi rasmga qarang). Yerdagi kuzatuvchi patrul kemasi dushman kemasini *0,1c* tezlik bilan quvib yetadi deb o‘ylaydi. Patrul kemasi ekipajlari dushman kemasini qanday tezlik bilan quvib yetyapmiz deb o‘ylaydi? **Javob:** *0,357c*



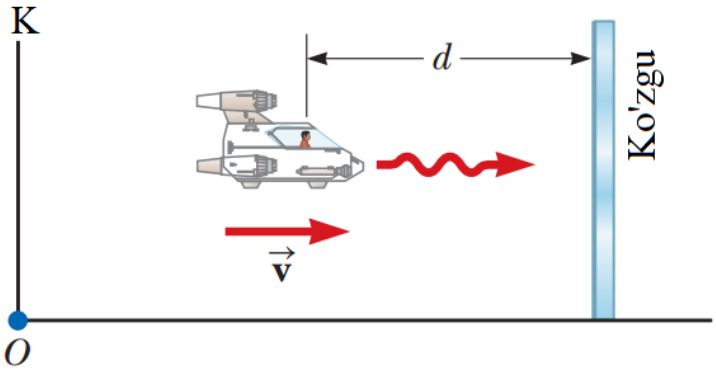
25.13. Ikki planeta biror sanoq sistemasiga nisbatan bir-biriga to‘qnashadigan trayektoriya bo‘ylab bir xil *0,25c* tezlik bilan yaqinlashmoqda. Birinchi planetadan ikkinchisiga kosmik kema uchirildi. Bu kosmik kemani ikkinchi planetadagi kuzatuvchi 0,75c tezlik bilan yaqinlashayotganini qayd etadi. Kosmik kemaning tanlangan sanoq sistemasidagi tezliqi qanday? Kosmik kema birinchi planetaga nisbatan qanday tezlikda uchirilgan? **Javob:** $\frac{8}{13}c$; $\frac{19}{44}c$

25.14. Ikki planeta bir-biriga to‘qnashadigan trayektoriya bo‘ylab *0,25c* ga teng nisbiy tezlik bilan yaqinlashmoqda. Birinchi planetadan ikkinchisiga kosmik kema uchirildi. Bu kosmik kemani ikkinchi planetadagi kuzatuvchi *0,75c* tezlik bilan yaqinlashayotganini qayd etadi. Kosmik kema birinchi planetaga nisbatan qanday tezlikda uchirilgan? **Javob:** *0,615c*

25.15. Relyativistik tezlikda harakatlanayotgan ikkita kosmik kemadan biri ikkinchisiga dron uchiradi. Bu dron 1-kemadan *0,75c* tezlikda uzoqlashib, ikkinchisiga *0,95 c* tezlik bilan yaqinlashadi. Kosmik kemalarning bir-biriga nisbatan tezligi qanday bo‘lgan? **Javob:** *0,696c*

25.16. Kosmik kemadagi kosmanavt ko‘zgu tomonga qarab rasmdagi K sanoq sistemasiga nisbatan *0,65c* tezlik bilan harakatlanmoqda. Ko‘zgi *K* sanoq sistemasiga nisbatan tinch turibdi. Kosmanavt kemadan ko‘zgu tomonga yorug‘lik impulsini yuboradi va impuls ko‘zgudan orqaga kema tomonga qaytadi. Impuls yuborilgan vaqt momentida kema ko‘zgudan (K sistemadagi kuzatuvchi hisobi bo‘yicha) $d=5{,}66\cdot10^{10}$

m masofada edi. Impulsning umumiy sayr sayr vaqti K sistemadagi hamda kosmik kemadagi kuzatuvchilar nimaga teng? **Javob:** *229 s; 174 s*



25.17. Katta yo‘lda turadigan DAN xodimi foydalanadigan radar asbobining ishlashi Doppler siljishiga asoslangan bo‘lib, shu siljish tufayli avtomobillarning tezligini aniqlaydi. Mikroto‘lqinning radardan chiqish chastotasi *100 GGs* bo‘lib, qaytgan exosignal chastotasi esa bundan *15 kGs* ga kattaroq. Avtomobilning tezligi qanday bo‘lgan? **Javob:** *45 m/s*

25.18. Agar protonning impulsi $4{,}48\cdot10^{-19}$ *kg·m/s* ga teng bo‘lsa, uning tezligi anday? Protonning tinchlikdagi massasi $m_0=1{,}67\cdot10^{-27}$ *kg*. **Javob:** *2000 km/s*

25.19. Buyuk portlash hodisasidan keyin 10^{68} *J* energiya hosil bo‘lgan deb baholanadi. Bu energiya bilan har birining massasi $4\cdot10^{30}$ *kg* bo‘lgan nechta yulduz hosil bo‘lishi mumkin? **Javob:** $2{,}78\cdot10^{20}$ *ta*

26-MAVZU: Fizik mayatnik. Buralma mayatnik. Torsial mayatnik. Garmonik tebranma harakatga boshqa misollar

Mavzuga oid muhim formulalar

Fizik mayatnikda tezlanish va koordinata orasidagi bog‘lanish

$$a_x = -\frac{mg\ell}{I}x \qquad yoki \qquad \ddot{x} = -\frac{mg\ell}{I}x$$

Fizik mayatnik uchun amplituda qiymatlar

$$x_m = A, \qquad \vartheta_m = A\sqrt{\frac{mg\ell}{I}}, \qquad a_m = A\frac{mg\ell}{I}$$

Fizik mayatnik uchun siklik chastota, tebranish chastotasi va tebranish davri

$$\omega = \sqrt{\frac{mg\ell}{I}}, \qquad \nu = \frac{1}{2\pi}\sqrt{\frac{mg\ell}{I}}, \qquad T = 2\pi\sqrt{\frac{I}{mg\ell}}$$

Buralma mayatnik uchun formulalar

$$M = I\varepsilon = I\ddot{\theta}, \qquad \ddot{\theta} = -\frac{\kappa}{I}\theta = -\omega^2\theta, \qquad \dot{\theta}_m = \theta_m\omega, \qquad \varepsilon_m = \theta_m\omega^2$$

$$\omega = \sqrt{\frac{\kappa}{I}}, \qquad \nu = \frac{1}{2\pi}\sqrt{\frac{\kappa}{I}}, \qquad T = 2\pi\sqrt{\frac{I}{\kappa}}$$

26-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Rasmda *L=1 m* uzunlikdagi tayoq bir uchidan osilgani tasvirlangan. Bunda tayoqning massa markazidan osilish nuqtasigacha masofa h=L/2 ga teng. Tayoqning tebranish davrini aniqlang, davr tayoq massasiga bog‘liqmi? Keltirilgan uzunlikni aniqlang.

Berilgan:

L=1 m

H=L/2

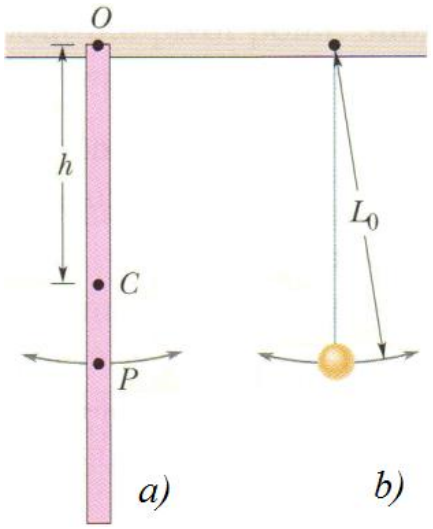
$T = ?$

$L_0 = ?$

Yechilishi:

Tayoqni massasi bitta nuqtada to‘planmagan, balki uni uzunligi bo‘ylab taqsimlangan. Shuning uchun rayoq matematik mayatnik bo‘la olmaydi, uni fizik mayatnik deb qaraymiz.

Tayoqni bir jinsli sterjen deb olamiz va uni inersiya momentini osilgan nuqtaga nisbatan aniqlaymiz.



$$I_a = \frac{1}{12}mL^2 + mh^2 = \frac{1}{12}mL^2 + m\left(\frac{L}{2}\right)^2 = \frac{1}{3}mL^2$$

Tebranish davrini hisoblaymiz.

$$T = 2\pi\sqrt{\frac{I}{mgh}} = 2\pi\sqrt{\frac{mL^2/3}{mgL/2}} = 2\pi\sqrt{\frac{2L}{3g}} = 2\cdot 3{,}14\sqrt{\frac{2\cdot 1}{3\cdot 9{,}81}} = 1{,}64\,s$$

Yuqoridagi formuladan ko‘rinadiki davr massaga bog‘liq emas ekan. Endi keltirilgan uzunlikni aniqlaymiz.

$$L_0 = \frac{I}{mh} = \frac{mL^2/3}{mL/2} = \frac{2}{3}L = 0{,}667\,m$$

Tayoqning O osilish nuqtasidan $L_0 = \frac{2}{3}L$ masofada *P* nuqtani belgilaymiz. Ana shu P nuqtaga tayoqning butun massasini bitta nuqtaga jamlanganda edi, u tayoqning tebranish davri bilan bir xil davrdagi matematik mayatnikka aylangan bo‘lar edi.

Javob: *T=1,64 s; davr massaga bog‘liq emas;* $L_0 = \frac{2}{3}L = 0{,}667\,m$

Masala № 2. Fizik mayatnik rasmdagi kabi *r=10 sm* radiusli va *m=500g* massali bir jinsli disk hamda diskka mahkamlangan *L=50 sm* uzunlikdagi va *M=250 g* massali bir jinsli sterjendan iborat bo‘lsin. Fizik mayatnik uchun quyidagilarni aniqlang: a) osilish nuqtasiga nisbatan inersiya momentini; b) massa markazidan osilish nuqtasigacha masofani; c) tebranish davrini; d) keltirilgan uzunlikni.

Berilgan:
r=10 sm
m= 500 g
L=50 sm
M=250 g
H=L/2

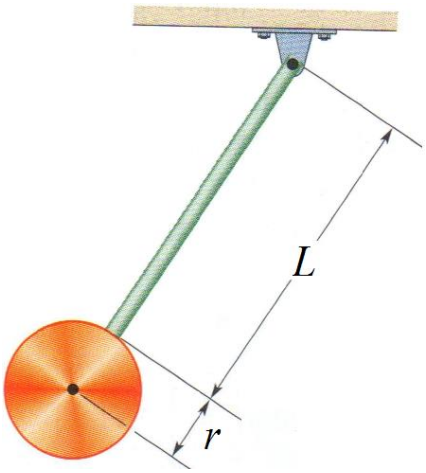
$a) I = ?$
$b) OC = ?$
$c) T = ?$
$d) L_0 = ?$

Yechilishi:

a) Sterjenning inersiya momentini osilgan nuqtaga nisbatan aniqlaymiz.

$$I_1 = \frac{1}{12}ML^2 + m\left(\frac{L}{2}\right)^2 = \frac{1}{3}ML^2 =$$

$$= \frac{1}{3}\cdot 0{,}25\cdot 0{,}5^2 = 0{,}02083\ kg\,m^2$$



Diskning o‘z markaziga nisbatan inersiya momenti $\frac{1}{2}mr^2$ ga, mayatnik osilgan nuqtaga nisbatan inersiya momenti esa

$$I_2 = \frac{1}{2}mr^2 + m(L+r)^2 = \frac{1}{2}\cdot 0{,}5\cdot 0{,}1^2 + 0{,}5\cdot 0{,}6^2 = 0{,}0025 + 0{,}18 = 0{,}1825\ kg\,m^2$$

Inersiya momenti additiv kattalikdir. Shuning uchun umumiy inersiya momentini sterjen va diskning inersiya momentlari yig‘indisi tashkil etadi.

$$I = I_1 + I_2 = 0{,}02083 + 0{,}1825 = 0{,}20333\,kg\,m^2$$

b) Osilgan nuqtani koordinata bosh deb qabul qilib massa markazi koordinatasini radius-vwktor orqali aniqlaymiz.

$$r_C = \frac{m_1 r_1 + m_2 r_2}{m_1 + m_2};\ \Rightarrow OC = \frac{M \cdot L/2 + m \cdot (L + r)}{M + m} = \frac{0,25 \cdot 0,25 + 0,5 \cdot 0,6}{0,25 + 0,5} = 0,483m = 48,3sm$$

c) Mayatnikning tebranish davrini aniqlaymiz.

$$T = 2\pi\sqrt{\frac{I}{(M+m)g \cdot OC}} = 2 \cdot 3,14\sqrt{\frac{0,20333}{0,75 \cdot 9,81 \cdot 0,483}} = 6,28 \cdot 0,239 = 1,5s$$

d) Keltirilgan uzunlikni aniqlaymiz.

$$L_0 = \frac{I}{(M+m) \cdot OC} = \frac{0,20333}{0,75 \cdot 0,483} = 0,561m = 56,1sm$$

Javob: $a)\, I = 0,20333\ kg\,m^2;\ b) OC = 48,3sm;\ c) T = 1,5s;\ d)\, L_0 = 56,1sm$

Masala № 3. Radiusi *15 sm* va massasi *95 kg* bo‘lgan shar vertikal osma simga osib qo‘yilgan. Sharni *0,8 rad* burchakka burish uchun unga 0,2 Nm burovchi moment qo‘yish kerak bo‘ladi. Buralma tebranish davri qanday? Shu sharni *0,25 rad* burchakka burib, so‘ng qo‘yib yuborilgan holat uchun harakat tenglamasini yozing.

Berilgan:	*Yechilishi:*
R=0,15 m	Avvalo sharning vertikal o‘qqa nisbatan inersiya momentini abiqlaymiz.
m=95 kg	$I = \frac{2}{5}mR^2 = \frac{2}{5} \cdot 95 \cdot 0,15^2 = 0,855\ kg\,m^2$
θ=0,8 rad	
M=0,2 Nm	
θ_{max}*=0,25 rad*	Endi sharning buralma bikrligini aniqlaymiz.
$T = ?$	$\kappa = \frac{M}{\theta} = \frac{0,2\,Nm}{0,8\,rad} = 0,25\ \ N \cdot m/rad$
$\theta = \theta(t) - ?$	

Endi buralma tebranishdagi davrni aniqlaymiz.

$$T = 2\pi\sqrt{\frac{I}{\kappa}} = 6,28\sqrt{\frac{0,855}{0,25}} = 11,6s$$

Buralma tebranishdagi harakat tenglamasini yozamiz.

$$\theta = \theta_m \cos\omega t = \theta_m \cos\left(\sqrt{\frac{\kappa}{I}}t\right) = 0,25\cos\left(\sqrt{\frac{0,25}{0,855}}t\right) = 0,25\cos 0,54t$$

Javob: $T = 11,6s;\ \theta = 0,25\cos 0,54t$

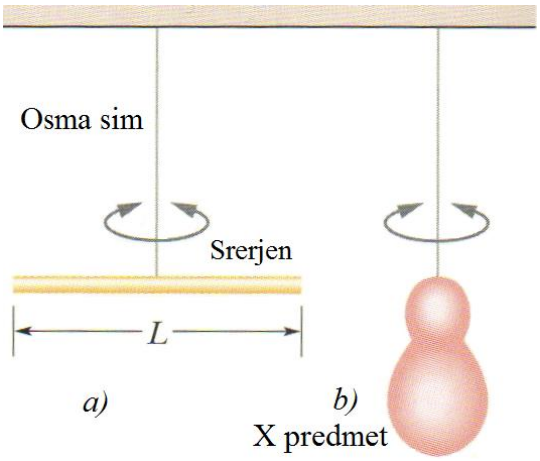
Masala № 4. Rasmda massasi *m=135 g* va uzunligi *L=12,4 sm* bo‘lgan bir jinsli sterjen o‘rtasidan uzun osma simga osilgani tasvirlangan. Uning tebranish davri $T_a = 2,53s$ ekani aniqlandi. Shakli noma’lum bo‘lgan X predmet xuddi shu simga osilganda tebranish davri $T_b = 4,76s$ ekani ma’lum bo‘ldi. X predmetning osilgan simga nisbatan aylanma inersiya momenti nimaga teng?

Berilgan:
m=135 g
L=12,4 sm
$T_a = 2{,}53s$
$T_b = 4{,}76s$
$I_b = ?$

Yechilishi:
Dastlab sterjenning osmaga niabatan inersiya momentini aniqlaymiz.

$$I_a = \frac{1}{12}mL^2 = \frac{1}{12}\cdot 0{,}135\cdot 0{,}124^2 =$$
$$= 1{,}73\cdot 10^{-4}\ kg\,m^2$$

Sterjen va X predmetning buralma tebranish davrlari



$T_a = 2\pi\sqrt{\frac{I_a}{\kappa}}$ va $T_b = 2\pi\sqrt{\frac{I_b}{\kappa}}$ bo'ladi. Ularning nisbatidan esa X predmetning inersiya momentini aniqlaymiz.

$$\frac{T_b}{T_a} = \sqrt{\frac{I_b}{I_a}},\ \rightarrow I_b = I_a\left(\frac{T_b}{T_a}\right)^2 = 1{,}73\cdot 10^{-4}\left(\frac{4{,}76}{2{,}53}\right)^2 = 1{,}73\cdot 10^{-4}\cdot 3{,}54 = 6{,}12\cdot 10^{-4}\ kg\,m^2$$

Javob: $I_b = 1{,}63\cdot 10^{-3}\ kg\,m^2$

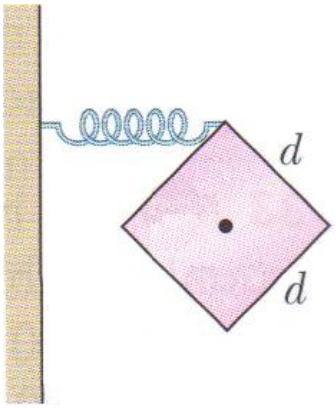
Masala № 5. Rasmdagi kubning massasi *m=3kg*, qirrasi *d=6 sm* bo'lib, u o'zinini markazidan o'tgan o'q atrofida aylanma harakat qila oladi. Kubning bir qirrasiga bikrligi *k=1200 N/m* bo'lgan prujina orqali vartikal devorga mahkamlangan. Agar kubni muvozonat vaziyatidab $\varphi_m = 3^0$ burchakka burib qo'yib yuborilsa, harakat tenglamasi qanday bo'ladi? Tebranish davri-chi?

Berilgan:
m=3 kg
d=6 sm
k=1200 N/m
$\varphi = \varphi(t) - ?$
$T = ?$

Yechilishi:
Avvalo kubning markazidan o'tuvchi o'qqa nisbatan kubning inersiya momentini aniqlaymiz.

$$I = \frac{1}{12}m\left(d^2 + d^2\right) = \frac{1}{6}md^2$$

Kubni ixyiyoriy φ burchakka burganda prujina $x = \frac{d}{\sqrt{2}}\varphi$ masofaga absalyut



deformatsiyalanadi. Bunda prujinada $F_e = -kx = -k\frac{d}{\sqrt{2}}\varphi$ ga teng elastiklik kuchi paydo bo'lib, bu kuch kub markaziga nisbatan $M = F_e\cdot\frac{d}{\sqrt{2}} = -k\frac{d^2}{2}\varphi$ ga teng burovchi moment hosil qiladi. Boshqa tomonda esa burovchi moment

$M = I\varepsilon = \frac{1}{6}md^2\ddot{\varphi}$ ga tengdir. Bu momentlarni tenglab, so‘ngra hararkat tenglamasini hosil qilish mumkin.

$$\frac{1}{6}md^2\ddot{\varphi} = -k\frac{d^2}{2}\varphi, \quad \rightarrow \quad \ddot{\varphi} = -\frac{3k}{m}\varphi = -\frac{3\cdot 1200}{3}\varphi = -1200\varphi$$

Bu yerda siklik chastota

$$\frac{3k}{m} = \omega^2, \quad \rightarrow \quad \omega = \sqrt{\frac{3k}{m}}$$

dan tebranish davri

$$T = 2\pi\sqrt{\frac{m}{3k}} = 2\cdot 3{,}14\cdot\sqrt{\frac{3}{3\cdot 1200}} = 0{,}181s$$

ga teng bo‘ladi.

Javob: $\ddot{\varphi} = -1200\varphi; T = 0{,}181s$

Masala № 6. Rasmda U-simon nayga *M=10 kg* simob quyilgani tasvirlangan. Nayning ko‘ndalang yuzasi *S=20 sm²* ga teng. Agar yelkalardan birini bosib qo‘yib yuborilish orqali erkin tebranishlar hosil qilindi deb faraz qilinsa, bu tebrangich *t=1 min* vaqtda necha marta tebranadi?

Berilgan:

$M = 10kg$

$S = 20sm^2$

$\rho = 13600kg/m^3$

$g = 9{,}81\,m/s^2$

N=?

Yechilishi:

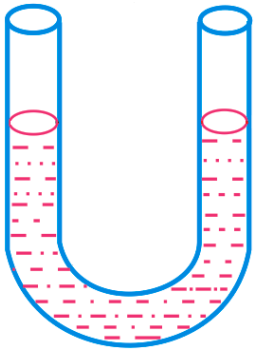
Tebranishlar chastotasini aniqlaymiz.

$$\nu = \frac{1}{2\pi}\sqrt{\frac{2\rho g S}{M}} = \frac{1}{6{,}28}\cdot\sqrt{\frac{2\cdot 13600\cdot 9{,}81\cdot 2\cdot 10^{-3}}{10}} =$$

$$= 1{,}163Hz$$

Tebtranishlar sonini aniqlaymiz.

$$N = \nu t = 1{,}163\cdot 60 \approx 70$$



Javob: *N=70 marta*

26-amaliy mashg‘ulot topshirig‘i

26.1. Amplitudasi *1 mm*, chastotasi *1000 Hz*, boshlang‘ich fazasi *π/3* bo‘lgan garmonik tebranishlarning tenglamasini tuzing. **Javob:** $x = 0{,}001\cos(2000\pi + \pi/3)$

26.2. Prujinaga osilgan *20 g* massali jism tebranishining maksimal potensial energiyasi *1 J* bo‘lsa, jismning maksimal tezligi qanday bo‘ladi? **Javob:** *10 m/s*

26.3. Mexanik tebranishlar $x = 0{,}3\cos(16\pi t + \pi/2)$ qonuniyat bo‘yicha ro‘y beradi. Tebranishlar davrini toping (s). Tezlik tenglamasini yozing. **Javob:** $T = 0{,}125s;\ \vartheta = -4{,}8\pi\sin(16\pi t + \pi/2)$

26.4. Garmonik tebranayotgan jismning harakat tenglamasi $x = 0{,}5\cos 10\pi t$ Jism tebranishlarining chastotasi qanday? Tezlanish tenglamasini yozing. **Javob:** $a = -50\pi^2 \cos 10\pi t$

26.5. Platformani *2,5 sm* amplituda va *6,6 Hz* chastota bilan tebratilganda unda qanday maksimal tezlanish paydo bo‘ladi? **Javob:** *6,6 m/s²*

26.6. Tebranayotgan jismning muvozanat vaziyatidan siljishi davrning qanday qismida amplitudaning yarmiga teng bo‘ladi? **Javob:** *T/12*

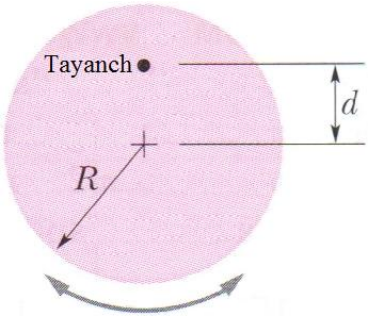
26.7. Elektrik britva *2 mm* masofa oralig‘ida *100 Hz* chastota bilan ilgarilanma-qaytma harakat ko‘rinishida garmonik tebranadi. Britva tig‘ining maksimal tezlik va tezlanishini aniqlang. **Javob:** $\vartheta_{\max} = 1{,}256\, m/s;\ a_{\max} = 788{,}8\ m/s^2$

26.8. Nuqta o‘zaro tik bo‘lgan ikkita tebranishda ishtirok etadi. Bu tebranishlar $x = 6\cos(2\pi t + \pi/4)\,[sm]$ va $y = 4\sin(2\pi t + \pi/4)\ [sm]$ qonuniyatga bo'ysunadi. Ikki tebranishni qo‘shilishidan hosil bo‘lgan tebranishning trayektoriya tenglamasini yozing va trayektoriya turini ayting. Boshlang‘ich nuqtasini koordinatalarini va harakat yo‘nalishini ko‘rsating. **Javob:** $\frac{x^2}{36} + \frac{y^2}{16} = 1$ *ellips;* $\left(3\sqrt{2}\ sm;\ 2\sqrt{2}\ sm\right)$ *nuqtadan boshlab soat miliga qarama-qarshi yo ‘nalishda.*

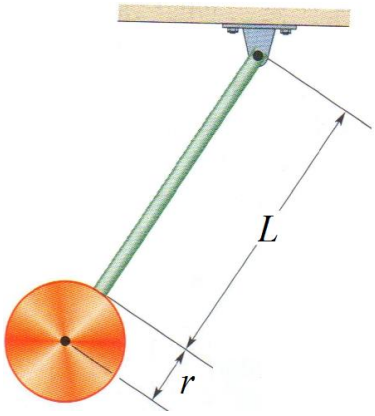
26.9. Qadimgi osma soatning buralma g‘ildiragi *π rad* amplituda hamda *0,6 s* davr bilan buralma garmonik tebranadi. Quyidagilarni aniqlang: *a)* g‘ildirakning maksimal burchak tezligini; *b)* burchak siljishi *π/2 rad* ga teng bo‘lgan paytdagi burchak tezlikni; c) burchak siljishi *π/4 rad* ga teng bo‘lgan paytdagi burchak tezlanishini. **Javob:** $a)\ \dot{\theta}_{\max} = 33 rad/s;\ b)\ \dot{\theta} = 28{,}5 rad/s;\ c)\ \ddot{\theta} = 258{,}3 rad/s^2$

26.10. Radiusi *15 sm* va massasi *95 kg* bo‘lgan shar vertikal osma simga osib qo‘yilgan. Sharni *0,8 rad* burchakka burish uchun unga *0,2 N·m* burovchi moment qo‘yish kerak bo‘ladi. Buralma tebranish davri qanday? Shu sharni *0,25 rad* burchakka burib, so‘ng qo‘yib yuborilgan holat uchun harakat tenglamasini yozing. **Javob:** $T = 11{,}6\,s;\ \theta = 0{,}25\cos 0{,}54t$

26.11. Rasmda *R=2,35 sm* radiusli qattiq diskdan iborat fizik mayatnik tasvirlangan. Bu mayatnik disk markazidan *d=1,5 sm* masofad tayanchga osib qo‘yilgan holda kichik tebranishlar bajarmoqda. Tebranishlar davrini aniqlang. $g = 9{,}81 m/s^2$. **Javob:** *T=0,366 s*

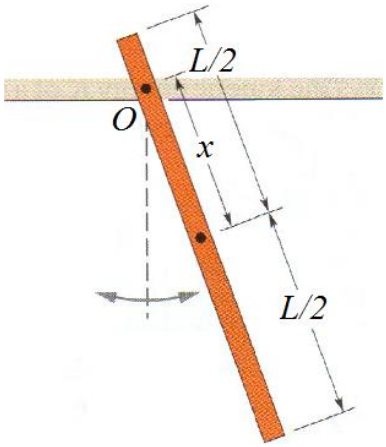


26.12. Fizik mayatnik rasmdagi kabi *r=10 sm* radiusli va *m=500g* massali bir jinsli disk hamda diskka mahkamlangan *L=50 sm* uzunlikdagi va *M=250 g* massali bir jinsli sterjendan iborat bo‘lsin. Fizik mayatnik uchun quyidagilarni aniqlang: a) osilish nuqtasiga nisbatan inersiya momentini; b) massa markazidan osilish nuqtasigacha masofani; c) tebranish davrini; d) keltirilgan uzunlikni. **Javob:**

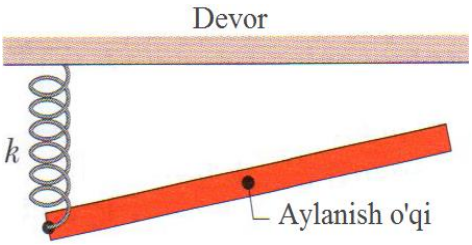


26.13. Rasmdagi bir *L=165 sm* uzunlikdagi jinsli tayoq fizik mayatnik sifatida tebranmoqda. Tayoqning *O* osilish nuqtasi va massa markazi orasidagi *x* masofa qanday bo‘lganda tayoqning tebranish davri eng kichik bo‘ladi? Tebranish davrining eng kichik qiymati nimaga teng? **Javob:**

$$x=\frac{\ell}{2\sqrt{3}}=47,6\,sm;\ T_{\min}=2\pi\sqrt{\frac{\ell}{\sqrt{3}\,g}}\approx 1,96\,s$$



26.14. Rasmdagi *m=0,6 kg* massali bir jinsli sterjen o‘zining o‘rtasidan o‘tgan o‘q atrofida erkin aylana oladi. Sterjenning bir uchi erkin tebrana oladigan bikrligi *k=1530 N/m* bo‘lgan prujina orqali tepadagi devorga mahkamlangan. Balka muvozonat holatida devorga parallel bo‘ladi. Sterjenni muvozonat holatidan bir oz chiqarib sekin qo‘yib yuborilsa, erkin tebranishlar davri nimaga teng? **Javob:** *T=71,8 ms*



27-MAVZU: Mexanik to‘lqinlarning tarqalishi. Turg‘un to‘lqinlar. Mexanik to‘lqinlar interferensiyasi va difraksiyasi.

Mavzuga oid muhim formulalar

$k=\frac{2\pi}{\lambda}$	*Siklik to‘lqin soni*
Yassi to‘lqin tenglamasi $y(x,t)=A\sin\left(\frac{2\pi}{\lambda}(x-\vartheta t)\right)$ *yoki* $y(x,t)=A\sin(kx-\omega t)$	
$\Delta\varphi=2\pi\frac{\Delta x}{\lambda}$	*To‘lqinning ikki nuqtasi orasidagi fazalar farqi*
$\vartheta=\lambda\nu$	*To‘lqinning tarqalish tezligi*
$y(x,t)=y_1(x,t)\pm y_2(x,t)$	*Yassi to‘lqinlar uchun superpozitsiya prinsipi*
$\Delta\ell=2k\cdot\frac{\lambda}{2}=k\lambda$	*Maksimumlar sharti*
$\Delta\ell=(2k-1)\cdot\frac{\lambda}{2}$	*Minimumlar sharti*

27-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. *Suv yuzida tarqalayotgan to'lqin tufayli po'kak 5 s da 10 marta tebrandi. Agar to'lqinning ikkita qo'shni do'ngligi orasidagi masofa 1 m bo'lsa, uning tarqalish tezligi qanday? Agar muhit zarrachalari 12 sm amplituda bilan tebranayotgan bo'lsa, u holda bu to'lqin uchun yassi to'lqin tenglamasi qanday?*

Berilgan:

$t=5\ s$

$N=10$

$\lambda=1\ m$

$v=?$

Yechilishi:

To'lqin tezligi quyidagicha topiladi:

$$v=\frac{\lambda}{T}=\frac{N\lambda}{t}=\frac{10\cdot1}{5}=2\ m/s$$

Bu yerda $T=\frac{t}{N}$ *formuladan foydalandik.*

Endi to'lqin tenglamasini tuzamiz.

$$y(x,t)=A\sin\left(\frac{2\pi}{\lambda}(x-\vartheta t)\right)=0{,}15m\cdot\sin\left(\frac{2\pi}{1m}\left(x-2\frac{m}{s}\cdot t\right)\right)$$

$$=0{,}15\sin(2\pi x-4\pi t)\ [\mathrm{m}]$$

Javob: $\vartheta=2\frac{m}{s}$; $y(x,t)=0{,}15\sin(2\pi x-4\pi t)\ [\mathrm{m}]$;

Masala № 2. *G'alayonlanish pulsi Ox o'qi bo'ylab o'ng tomonga quyidagi harakat tenglamasi bo'yicha harakatlanmoqda:*

$$y(x,t)=\frac{2}{(x-3t)^2+1}$$

Bu yerda y va x koordinatalar santimetrlarda, t vaqt esa sekundlarda o'lchanadi. Vaqtning t=0 s, t=1 s va t=2 s onlari uchun to'lqin funksiyasini tuzing hamda ularning grafiklarini tasvirlang.

Yechilishi:

Vaqtning t=0 s oni uchun to'qin funksiyasi

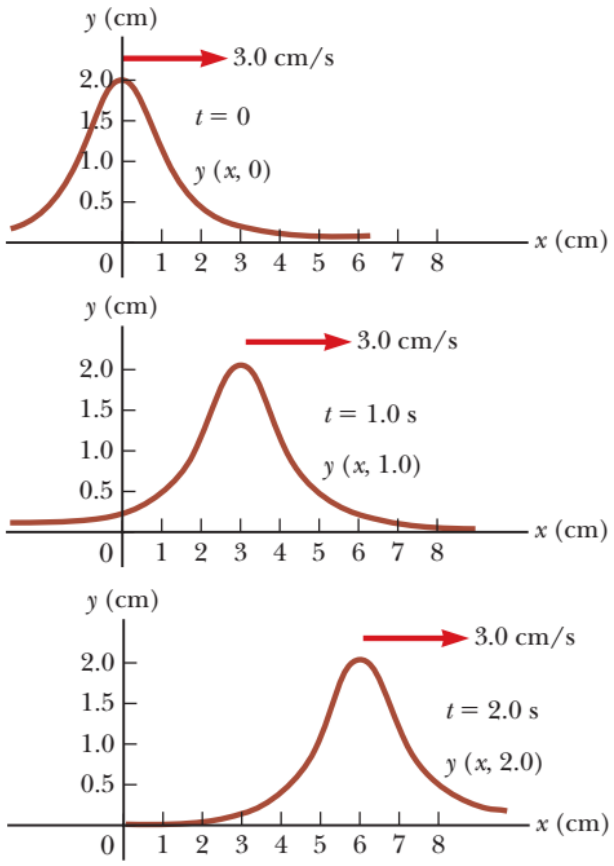
$$y(x,0)=\frac{2}{(x-3\cdot 0)^2+1}=\frac{2}{x^2+1}$$

ko'rinishga ega. Bu funksiyaning grafigi x=0 to'g'ri chiziqqa (ya'ni Oy o'qqa) nisbatan simmetrik hamda x=0 nuqtada y=2 ga teng maksimal qiymat qabul qiladi. Shunga asosan t=0 s vaqt oni uchun pulsning ko'rinishi a-rasmdagi kabi bo'ladi.

Vaqtning t=1 s oni uchun to'qin funksiyasi

$$y(x,1)=\frac{2}{(x-3\cdot 1)^2+1}=\frac{2}{(x-3)^2+1}$$

ko'rinishga ega. Bu funksiyaningg grafigi x=3 to'g'ri chiziqqa nisbatan simmetrik hamda x=3 nuqtada y=2 ga teng maksimal qiymat qabul qiladi. Shunga asosan t=1 s vaqt oni uchun pulsning ko'rinishi b-rasmdagi kabi bo'ladi.



Vaqtning t=2 s oni uchun to'qin funksiyasi

$$y(x,2)=\frac{2}{(x-3\cdot 2)^2+1}=\frac{2}{(x-6)^2+1}$$

ko'rinishga ega. Bu funksiyaningg grafigi x=6 to'g'ri chiziqqa nisbatan simmetrik hamda x=6 nuqtada y=2 ga teng maksimal qiymat qabul qiladi. Shunga asosan t=2 s vaqt oni uchun pulsning ko'rinishi c-rasmdagi kabi bo'ladi.

Yuqorida tanishib o'tgan 3 ta to'lqin funksiyasi hamda ularning grafiklaridan ko'rish mumkinki, g'alayonlanish pulsi ϑ=3 cm/s tezlik bilan o'ng tomonga qarab harakatlanmoqda ekan.

Javob: $y(x,0)=\frac{2}{x^2+1};\ y(x,1)=\frac{2}{(x-3)^2+1};\ y(x,2)=\frac{2}{(x-6)^2+1}$

Masala № 3. *Bir xil fazada tebranuvchi va atrof muhitda bir xil chastotali hamda amplitudali* $(A_1=A_2=1sm)$ *yassi to'lqin hosil qiluvchi ikkita manba bor. Birinchi manbadan ℓ_1=3,5 m va ikkinchi manbadan ℓ_2=5,4 m masofada bo'lgan muhit nuqtasining tebranish amplitudasi A ni toping. Ko'rilayotgan nuqtada tebranishlar yo'nalishi mos keladi. To'lqin uzunligi λ=0,5 m.*

Berilgan	*Yechilishi*
$A_1=A_2=1sm$ $\varphi_{0.1}=\varphi_{0.2}=0$ $\ell_1=3,5m$ $\ell_2=5,4m$ $\lambda=0,5m$	*Har ikkala manbadan tarqalayotgan to'lqinlar uchun to'lqin tenglamasini yozamiz.* $y_1(x,t)=A_1\sin\left(\frac{2\pi}{\lambda}(x-\vartheta t)+\varphi_{0.1}\right)=A_1\sin\left(\frac{2\pi}{\lambda}(x-\vartheta t)\right)$ $y_2(x,t)=A_2\sin\left(\frac{2\pi}{\lambda}(x-\vartheta t)+\varphi_{0.1}\right)=A_2\sin\left(\frac{2\pi}{\lambda}(x-\vartheta t)\right)$
A=?	*Masala shartida faqat natijaviy amplituda so'ralgani uchun*

biz to'lqin tenglamasining vaqtga bog'liq qismini tashlab yuboramiz.

$$y_1(x)=A_1\sin\left(\frac{2\pi}{\lambda}x\right),\quad y_2(x)=A_2\sin\left(\frac{2\pi}{\lambda}x\right)$$

Tenglamadagi x o'zgaruvchi o'rniga kuzatilayotgan nuqtadan manbalargacha bo'lgan masofalarni qo'yamiz va superpozitsiya prinsipidan foydalanib masalani ishlaymiz.

$$y(x)=y_1(x)+y_2(x)=A_1\sin\left(\frac{2\pi}{\lambda}x\right)+A_2\sin\left(\frac{2\pi}{\lambda}x\right)$$

$$A=A_1\sin\left(\frac{2\pi}{\lambda}\ell_1\right)+A_2\sin\left(\frac{2\pi}{\lambda}\ell_2\right)=A_1\sin\left(\frac{2\pi}{0,5m}\cdot 3,5m\right)+A_2\sin\left(\frac{2\pi}{0,5m}\cdot 5,4m\right)=$$

$$=A_1\sin(14\pi)+A_2\sin(20,8\pi)=1,73sm$$

Javob: *A=1,73 sm*

27-amaliy mashg‘ulot topshirig‘i

27.1. *18 m* oraliqqa *4,5* ta to‘lqin uzunligi joylashsa, bu to‘lqin uzunligi qanday (m)? **Javob:** *4 m*

27.2. To‘lqin tarqalish yo‘nalishida olingan bir to‘g‘ri chiziqda yotuvchi ikki nuqta tebranishlarining fazalari farqi 2π ga teng. Agar shu nuqtalar orasidagi masofa *2 m* bo‘lsa, to‘lqin uzunligi qanday? **Javob:** *2 m*

27.3. Qayiq *1,5 m/s* tezlik bilan tarqalayotgan to‘lqin ustida tebranmoqda. To‘lqinning bir-biriga eng yaqin ikki do‘ngligi orasidagi masofa *9 m*. Qayiqning tebranishlar davrini toping. **Javob:** *6 s*

27.4. Tebranish chastotasi *165 Hz* bo‘lgan to‘lqin *330 m/s* tezlikda tarqalmoqda. To‘lqin uzunligi qanday? **Javob:** *2 m*

27.5. Agar tovush manbaidan *1,7 km* masofadagi to‘siqaan qaytgan aks sado, tovush chiqarilgach 10 s dan so‘ng eshitilgan bo‘lsa, tovushning shu muhitda tarqalisn tezligi qanday? **Javob:** *340 m/s*

27.6. Tovush havodan suvga o‘tganda, uning to‘lqin uzunligi qanday o‘zgaradi? Tovushning havodagi tezligi $v_x=330$ *m/s*, suvdagi tezligi $v_c=1485$ *m/s*. **Javob:** *4,5 marta ortadi*

27.7. Tovush havodan po‘latga o‘tganda, to‘lqin uzunligi qanday o‘zgaradi? Tovushning havodagi tezligi *340 m/s* ga, po‘latdagisi esa *5100 m/s* ga teng. **Javob:** *15 marta ortadi*

27.8. Davri $T=1,2$ *s* va tebranish amplitudasi $A=2$ *sm* bo‘lgan to‘lqin $\vartheta=15$*m/s* tezlik bilan tarqalmoqda. Manbaning tebranishi boshlanishidan $t=4$ *s* vaqt o‘tgandan keyin paytda manbadan $x=45$ *sm* uzoqlikdagi masovada siljish $y(x,t)$ nimaga teng? **Javob:** $y(x,t)= -1,73$ *sm*

27.9. Bir-biridan $\Delta x=50$ *sm* masofada bo‘lgan ikki nuqta $\vartheta=50$ *m/s* tezlik bilan tarqalayotgan to‘lqin chizig‘ida yotadi. Tebranish davri $T=0,05$ *s*. Bu nuqtalardagi tebranishlar qanday $\Delta\varphi$ fazalar farqiga ega? **Javob:** $\Delta\varphi = 72^0$

27.10. Agar muhitning bir-biridan $\Delta x=10$ *sm* masofadagi ikki nuqtasi tebranishlarining fazalar farqi $\Delta\varphi=\pi/3$ bo‘lsa, elastik muhitda bu to‘lqin qanday ϑ tezlikda tarqaladi? Tebranis chastotasi $v=50$ *Gs*. **Javob:** *15 m/s*

28-MAVZU: Tovush hodisalari. Doppler effekti. Tovushning intensivligi, qattiqligi va foni

Mavzuga oid muhim formulalar

$\vartheta = \sqrt{\frac{\gamma RT}{M}}$	*Gazlarda tovushning tarqalish tezligi*
$\vartheta = \sqrt{\frac{E}{\rho}}$	*Qattiq jismlarda tovushning tarqalish tezligi*
$I = \frac{W}{St} = \frac{N}{S} \quad \left[\frac{Vt}{m^2}\right]$	*Tovush to'lqinining intensivligi*
$L = \lg\left(\frac{I}{I_o}\right)$ [B] *yoki* $L = 10\lg\left(\frac{I}{I_o}\right)$ [dB]	*Tovush qattiqligi*
Bir necha manba hosil qilgan qattiqliklarni qo'shish $L = 10 \cdot \lg\left(e^{L_1/10} + e^{L_2/10} + e^{L_3/10} + ...e^{L_N/10}\right)$ [dB] $L = 10 \cdot \left(\lg N + L\right)$ [dB]	

Doppler siljishi $\nu' = \frac{\vartheta \pm \vartheta_K}{\vartheta \mp \vartheta_M}\nu$	Kuzatuvhchi tinch turibdi	Kuzatuvhchi manba tomonga harakatlanmoqda	Kuzatuvhchi manbadan uzoqlashmoqda
Manba tinch turibdi	$\nu' = \nu$	$\nu' = \frac{\vartheta + \vartheta_K}{\vartheta}\nu$	$\nu' = \frac{\vartheta - \vartheta_K}{\vartheta}\nu$
Manba kuzatuvhchi tomonga harakatlanmoqda	$\nu' = \frac{\vartheta}{\vartheta - \vartheta_M}\nu$	$\nu' = \frac{\vartheta + \vartheta_K}{\vartheta - \vartheta_M}\nu$	$\nu' = \frac{\vartheta - \vartheta_K}{\vartheta - \vartheta_M}\nu$
Manba kuzatuvhchidan uzoqlashmoqda	$\nu' = \frac{\vartheta}{\vartheta + \vartheta_M}\nu$	$\nu' = \frac{\vartheta - \vartheta_K}{\vartheta + \vartheta_M}\nu$	$\nu' = \frac{\vartheta + \vartheta_K}{\vartheta + \vartheta_M}\nu$

28-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. *Tovush to'lqinining ν=1000 Gs chastotasi uchun intensivlik qiymatlari eshitish bo'sag'asida $I_0 = 10^{-12}\frac{W}{m^2}$ ga, quloqda og'riq hosil qilish bo'sag'asida $I_{\max} = 10\frac{W}{m^2}$ ga teng bo'lsa, u holda havo molekulalari qanday*

amplitudalar bilan tebranadi? Havoning zichligi $\rho = 1,29\frac{kg}{m^3}$ *, tovush tezligi* $\vartheta = 330\frac{m}{s}$.

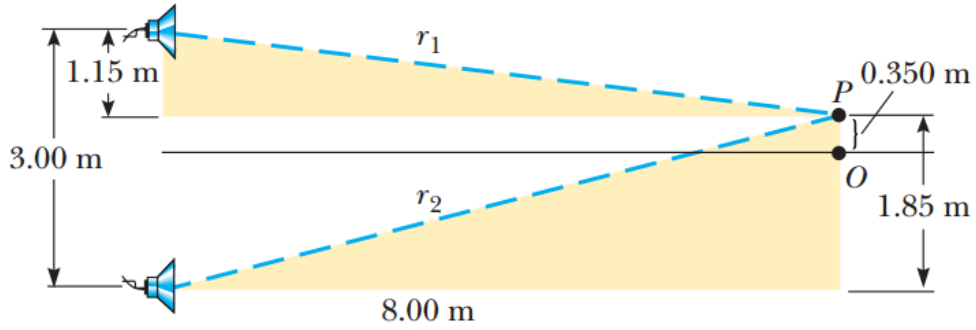
Berilgan	*Yechilishi*
$\nu = 1000\,Gs$	*To'lqin energiyasi formulasi*
$I_0 = 10^{-12}\frac{W}{m^2}$	$E = \frac{m_0\vartheta^2}{2} = \frac{\rho V(\omega A)^2}{2} = \frac{1}{2}\rho V\omega^2 A^2$
$I_{max} = 10\frac{W}{m^2}$	*Intensivlik formulasi*
$\rho = 1,29\frac{kg}{m^3}$	$I = \frac{E}{St} = \frac{E\vartheta}{V} = \frac{1}{2}\rho V\omega^2 A^2\cdot\frac{\vartheta}{V} = \frac{1}{2}\rho\vartheta\omega^2 A^2$
$\vartheta = 330\frac{m}{s}$	*dan amplituda formulasini hosil qilamiz.*
	$A = \frac{1}{\omega}\sqrt{\frac{2I}{\rho\vartheta}} = \frac{1}{2\pi\nu}\sqrt{\frac{2I}{\rho\vartheta}}$
A=?	*Endi har bir hol uchun hisoblash ishlarini bajaramiz.*

$$A_1 = \frac{1}{2\pi\nu}\sqrt{\frac{2I_1}{\rho\vartheta}} = \frac{1}{2\pi\cdot 1000\,Gs}\sqrt{\frac{2\cdot 10^{-12}\frac{W}{m^2}}{1,29\frac{kg}{m^3}\cdot 330\frac{m}{s}}} = 1,09\cdot 10^{-11}m$$

$$A_2 = \frac{1}{2\pi\nu}\sqrt{\frac{2I_1}{\rho\vartheta}} = \frac{1}{2\pi\cdot 1000\,Gs}\sqrt{\frac{2\cdot 10\frac{W}{m^2}}{1,29\frac{kg}{m^3}\cdot 330\frac{m}{s}}} = 3,45\cdot 10^{-5}m$$

Javob: *A_1=1,09·10^{-11} m; A_2=3,45·10^{-5} m*

Masala № 2. *Bir-biridan 3 m masofada turgan ikkita tovush karnayi bir xil tebranadi. Karnaylarni tutashtiruvchi chiziqning o'rtasidan 8 m masofada O nuqtada tinglovchi turibdi. Keyin tinglovchi O nuqtadan 0,35 m masofada turgan P nuqtaga tomon yura boshladi (rasmga qarang). P nuqtaga yetganda birinchi minimum tufayli tovush eshitilmay qoldi. Karnaylar qanday chastota bilan tebranmoqda? Tovush tezligi 343 m/s.*



Yechilishi:

P nuqtadan karnaylargacha bo'lgan r_1 va r_2 masofalarni topamiz.

$$r_1 = \sqrt{(8m)^2 + (1{,}15m)^2} = 8{,}08\ m$$

$$r_2 = \sqrt{(8m)^2 + (1{,}85m)^2} = 8{,}21\ m$$

Yo'llar farqini topamiz.

$$\Delta r = r_2 - r_1 = 8{,}21m - 8{,}08m = 0{,}13\ m$$

P nuqtada dastlabki minimum sharti (n=0) bajarilgani uchun minimum shartidan foydalanib karnaylar chiqarayotgan tovush to'lqinlarining uzunligini aniqlaymiz.

$$\Delta r = (2n+1)\frac{\lambda}{2} = \frac{\lambda}{2}, \ \rightarrow \ \lambda = 2\Delta r = 0{,}26\ \text{m}$$

Endi tovush to'lqini (ya'ni karnaylarning tebranish) chastotasini aniqlaymiz.

$$\vartheta = \lambda\nu, \ \rightarrow \ \nu = \frac{\vartheta}{\lambda} = \frac{343m/s}{0{,}26m} = 1300\ Gs = 1{,}3\ kGs$$

Javob: *v=1,3 kGs*

Masala № 3. *Ertalab tongda soatning uyg'otuvchi signali yoqildi va 600 Gs chastota bilan jiringlashni boshladi. Uyqusini qizg'angan o'quvchi soatni o'chirib qo'yib yana uxlamoqchi b'oldi. Lekin, soatning signalni o'chiruvchi tugmasi ishdan chiqqanligi sababli o'chmasdan jiringlashni davom etdi. Shunda jahli chiqqan o'quvchi soatni 15 m balandlikdagi to'rtinchi qavat derazasidan uloqtirdi. O'quvchi soatning yer sirtiga urilishdan oldingi jiringlash ovozini qanday chastota bilan eshitadi? Tovush tezligini 343 m/s erkin tushish tezlanishini 9,8 m/s² deb oling.*

Berilgan	*Yechilishi*
v=600 Gs	*Soat yerga tushayotganda kuzatuvchidan uzoqlashuvchi manba vazifasini o'taydi. Soatning yerga urilish tezligi bizga kinematikadan tanish bo'lgan formula bilan aniqlanadi.*
ϑ=343 m/s	
h=15 m	
g=9,8 m/s²	
v_K=?	

$$\vartheta_{tush} = \sqrt{2gh} = \sqrt{2 \cdot 9{,}81\frac{m}{s^2} \cdot 15m} \approx 17\frac{m}{s} = \vartheta_M$$

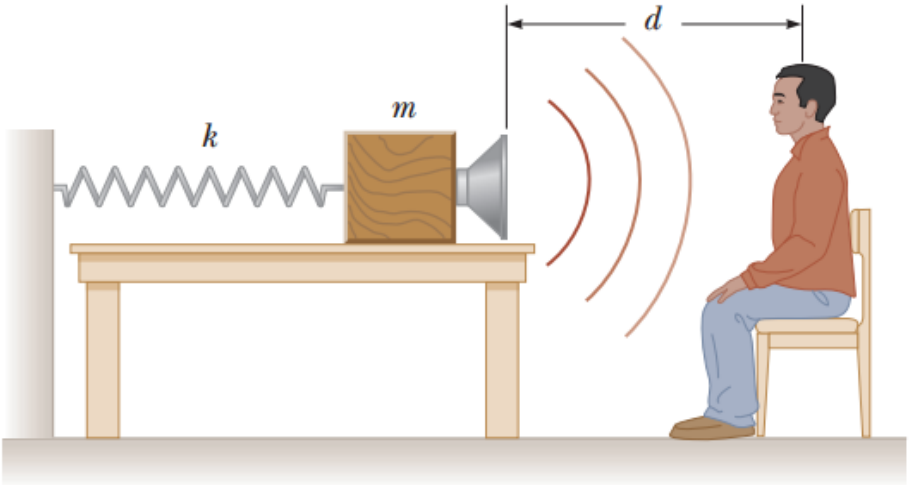
Endi o'quvchi uchun tuyulma chastotani aniqlaymiz.

$$\nu' = \frac{\vartheta}{\vartheta + \vartheta_M}\nu = \frac{343\frac{m}{s}}{343\frac{m}{s} + 17\frac{m}{s}} \cdot 600\,Gs \approx 571{,}7\ Gs$$

Javob: *v_K=571,7 Gs*

Masala № 4. *Stolning silliq ustida turgan kolonka bikrligi k=20 N/m bo'lgan prujina orqali vertikal devorga rasmdagi kabi mahkamlangan. Kolonka va prujinananing birgalikdagi massasi m=5 kg ga teng bo'lib, prujina elastikligi*

tufayli kolonka A=0,5 m amplituda bilan erkin tebranmoqda. Kolonka v=440 Gs ga teng monochastotali tovush chiqaradi. Kuzatuvchi qabul qiladigan eng katta va eng kichik tuyulma chastotalarni aniqlang.



Berilgan	*Yechilishi*
v=440 Gs	*Prujina o'z tebranishi davomida faqat muvozonat*
A=0,5 m	*vaziyatidan o'tish onidagina maksimal tezlikka erishadi.*
m=5kg	*Tezlikning bu qiymatiga amplitda deyiladi va u quyidagicha*
k=20 N/m	*bo'ladi:*
$\nu'_{max}, \nu'_{min} = ?$	

$$\vartheta_{max} = A\sqrt{\frac{k}{m}} = 0,5m \cdot \sqrt{\frac{20\,N/m}{5kg}} = 1\frac{m}{s}$$

Prujina tebranma harakati tufayli kuzatuvchiga yaqinlashishi

yoki undan uzoqlashishi mumkin. Kuzatuvchi qabul qiladigan tuyulma chastotaning qiymati kolonka yaqinlashayotganda eng katta, uzoqlashayot-ganda esa eng kichik bo'ladi. Tuyulma chastotaning ana shu qiymatlarini aniqlaymiz. Tovush tezligini 340 m/s deb oling.

$$\nu'_{max} = \frac{\vartheta}{\vartheta - \vartheta_{max}}\nu = \frac{340\frac{m}{s}}{340\frac{m}{s} - 1\frac{m}{s}} \cdot 440\,Gs = 441,3\,Gs$$

$$\nu'_{min} = \frac{\vartheta}{\vartheta + \vartheta_{max}}\nu = \frac{340\frac{m}{s}}{340\frac{m}{s} + 1\frac{m}{s}} \cdot 440\,Gs = 538,7\,Gs$$

Javob: $\nu'_{max} = 441,3\,Gs,\ \nu'_{min} = 438,7\,Gs$

28-amaliy mashg'ulot topshirig'i

28.1. Tovush *290 K* va *350 K* temperaturalarda havoda qanday tezlikda tarqaladi?
Javob: *339 m/s; 375 m/s*

28.2. Tovush manbaidan $\ell=800\ m$ masofada turgan kuzatuvchi havodan kelgan tovushni suvdan kelgan tovushga nisbatan $\Delta t=1,7\ s$ kech eshitadi. Agar havoning harorati $T=320\ K$ bo‘lsa, tovushning suvdagi tezligi topilsin. **Javob:** *1500 m/s*

28.3. Dengiz chuqurligini exolot bilan aniqlashda tovush signali yuborilganidan *6 s* o‘tgach qaytib kelgan. Agar dengiz chuqurligi *4500 m* bo‘lsa, tovushning suvdagi tezligi qanday (*m/s*)? **Javob:** *1500 m*

28.4. Dengiz chuqurligi exolot yordamida aniqlanadi. Agar exolotdan yuboriigan ultratovush impulslari *2 s* dan so‘ng qaytgan bo‘lsa, dengiz chuqurligi qanday (*m*)? Tovushning suvda tarqalish tezligi *1480 m/s*. **Javob:** *1480 m*

28.5. Bo'ylama tebranishlarning ushbu elestik muhitlarda tarqalish tezliklari aniqlansin: *a)* alyuminiy; *b)* mis; *c)* volfram. Bu elastik muhitlarning zichliklari mos holda *2700 kg/m^3, 8900 kg/m^3, 19300 kg/m^3* ga, elastik (Yung) modullari esa mos holda *69 GPa, 98 GPa, 380 GPa* ga teng. **Javob:** *a) 5060 m/s; b) 3310 m/s; c) 4440 m/s*.

28.6. **Yer sirtidagi havoning temperaturasi T=300 K. Yuqorga ko‘tarilgan sari har 100 metrda temperatura $\Delta T=1,7\ K$ ga sovib boradi. Yerdan tarqalgan tovush qancha vaqtda $h=8000\ m$ balandlikka yetib boradi? **Javob:** *25,8 s*

28.7. Tovushning intensivligi $I=1\ W/m^2$. Agar tovush normal sharoitda tarqalayotgan bo‘lsa, tovush to‘lqini energiyasining o‘rtacha hajmiy zichligi ω nimaga teng? **Javob:** *3 mJ/m^3*

28.8. Gudogining chastotasi $\nu=300\ Gs$ bo‘lgan harakatsiz elektrovoz yonidan $\vartheta_K=40\ m/s$ tezlik bilan poyezd o‘tmoqda. Poyezddagi yo‘lovchi uchun gudok ovozining tuyulma chastotasi qanday? *a)* Poyezd elektrovozga yaqinlashmoqda; *b)* poyezd elektrovozdan uzoqlashmoqda. Tovush tezligini *340 m/s* deb oling. **Javob:** *a) 336 Gs; b) 265 Gs*

28.9. Poyezd harakatsiz kuzatuvchining yonidan o‘tganida signal tovushining balandligi keskin o‘zgaradi. Agar poyezdning tezligi $\vartheta_M=15\ m/s$ bo‘lsa, chastotaninf nisbiy o‘zgarishi $\Delta\nu/\nu$ nimaga teng? Tovush tezligini *340 m/s* deb oling. **Javob:** *0,09*

28.10. Poyezd $\vartheta_M=120\ km/soat$ tezlik bilan harakatlanmoqda. U $\tau_0=5\ s$ davom etuvchi gudok chaldi. Harakatsiz kuzatuvchi uchun bu hushtakning tuyulma eshitish vaqti qancha davom etadi? *a)* Poyezd kuzatuvchiga yaqinlashmoqda; *b)* poyezd kuzatuvchidan uzoqlashmoqda. Tovush tezligini *348 m/s* deb oling. **Javob:** *a) 4,52 m/s; b) 5,48 m/s*

29-MAVZU: Paskal qonuni. Tutash idishlar, gidravlik press. Arximed qonuni.

Mavzuga oid muhim formulalar

$p = \frac{F}{S}$	*Bosim*
Bosimning karraliva ulushli qiymatlari $1kPa = 10^3\ Pa, \quad 1MPa = 10^6\ Pa, \quad 1GPa = 10^9\ Pa$ $1mPa = 10^{-3}\ Pa, \quad 1\mu Pa = 10^6\ Pa, \quad 1nPa = 10^{-9}\ Pa, \quad 1pkPa = 10^{-12}\ Pa$	
Normal atmosfera bosimi $1atm. = 760\,mm.sm.ust = 101\,325\ Pa$ $p_{atm} = \rho_{simob} g\,h = 13600 \cdot 9{,}8 \cdot 0{,}76 = 101\,325\ Pa$ $1mm.sm.ust = 9{,}8\ m/s^2 \cdot 13600\ kg/m^3 \cdot 10^{-3}\ m = 133{,}3\ Pa$	
$p_h = p_0 \cdot e^{-\frac{m_0 g h}{kT}} = p_0 \cdot e^{-\frac{M g h}{RT}}$	*Atmosfera bosimining balandlikka bog'liqligi*
$p = \frac{F}{S} = \rho g h$	*Gidrostatik bosim*
$\frac{F_2}{F_1} = \frac{S_2}{S_1} = \frac{h_1}{h_2}$	*Gidravlik press formulasi*
$\frac{h_2}{h_1} = \frac{\rho_1}{\rho_2}$	*Tutash idish formulasi*
$p_{yon} = \frac{1}{2}\rho g h$	*Idish yon devoriga beriladigan o'rtacha gidrostatik bosim*
$p_{um.yon} = p_{atm} + \frac{1}{2}\rho g h \approx 10^5 + \frac{1}{2}\rho g h$	*Idish yon devoriga beriladigan o'rtacha umumiy bosim*
$F_{yon} = p_{yon} S_{yon} = \frac{1}{2}\rho g h S$	*Idish yon devoriga beriladigan o'rtacha gidrostatik bosim kuchi*
$F_{yon} = p_{yon} S_{yon} = \frac{1}{2}\rho g h S$	*Idish asosiga beriladigan o'rtacha gidrostatik bosim kuchi*
$F_A = P_0 = \rho_s V_j g$	*Arximed kuchi*
$V_1 = \frac{\rho_j}{\rho_s} \cdot V_j, \quad V_2 = \frac{\rho_s - \rho_j}{\rho_s} \cdot V_j$	*Cho'kmaydigan jismning cho'kkan va cho'kmagan qismi*
$F = F_A - F_{og'} = (\rho_s - \rho_j) V_j g$	*Cho'kmaydigan jismning yuk ko'tarish qobiliyati*
$P = F_{og'} - F_A = (\rho_j - \rho_s) V_j g$	*Cho'kuvchi jismning suyuqlikdagi og'irligi*
$a = \frac{\rho_j - \rho_0}{\rho_j} g$	*Cho'kuvchi jismning cho'kish tezlanishi*

29-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Hamshira bemorga ukol yubormoqda. Ukol porsheni radiusi *1,1 sm* bo‘lib, hamshira porshenni *42 N* kuch bilan bosmoqda. Bunda suyuqlik qancha qo‘shimcha bosim oladi?

Berilgan:

$F=42\ N$

$r=1,1\ sm$

$\Delta P=?$

Yechilishi:

Porshen yuzasini topamiz.

$$S=\pi r^2=3,14\cdot\left(1,1\cdot10^{-2}\right)^2=3,8\cdot10^{-4}m^2$$

Qo‘shimcha bosimni topamiz.

$$\Delta P=\frac{F}{S}=\frac{42}{3,8\cdot10^{-4}}=1,105\cdot10^5\ Pa=110,5\ kPa$$

Javob: $\Delta P=110,5\ kPa$

Masala № 2. Slindrik idishga bir-biri bilan aralashmaydigan uchta suyuqlik quyildi. Ularning hajmlari va zichliklari mos holda $V_1=0,5l,\ \rho_1=2,6\frac{g}{sm^3}$, $V_2=0,25l,\ \rho_2=1\frac{g}{sm^3}$, $V_3=0,4l,\ \rho_3=0,8\frac{g}{sm^3}$ ga teng. $1l=1000\,sm^3$. Suyuqliklar idish tubiga qanday kuch bilan bosadi?

Berilgan:

$V_1=0,5l,\rho_1=2,6\frac{g}{sm^3}$

$V_2=0,25l,\ \rho_2=1\frac{g}{sm^3}$

$V_3=0,4l,\ \rho_3=0,8\frac{g}{sm^3}$

F=?

Yechilishi:

Suyuqlilar hajmlari

$V_1=0,5l=500\,sm^3, V_2=0,25l=250\,sm^3, V_3=0,4l=400\,sm^3$

ga, massalari esa

$$m_1=\rho_1V_1=2,6\frac{g}{sm^3}\cdot500\,sm^3=1300\,g=1,3kg$$

$$m_2=\rho_2V_2=1\frac{g}{sm^3}\cdot250\,sm^3=250\,g=0,25kg$$

$$m_3=\rho_3V_3=0,8\frac{g}{sm^3}\cdot400\,sm^3=320\,g=0,32\,kg$$

ga teng bo‘ladi. Har bir suyuqlikning og‘irliklari qo‘shilib idish tubiga ko‘rsatiladigan jami og‘irlikni hosil qiladi.

$$F=\left(m_1+m_2+m_3\right)g=\left(1,3+0,25+0,32\right)\cdot9,81=18,35\,N$$

Javob: $F=18,35\ N$

Masala № 3. Havo nasosining ixtirochisi *Otto von Guericke* 1654-yilda ancha avval 8 tadan otni ikki tomonga tortib ocha olmagan ikkita yarimsferaga demonstratsion ko‘rinish berdi. U yarimsferani juda mustahkam va *R* radiusli yupqa devorli deb hisobladi. Yarimsferalarni ochish uchun talab etiladigan kuch miqdori $F=\pi R^2\Delta P$ formuladan aniqlanadi deb taxmin qildi. Bunda ΔP – sfera

ichidagi va tashqarisidagi bosimlar farqi. Radius $R = 30\,sm$, ichki bosim $P_1 = 0{,}1atm$ va tashqi bosim $P_2 = 1atm$ deb hisoblab, yarimsferalarni ochish mumkin bo'lgan kuchning qiymatini aniqlang. $1atm = 101{,}3kPa$.

Berilgan:

$R = 30\,sm$

$P_1 = 0{,}1atm$

$P_2 = 1atm$

$F = ?$

Yechilishi:

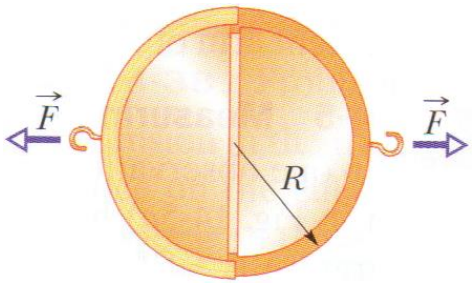
Sfera ko'ndalang kesim yuzasini topamiz.

$S = \pi R^2 = 3{,}14 \cdot (0{,}3)^2 = 0{,}2826\,m^2$

Bosimlar farqini topamiz.

$\Delta P = P_2 - P_1 = 1atm - 0{,}1atm =$

$= 0{,}9\,atm = 91{,}17\ kPa$



So'ralgan kuchni topamiz.

$F = \pi R^2 \Delta P = S\,\Delta P = 0{,}2826\ m^2 \cdot 91{,}17\,kPa = 25{,}76\,kN$.

Javob: $F = 25{,}76\ kN$

Masala № 4. Bo'yi *183 sm* bo'lgan odamning miyasidagi va oyog'idagi gidrostatik qon bosimlar farqini aniqlang. Qonning zichligi *1060 kg/m³*. $g = 9{,}81\ m/s^2$.

Berilgan:

$h = 183\ sm$

$\rho = 1060\ kg/m^3$

$g = 9{,}81\ m/s^2$

$E_{k.\max} = ?$

Yechilishi:

Girostataik bosimlar farqi ushbu

$\Delta P = \rho g h$

formulaga asosan

$\Delta P = 1024 \cdot 1{,}83 \cdot 9{,}81 = 18383\,Pa = 18{,}383\ kPa$

bo'ladi

Javob: *18,383 kPa*

Masala № 5. Uzoq masq qilgan g'avvoslar o'pkasi ko'krak bo'slig'i ichida va tashqarisida bosimlar farqi *0,6 atm* gacha yuklanishga dosh bera oladi. Bu g'avvos o'lik dengizga qurollanmagan (skafandersiz) holda necha metrgacha chuqurlikkacha tusha oladi? O'lik dengiz suvi zichligi $1500\ kg/m^3$ga teng. $1\ atm = 101{,}3\ kPa,\ g = 9{,}81\ m/s^2$.

Berilgan:

$\Delta P = 0{,}06\ atm$

$\rho = 1500\ kg/m^3$

$g = 9{,}81\ m/s^2$

$1\ atm = 101{,}3\ kPa$

h=?

Yechilishi:

Girostataik bosimlar farqi ushbu

$\Delta P = \rho g h$

formulaga asosan, chuqurlik

$$h = \frac{\Delta P}{\rho g} = \frac{0{,}6 \cdot 101300}{1500 \cdot 9{,}81} = 4{,}13m$$

bo'ladi

Javob: 4,*13 m*

Masala № 6. Rasmda bikrligi $k = 3,75 \cdot 10^4\ N/m$ bo‘lgan prujina gidravlik pressning tashqi tomoni va qattiq tirgak balka orasida turgani tasvirlangan. Vaznsiz bo‘sh idish kichik yuzali porshen ustida turibdi. Kichik porshen yuzasi *S* ga, katta porshen yuzasi esa *18 S* ga teng. Dastlab prujina deformatsiyalanmagan holatda turibdi. Prujina 5 sm ga siqilish uchun bo‘sh idishga necha kilogramm qum solish kerak bo‘ladi? $g = 9,81\ m/s^2$.

Berilgan:

$k = 3,75 \cdot 10^4\ N/m$

$S_1 = S,\ S_2 = 18S$

$x = 5\,sm$

$g = 9,81\ m/s^2$

m=?

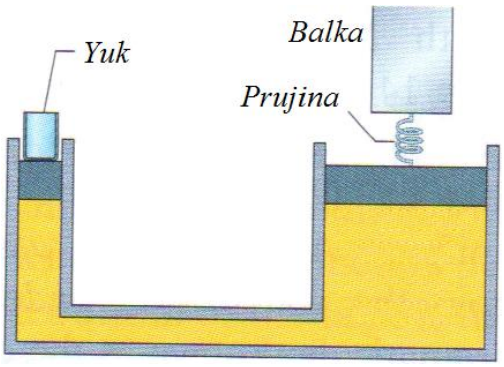
Yechilishi:

Prujina x=5 sm ga deformatsiyalanganda unda

$F_2 = kx = 3,75 \cdot 10^4 \cdot 0,05 = 1875\,N$

ga teng elastiklik kuchi hosil bo‘ladi. Bu kuch katta yelkada

$P_2 = \dfrac{F_2}{S_2} = \dfrac{1875}{18S}$



ga teng bosim hosil qiladi. Mos holda birinchi yelkada ham

$$P_1 = \frac{F_1}{S_1} = \frac{mg}{S} = \frac{9,81m}{S}$$

ga teng bosim hosil bo‘ladi. Paskal qonuniga ko‘ra yelkalardagi bosimlar teng.

$$P_1 = P_2,\ \rightarrow\ \frac{9,81m}{S} = \frac{1875}{18S},\ \rightarrow\ m = \frac{1875}{18 \cdot 9,81} = 10,62\,kg.$$

Javob: 10,*62 kg*

29-amaliy mashg‘ulot topshirig‘i

29.1. Suv, spirt va simobda *0,5 m* chuqurlikda bosimni aniqlang. Spirtning zichligi $800\,kg/m^3$ ga teng. **Javob:** *4,9 kPa; 3,9 kPa; 66,6 kPa*

29.2. Suvning erkin sirtiga bo‘lgan atmosfera bosimi balandligi *750 mm* bo‘lgan simob ustunining bosimiga teng bo‘lsa, suvda qanday chuqurlikda to‘la bosim $5 \cdot 10^5\,Pa$ ga teng bo‘ladi? **Javob:** *~ 40 m*

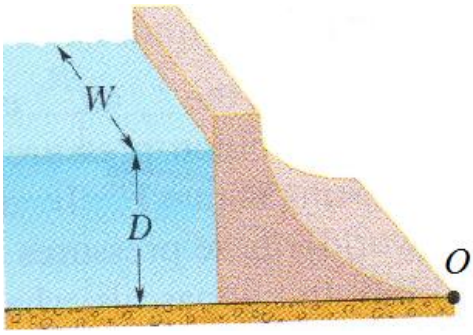
29.3. Balandligi *5 m* bo‘lgan katta akvarium *2 m* balandlikkacha toza suv bilan to‘ldirilgan. Akvariumning bitta yon devori plastikdan ishlangan bo‘lib, uning eni *9 m* ga teng. Agar akvariumga yana sub quyish natijasida suv sathi *4m* gacha oshgan bo‘lsa, shu yon devorga ta’sir qiluvhci gidrostatik bosim kuchi qanchaga oshgan? $g = 10\ m/s^2$. **Javob:** $\Delta F = 540\,kN$

29.4. Offis derazasi $3,4m \times 2,1m$ o‘lchamga ega. Bo‘ron ko‘tarilishi tufayli tashqaridagi bosim *0,93 atm* gacha tushib ketadi. Lekin, ichkaridagi bosim *1 atm* ga teng. Qanday

kattalikdagi natijaviy bosim kuchi tashqatiga yo‘nalgan bo‘ladi? $1atm = 101,3kPa$.

Javob: *50,63 kN*

29.5. To‘g‘ondagi suv to‘sig‘ining balandligi *D=35 m*, eni *W=314 m* ga teng. Quyidagilarni aniqlang: a) To‘g‘onning vertikal devoriga suv ustunining gidrostatik bosim kuchini; b) bu bosim kuchining to‘g‘onning *O* nuqtasiga nisbatan aylantirubchi momentini (shu moment to‘g‘onni yemirilishiga olib keladi) $g = 9,81\ m/s^2$. **Javob:**

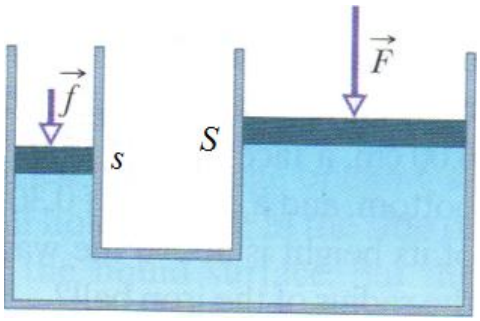


$a) F = 1,887 \cdot 10^7\ N;\ b) M = 3,3 \cdot 10^{10}\ Nm$

29.6. Gidravlik pressda kichik porshenning yuzi $6sm^2$, katta porshenning yuzi esa $600sm^2$. Kichik porshenga *400 N* kuch, kattasiga *36 000 N* kuch ta’sir etadi. Bu press kuchdan qancha yutuq beradi? Ishqalanish bo‘lmaganda-chi? **Javob:** *90 marta; 10 marta;*

29.7. Yuzi $250sm^2$ bo‘lgan nasos porsheniga suyuqlikning ko‘rsatayotgan bosimi $12 \cdot 10^5\ Pa$ ga teng bo‘lsa, bosim kuchini muvozonatlovchi kuch qanday bo‘ladi? **Javob:** *29,4 kN*

29.8. Rasmdagi gidravlik pressning yuzasi *s* bo‘lgan kichik porsheniga *f* ga teng kuch qo‘yilgan. Yuzasi *S* ga teng katta porshen tinch turish uchun unga qanday *F* kuch qo‘yish kerak bo‘ladi? Agar diametrlari *3,8 sm* va *53 sm* bo‘lgan muvozonatda turgan porshenlarning kattasiga *F=20kN* kuch qo‘yilgan bo‘lsa, u holda kichik yelkadagi *f* kuch nimaga teng?



Javob: $F = \frac{S}{s} f;\ f = \left(\frac{r}{R}\right)^2 F = 103N$

29.9. Tutash idishlarda balandligi *10,35 sm* bo‘lgan suv ustuni balandligi *11,5 sm* bo‘lgan mineral moy ustuni bilan muvozonatlashib turibdi. Shu moyning zichligini aniqlang. **Javob:** $900\ kg/m^3$

29.10. Birining diametri ikkinchisidan 4 martta katta bo‘lgan ikkita tutash idishga simob solingan. Agar kichik diametrli idishga balandligi *70 sm* bo‘lgan suv solinsa, simob sathlari qanchaga o‘zgaradi? **Javob:** $\Delta h_1 = 0,3sm;\ \Delta h_2 = 4,8sm$

29.11. Barometr tog‘ etagida $1,013 \cdot 10^5\ Pa$ ni, tog‘ cho‘qqisida esa $0,962 \cdot 10^5\ Pa$ ni ko‘rsatdi. Tog‘ning balandligi qancha? **Javob:** *~ 460 m*

29.12. Zichligi $7870\ kg/m^3$ bo‘lgan po‘latdan yasalgan langar suvga tashlanganda u *210 N* ga yengillasdi. Langarning hajmi va massasi nimaga teng? $g = 9,81\ m/s^2$.

Javob: $V = 21,4l;\ m = 168,5kg$

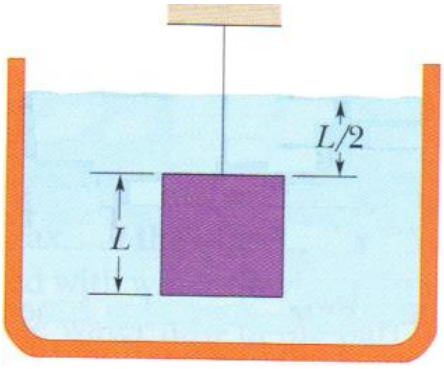
29.13. Ichki radiusi *8 sm*, tashqi radiusi *9 sm* bo‘lgan ichi bo‘sh shar zichligi $820\,kg/m^3$ bo‘lgan suyuqlikda yarmi botgan holda suzmoqda. Shar materialining zichligi va massasi nimaga teng? $g=9{,}81\,m/s^2$. **Javob:** $\rho=4905\,kg/m^3;\ m=4{,}456\,kg$.

29.14. Kema kapitani zichligi $917\,kg/m^3$ bo‘lgan aysbergning qanday qismini (protsentda) ko‘rishi mumkin? Dengiz suvining zichligi $1024\,kg/m^3$ ga teng. Agar dengiz suvi chuchuk suv bo‘lganida-chi? **Javob:** *89,55%; 91,7%*

29.15. Og‘irligi 356 N dan bo‘lgan uchta bola diametri 30 sm, uzunligi 2 m, zichligi $800\,kg/m^3$ bo‘lgan to‘sinlardan sol yasahdi. Bolalar chuchuk suvda cho‘kmasdan suzib ketishi uchun nechta to‘sin kerak bo‘ladi? $g=9{,}81\,m/s^2$. **Javob:** *4ta*

29.16. Ichida g‘ovagi bo‘lgan po‘lat jism havoda *6000 N*, toza suvda *4200 N* og‘irlikka ega. Po‘lat jism materialining zichligi $7870\,kg/m^3$ ga teng. G‘ovakning hajmi nimaga teng? $g=9{,}81\,m/s^2$. **Javob:**

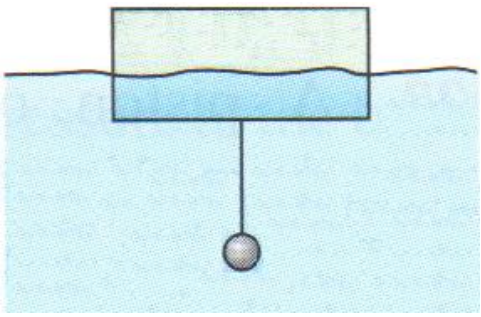
29.17. Qirrasi *L=0,6 m* va massasi *m=450 kg* bo‘lgan kub zichligi $\rho=1030\,kg/m^3$ bo‘lgan suyuqlikda arqon yordamida to‘la botirilgan holda ushlab turilibdi. Tashqi atmosfera bosimini *1atm* deb hisoblab, kubning yuqorigi yuzasiga va pastki yuzasiga ta’sir qiluvchi umumiy bosim kuchlarini hamda ipning taranglik kuchini aniqlang. $1atm=101{,}3kPa$, $g=9{,}81\,m/s^2$. **Javob:** $F_1=37{,}56\,kN;$ $F_2=39{,}74kN;T=2234\,N$



29.18. Agar og‘irligi *7,8 N* bo‘lgan metall parchasining suvdagi og‘irligi 6,8 N ga, bennzindagi og‘irligi *7,1 N* ga teng bo‘lsa, metallning zichligi qanday? **Javob:** 2500 / *kg m*3

29.19. Ruxdan ichi g‘ovak qilib yasagan va tashqi hajmi $300\,sm^3$ bo‘lgan shar suvda yarmi botgan holda suzib yuribdi. Shardagi g‘ovak qismning hajmini aniqlang (sm^3). **Javob:** *279*

29.20. Po‘lat sharcha vaznsiz ip yordamida slindrning tagidan osib qo‘yilgan. Slindrning tepa va pastki asoslari yuzalari *12* sm^2, balandligi *6 sm*, zichligi *0,3* g/sm^3 ga teng bo‘lib, uning *2 sm* qismi suv yuziga chiqib turibdi. Po‘lat sharchaning radiusi nimaga teng? Po‘atning zichligi *7800* kg/m^3 ga teng. $g=9{,}81\,m/s^2$. **Javob:** *7,74 mm*



29.21. Zichligi $2{,}5\cdot 10^3$ kg/m^3 bo‘lgan plastmassa bo‘lagi suvda qanday tezlanish bilan pastga tushadi (m/s^2)? Qarshilik kuchini hisobga olmang. **Javob:** *6*

29.22. Suvdagi hajmi $0,5 m^3$ bo‘lgan qarag‘ay g‘o‘lasi *70 kg* massali odamni ko‘tarib tura oladimi? Qarag‘ayning zichligi $440 kg/m^3$ ga teng. **Javob:** *Ha*

29.23. Og‘irligi *750 N* bo‘lgan odamni ko‘tarib tura oladigan *50 sm* qalinlikdagi yassi muzning sirti eng kamida qanday bo‘lishi mumkin? Muzning zichligi $900 kg/m^3$. **Javob:** $1,5 m^2$

29.24. Jism prujinali taroziga osilgan. Tarozining ko‘rsatishi havoda *32 N*, jism suvga botirilganda *20 N* va boshqa noma’lum suyuqlikka botirilganda esa *24 N* ga teng. Noma’lum suyuqlikning zichligi nimaga teng? **Javob:** $667\ kg/m^3$

29.25. Radiusi *2sm* bo‘lgan shisha shar zichligi *1030 kg/m*^{3} bo‘lgan sutli idishning tagida cho‘kib turibdi. Idish tagining normal reaksiya kuchi *89,6 mN* ga teng. Shisha sharning zichligi va massasini aniqlang. $g = 9,81\ m/s^2$. **Javob:** $\rho = 1,273\ g/sm^3;\ m = 42,63 g$

30-MAVZU: Suyuqlik oqimlari turlari. Oqim uzluksizlik tenglamasi. Ideal suyuqliklar oqimi uchun Bernulli tenglamasi.

Mavzuga oid muhim formulalar

$S_1 \vartheta_1 = S_2 \vartheta_2 = \ldots = S_N \vartheta_N = const$ $\vartheta_1 R_1^2 = \vartheta_2 R_2^2 = \ldots = \vartheta_N R_N^2 = const$	*Oqim uzluksizlik tenglamasi*
$N = \frac{1}{2}\rho S \vartheta^3$	*Suyuqlik oqimi quvvati*
Bernulli tenglamasi $P_1 + \rho g h_1 + \frac{\rho \vartheta_1^2}{2} = P_2 + \rho g h_2 + \frac{\rho \vartheta_2^2}{2} = P_3 + \rho g h_3 + \frac{\rho \vartheta_3^2}{2} = \ldots = P_N + \rho g h_N + \frac{\rho \vartheta_N^2}{2} = const$	

30-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Daryoga ikkita daradan oqim kelib qo‘shiladi. Birinchi oqimning kengligi *8,2 m*, chuqurligi *3,4 m* ga teng bo‘lib oqum tezligi esa *2,3 m/s* ga teng. Ikkinchi oqimniki esa kengligi 6,8 m, chuqurligi *3,2 m* ga teng bo‘lib, oqim tezligi *2,6 m/s* ga teng. Agar daryoning eni *10,5 m*, tezligi *2,9 m/s* ga teng bo‘lsa, u holda daryo chuqurligi nimaga teng?

Berilgan:

$a_1 = 8,2\,m, H_1 = 3,4\,m$

$\vartheta_1 = 2,3\ m/s$

$a_2 = 6,8\,m, H_2 = 3,2\,m$

$\vartheta_2 = 2,6\ m/s$

$a_3 = 10,5\,m, \vartheta_3 = 2,9\ m/s$

$H_3 = ?$

Yechilishi:

Ikkita daradagi oqimlarning ko‘ndalang yuzalari mos holda

$S_1 = a_1 H_1 = 8,2 \cdot 3,4 = 27,88\ m^2$

$S_2 = a_2 H_2 = 6,8 \cdot 3,2 = 21,76\ m^2$

ga, daryoniki esa

$S_3 = a_3 H_3 = 10,5 \cdot H_3$ ga teng.

Uzluksizlik tenglamasini qo‘llaymiz. Bunda ikkita daradan kelayotgan suvlar yig‘indisi daryodagi suvga teng.

$$S_1 \vartheta_1 + S_2 \vartheta_2 = S_3 \vartheta_3, \ \rightarrow \ S_1 \vartheta_1 + S_2 \vartheta_2 = a_3 H_3 \vartheta_3, \ \rightarrow \ H_3 = \frac{S_1 \vartheta_1 + S_2 \vartheta_2}{a_3 \vartheta_3} =$$

$$= \frac{27,88 \cdot 2,3 + 21,76 \cdot 2,6}{10,5 \cdot 2,9} = \frac{120,7}{30,45} = 3,964\ m$$

Javob: *3,964 m*

Masala № 2. Gorizontal trubaning keng qismining diametri *6 sm*. *B* qismda suvning tezligi $30\ sm/s$, bosimi *1atm*. Shu trubaning diametri *2 sm* bo‘lgan tor qismiga kavsharlangan vertikal nayda suv qancha balandlikka ko‘tariladi?

Berilgan:

$d_1 = 6\,sm = 6\cdot 10^2\,m$

$d_1 = 2\,sm = 2\cdot 10^2\,m$

$\vartheta_1 = 30\ sm/s = 0{,}3\ m/s$

$P_1 = 1atm = 10^5\,Pa$

h=?

Yechilishi:

Bernulli tenglamasiga ko‘ra

$$P_1 + \frac{\rho \vartheta_1^2}{2} = P_2 + \frac{\rho \vartheta_2^2}{2}$$

bo‘ladi. Vertikal naydagi bosim atmosfera bosimidan

$$P_1 - P_2 = \frac{\rho}{2}\left(\vartheta_2^2 - \vartheta_1^2\right) \qquad (1)$$

ga farq qiladi. Bosimning yetishmaslugi vertikal naydagi suv ustuni bilan muvozonatlashadi. Bunday ustunning og‘irligi ρShg ga teng, bu yerda $S-$ vertikal nayning ko‘ndalang kesimi. Shunday qilib,

$$\rho Shg = \left(P_1 - P_2\right)S$$

bo‘ladi. Bundan

$$h = \frac{P_1 - P_2}{\rho g} \qquad (2)$$

hosil bo‘ladi. Uzluksizlik tenglamasiga muvofiq

$$S_1\vartheta_1 = S_2\vartheta_2 \quad \text{yoki} \quad \frac{\pi d_1^2}{4}\vartheta_1 = \frac{\pi d_2^2}{4}\vartheta_2$$

ni olamiz. Bu yerda S_1 va S_2 lar trubaning keng va tor qismlarining ko‘ndalng kesimlari. Trubaning tor qisidagi suv rezligining qiymati ϑ_2 quyidagicha bo‘ladi:

$$\vartheta_2 = \vartheta_1\frac{d_1^2}{d_2^2} \qquad (3)$$

(1) va (3) formulalarni (2) ga qo‘ysak, so‘ralgan kattalikni aniqlaymiz.

$$h = \frac{P_1 - P_2}{\rho g} = \frac{\frac{\rho}{2}\left(\vartheta_2^2 - \vartheta_1^2\right)}{\rho g} = \frac{1}{2g}\left(\vartheta_1^2\frac{d_1^4}{d_2^4} - \vartheta_1^2\right) = \frac{\vartheta_1^2}{2g}\left(\frac{d_1^4}{d_2^4} - 1\right)$$

Endi berilgan kattaliklarni o‘rniga qo‘yib hisoblaymiz.

$$h = \frac{0{,}3^2}{2\cdot 9{,}8}\left(\frac{\left(6\cdot 10^{-2}\right)^4}{\left(2\cdot 10^{-2}\right)^4} - 1\right) = \frac{0{,}09}{19{,}6}\cdot 80 = 0{,}37\,m = 37\,sm$$

Javob: *h=37 sm.*

Masala № 3. Rasmda to‘g‘on, suv ombori va GESning ko‘ndalang kesimi tasvirlangan. Kirish trubasining yuzasi $S_1 = 0{,}74 m^2$ ga teng bo‘lib, suv bu trubaga $\vartheta_1 = 0{,}4 m/s$ tezlik bilan kiradi. Bu trubadan *D=180m* pastlikda esa kichikroq yuzali chiqish trubasi joylashgan bo‘lib, suv undan $\vartheta_2 = 9{,}5 m/s$ tezlik bilan chiqib GES trubinasini harakatlantiradi. Trubaning kirish va chiqishidagi bosimlar farqi nimga teng? $g = 9{,}81\ m/s^2$.

Berilgan:

$D=180\ m$

$S_1 = 0,74 m^2$

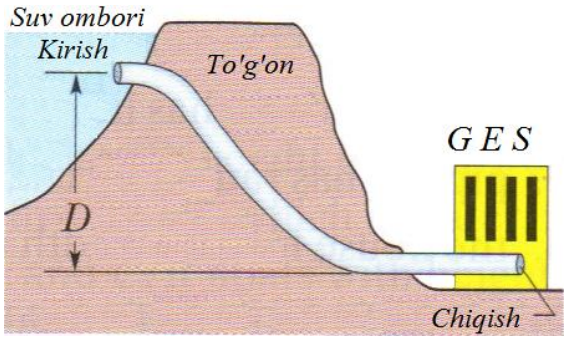
$\vartheta_1 = 0,4 m/s$

$\vartheta_2 = 9,5 m/s$

$\Delta P = ?$

Yechilishi:

So‘ralgan kattalikni Bernulli tenglamasidan foydalanib aniqlaymiz.



$$P_1 + \rho g h_1 + \frac{\rho \vartheta_1^2}{2} = P_2 + \rho g h_2 + \frac{\rho \vartheta_2^2}{2}$$

$$P_1 - P_2 = \rho g (h_2 - h_1) + \frac{\rho}{2}\left(\vartheta_2^2 - \vartheta_1^2\right)$$

Bunda $P_1 - P_2 = \Delta P,\ h_2 - h_1 = D$ ekanini e’tiborga olamiz.

$$\Delta P = \rho g D + \frac{\rho}{2}\left(\vartheta_2^2 - \vartheta_1^2\right) = 1000 \cdot 9,81 \cdot 180 + \frac{1000}{2}\left(9,5^2 - 0,4^2\right) = 1,811 \cdot 10^6\ Pa = 1,811 MPa$$

Javob: *1,811 Mpa*

Masala № 4. To‘g‘on oldida turgan chuchuk suv omborining chuqurligi *H=12 m* ga teng. *h=6 m* chuqurlikda esa gorizontal holda *d=4 sm* diametrli truba o‘tgan. Tiqin trubani ochilib ketishdan saqlab turadi. Tiqin va truba ichki devori orasidagi ishqalanish kuchini toping. Tiqin ochib yuborilsa *3 soat* vaqt ichida otilib chiqadigan suv hajmini aniqlang. $g = 9,81\ m/s^2$.

Berilgan:

H=12 m

h=6 m

d=4 sm

t=3 soat

$\Delta P = ?$

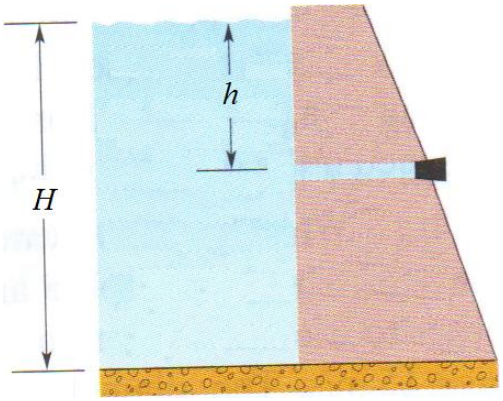
Yechilishi:

Teshikcha joylashgan sathda gidrostatik bosim

$P = \rho g h = 1000 \cdot 9,81 \cdot 6 = 58860\ Pa$

ga teng bo‘lib, bu bosim tiqinga

$$F = PS = P\frac{\pi d^2}{4} = 58860 \cdot \frac{3,14 \cdot 16 \cdot 10^{-4}}{4} =$$



=73,93 N kuch bilan bosadi. Tiqin va truba devori orasidagi ishqalanish kuchi esa shuncha kuch bilan ushlab turadi. Agar tiqin olinib, truba teshigi ochib yuborilsa, suv teshikdan

$$\vartheta = \sqrt{2gh} = \sqrt{2 \cdot 9,81 \cdot 6} = 10,85 m/s$$

tezlik bilan otilib chiqadi. Bunda t=3 soat vaqt davomida teshikchadan

$$V = S\ell = \frac{\pi d^2}{4}\vartheta t = \frac{3,14 \cdot 16 \cdot 10^{-4}}{4} \cdot 10,85 \cdot 3 \cdot 3600 = 147,2 m^3$$

Hhajmga teng suv oqib chiqadi.

30-amaliy mashg‘ulot topshirig‘i

30.1. Trubaning ko‘ndalang kesimidan *30 minut*da *0,6 kg* karbonat angidrid gazi oqib o‘tganligi ma’lum bo‘lsa, trubadagi gazning oqim tezligini toping. Gazning

zichligi $7{,}5\ kg/m^3$ ga, trubaning diametri *2sm* ga teng deb oling. **Javob:** 0,14 m/s

30.2. Bog‘da maysalarni suvlaydigan purkagichlar diametri *1,9 sm* bo‘lgan trubadan keladigan suv bilan ta’minlanadi. Purkagichning 20 ta teshiga bo‘lib, ularning har birining diametri *1,5 mm* ga teng. Agar trubadan keladigan suvning tezligi *0,91 m/s* ga teng bo‘lsa, u holda teshikhalardan otilib chiqayotgan tezligi nimaga teng? **Javob:** *7,3 m/s*

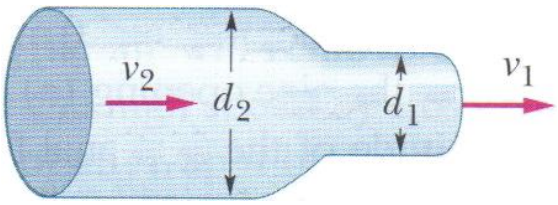
30.3. Ichki diametri *1,9 sm* bo‘lgan trubadan ichki diametrlari *1,3 sm* bo‘lgan uchta kichik trubalarga oqib o‘tadi. Agar kichik trubalarda suv sarflari *26, 16* va *11 L/min* bo‘lsa, u holda katta trubdagi suv sarfi nimaga teng (*L/min*)? Har bir kichik trubadagi va katta trubadagi suv oqimi tezliklarini aniqlang (*m/s*). **Javob:** *53; 3,266; 2,01; 1,382; 3,117*

30.4. Oqib chiqayotgan suvning tezligi $\vartheta = 10\,m/s$ bo‘lishi uchun gorizontal joylashgan suv purkagichning porsheniga qanday kuch qo‘yilishi kerak? Porshen radiusi $R = 2\,sm$. Ishqalanishni hisobga olmang. **Javob:** *63 N*

30.5. Hajmi $2\,m^3$ bo‘lgan suvni o‘zgaruvchan kesimli gorizontal quvur bo‘ylab *50 kPa* bosimli kesimdan *20 kPa* bosimli kesimga ko‘chishda bajarilgan ishni toping. **Javob:** *60 J*

30.6. Idishga har sekundda *0,2 l* suv quyiladi. Bunda idishdagi suvning sathi *8,3 sm* balandlikda o‘zgarmasdan qolishi uchun idish tubidagi teshikning diametri qanday bo‘lishi kerak? **Javob:** *1,4 sm*

30.7. Suv gorizontal trubadan rasmdagi kabi oqib, so‘ng tashqariga havoga $\vartheta_1 = 15\,m/s$ tezlik bilan otilib chiqadi. Truba diametrlari $d_1 = 3\,sm$ va $d_2 = 5\,sm$ ga teng. *t=10min* vaqtda necha *kg* suv oqib chiqadi? ϑ_2 tezlik nimaga teng? keng trubadagi bosim-chi? **Javob:** *6358,5 kg; 5,4 m/s; 97920 Pa*



30.8. Zichligi $900\,kg/m^3$ bo‘lgan suyuqlik gorizontal trubada oqmoqda. Trubaning *A* kesimdagi yuzasi *180* sm^2 ga, *B* kesimdagi yuzasi esa *900* sm^2 ga teng. Ikki kesimdagi bosimlar farqi *10,8 kPa* ga teng. Quyidagilarni aniqlang: a) *A* va *B* kesimlardagi tezliklarni; b) suv sarfinini hajmiy (*L/s*) va massaviy (*kg/s*) ko‘rinishdagi qiymatlarini.

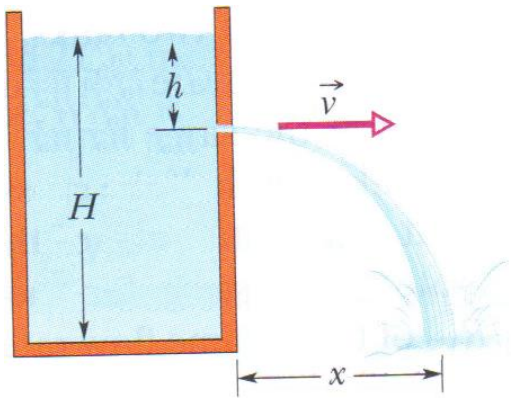
Javob: $a)\ \vartheta_A = 5\frac{m}{s};\ \vartheta_B = 1\frac{m}{s};\ b)\ Q_V = 90\frac{L}{s};\ Q_m = 81\frac{kg}{s}$

30.9. Diametri ancha katta bo‘lgan slindrik idish *H= 30 sm* gacha balandlikda suv bilan to‘ldirilgan. Idish tagidan ochilgan *6,2* sm^2 yuzali teshikdan suv pastga oqib tushmoqda. Suv sarfini *L/s* da hisoblab toping. Idish tagidan qancha *h* pastga

yetganda suv oqimi ko‘ndalang yuzasi ikki marta kamayadi? $g = 9{,}81 m/s^2$

Javob: *1,5 L/s; 90sm*

30.10. Rasmdagi slindrik idishdagi suyuqlik ustuni balandligi *H=40 sm* bo‘lib, suyuqlik sirtidan *h=12 sm* chuqurlikda teshikcha ochilgan. Quyidagilarni aniqlang: *a)* teshikdan chiqayotgan suv oqimi qanday *x* masofaga borib tushishini; *b)* ikkinchi teshik qancha chuqurlikdan ochilganda yana shu *x* masofaga tushishini; c) teshikcha suyuqlik sirtidan qancha chuqurlikdan ochilganda *x* qiymat maksimal bo‘lishini. $g = 9{,}81\ m/s^2$.



Javob: 36,7 *sm; 28 sm; 20 sm*

2-BOB
MOLEKULYAR FIZIKA

Har qanday moddaning ichki tuzilishi qanday? U yaxlit, uzluksizmi yoki xuddi qum uyurmasiga o‘xshash donador, diskret tuzilishga egami? Moddaning ichki tuzilishga egami degan savol qadimgi Yunonistonda qo‘yilgan bo‘lib, ammo eksperimental ma’lumotlar bo‘lmagani uchun bu savolga javob berish mumkin bo‘lmagan. Qadimgi yunon mutafakkirlari Levkipp va Demokrit aytib o‘tgan modda tuzilishi haqidagi atomizm g‘oyasini ikki ming yildan ortiq vaqt ichida tekshirishning iloji bo‘lmagan. Natijada vaqt o‘tishi bilan ularning ta’limoti esdan chiqa boshlaydi. O‘rta asrlarga kelib modda tuzilishi uzluksiz xususiyatga ega degan farazlar o‘rtaga tashlangan va moddalarning har bir holatida jismga kira oladagan va jismdan chiqa oladigan vaznsiz suyuqlik orqali tushuntirishga urinishlar bo‘lgan. Masalan, o‘sha davrda jismning isish yoki sovishini jismga teplorodning qo‘shilishi natijasida jism isiydi va aksincha soviydi deb hisoblangan.

Molekulyar fizika barcha moddalarni molekulalar va atomlardan tuzilgan deb moddalar tuzilishi, fizik xususiyatlari, modda agregat holatlarining temperatura va issiqlikka bog‘liqligi, gaz qonunlari, termodinamika va uning qonunlari va hokozalarni o‘rganadigan fizikaning katta bir bo‘limi hisoblanadi.

Biz o‘rganishni maqsad qilgan ushbu qo‘llanmada molekulyar fizikani quyidagi qismlarga bo‘lib o‘rganamiz:

- *Molekulyar kinetik nazariya*
- *Taqsimot qonunlari*
- *Ko‘chki hodisalari*
- *Termodinamika qonunlari*
- *Entropiya va uning o‘zgarishi*
- *Real gazlar uchun holat tenglamasi*
- *Qattiq jism va suyuqliklarning ichki xossalari*

1-MAVZU: Molekulyar kinetik nazariyaning asosiy tenglamasi. Avogadro soni. Nisbiy atom massasi, molyar massa, modda miqdori va molekulalar konsentratsiyasi.

Mavzuga oid muhim formulalar

$1\mathring{A} = 10^{-10}\ m$	*Atomlar o'lchamlarini baholashda ishlatiladigan uzunlik o'lchovi birligi – Anstrem va metr orasidagi bog'lanish*
$M_r = \dfrac{m_0}{\frac{1}{12}m_{0.C}}$	*Nisbiy atom massasi, molekulyar fizikada bundan kichik massa uchramaydi*
$1m.a.b = \dfrac{1}{12}m_{0.C} = 1,6605 \cdot 10^{-27}\ kg$	*Massaning atom birligi va kilogramm orasidagi bog'lanish*
$m_0 = \dfrac{1}{12}m_{0.C} \cdot M_r = 1m.a.b \cdot M_r$ $m_0 = \dfrac{M}{N_A}$	*Molekula yoki atom massasini aniqlash*
$N_A = 6,02 \cdot 10^{23}\ mol^{-1}$	*Avogadro doimiysi*
$M = m_0 N_A$	*Molyar massa*
$\nu = \dfrac{N}{N_A}$ *yoki* $\nu = \dfrac{m}{M}$	*Modda miqdori*
$N = \dfrac{m}{M}N_A$	*Molekula yoki atomlar sonini aniqlash formulasi*
$n = \dfrac{N}{V}$, $n = \dfrac{\rho N_A}{M}$	*Molekula yoki atomlar konsentratsiyasi formulasi*
$a = \dfrac{1}{\sqrt[3]{n}}$ *yoki* $a = \sqrt[3]{\dfrac{M}{\rho N_A}}$ *yoki* $a = \sqrt[3]{\dfrac{kT}{p}}$	*Moddaning molekula yoki atomlari orasidagi o'rtacha masofasini aniqlash formulalari*

1-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Gazning bitta molekulasining massasi $m_0 = 4,8 \cdot 10^{-26}\ kg$ ga teng. Shu gazning molyar massasi qanday (g/mol). $N_A = 6,02 \cdot 10^{23}\ mol^{-1}$.

Berilgan:

$m_0 = 4,8 \cdot 10^{-26}\ kg$

$N_A = 6,02 \cdot 10^{23}\ mol^{-1}$

M=?

Yechilishi:

$\nu = \frac{m}{M}$, $\nu = \frac{N}{\mathrm{Na}}$, massani o'rniga olib kelib qo'yamiz, $m = N \cdot m_0$ keyin esa modda miqdorilarni tenglashtirib:

$$\nu = \frac{m}{M} = \frac{N \cdot \mathrm{m_0}}{M} \qquad \frac{N \cdot \mathrm{m_0}}{M} = \frac{N}{\mathrm{N}_A}$$

$$M = \mathrm{m_0} \cdot \mathrm{N}_A = 4,8 \cdot 10^{-26} \cdot 6,02 \cdot 10^{23} = 29 \cdot 10^{-3}\ kg/mol$$

Javob: *29*

Masala № 2. *2 mol* suv necha cm^3 hajmni egallaydi?

Berilgan:

$\nu = 2\ mol$

$M = 18 \cdot 10^{-3}\ \frac{kg}{mol}$

$\rho = 1000\ kg/m^3$

$V = ?$

Yechilishi:

$\nu = \frac{m}{M}$, $m = \rho V$, $\nu = \frac{\rho \cdot V}{M}$

$V = \frac{M \cdot \nu}{\rho} = \frac{18 \cdot 10^{-3} \cdot 2}{1000} = 36 \cdot 10^{-6}\ m^3 = 36\ sm^3$

Javob: 36.

Masala № 3. Suv molekulalari orasidagi o‘rtacha masofa temir atomlari orasidagi o‘rtacha masofadan necha marta katta? $M_s = 18$ g/mol; M_t=32 g/mol. $\rho_s = 1000\ kg/m^3$, $\rho_t = 7800\ kg/m^3$.

Berilgan:

$\rho_s = 1000\ kg/m^3$

$\rho_t = 7800\ kg/m^3$

$M_s = 18 \cdot 10^{-3}\ \frac{kg}{mol}$

$M_t = 56 \cdot 10^{-3}\ \frac{kg}{mol}$

$a_s / a_t = ?$

Yechilishi:

Modda molekulalari orasidai o‘rtacha masofani aniqlash formulasidan foydalanamiz.

$$\begin{cases} a_s = \sqrt[3]{\frac{M_s}{\rho_s N_A}} & (1) \\ a_t = \sqrt[3]{\frac{M_t}{\rho_t N_A}} & (2) \end{cases} ; \Rightarrow (1):(2) \rightarrow \frac{a_s}{a_t} = \sqrt[3]{\frac{M_s}{M_t} \cdot \frac{\rho_t}{\rho_s}} =$$

$$= \sqrt[3]{\frac{18 \cdot 10^{-3}}{56 \cdot 10^{-3}} \cdot \frac{7800}{1000}} \approx 1{,}36$$

Javob: *1,36 marta katta*.

Masala № 4. Sirt yuzi $20\ sm^2$ bo‘lgan qurilmaning sirtiga *1 μm* qalinlikda oltin qatlami qoplandi. Qoplamda nechta oltin atomi bor? Avogadro doimiysi $N_A = 6{,}02 \cdot 10^{23}\ mol^{-1}$, oltinning atom massasi *197 m.a.b*, zichligi esa *19,3 g /sm ³*.

Berilgan:

$d = 1\ \mu m = 10^{-6}\ m$

$S = 2 \cdot 10^{-3}\ m^2$

$M = 197 \cdot 10^{-3}\ \frac{kg}{mol}$

$N_A = 6{,}02 \cdot 10^{23}\ mol$

$\rho = 19{,}3 \cdot 10^3\ \frac{kg}{m^3}$

$N - ?$

Yechilishi:

$N = \frac{m \cdot N_A}{M}$ formuladan topamiz va massa o‘rniga

$m = \rho \cdot v$ formulani qo‘yamiz $N = \frac{\rho \cdot v \cdot N_A}{M}$ hajm o‘rniga $V = S \cdot d$ qo‘yamiz,

$N = \frac{\rho \cdot S \cdot d \cdot N_A}{M}$

$N = \frac{19{,}3 \cdot 10^3 \cdot 2 \cdot 10^{-3} \cdot 10^{-6} \cdot 6{,}02 \cdot 10^{23}}{197 \cdot 10^{-3}} = 1{,}18 \cdot 10^{20}\ ta$

Javob: $1{,}18 \cdot 10^{20}$

1-amaliy mashg‘ulot topshirig‘i

6.45. Sulfat kislota (H_2SO_4) ning molyar massasini hisoblang. Bu kislota molekulasining massasi nimaga teng? **Javob:**

6.46. Karbonat angidrid gazi (CO_2) ning, is gazi (CO) ning va osh tuzi ($NaCl$) ning bitta molekulasining massasi nimaga teng? **Javob:**

6.47. *V=2 l* sig‘imli idishda *0,2 mol* miqdordagi kislorod gazi bor. Gazning zichligini aniqlang. **Javob:**

6.48. Hajmi *V=5 l* sig‘imli idishda *v=0,2 mol* miqdordagi noma’lum gaz bor. Agar gazning zichligi $\rho=1{,}12\ kg/m^3$ ga teng bo‘lsa, u holda bu gazning molyar massasi va qaysi gaz ekanini ayting. **Javob:** *M=28 g/mol; azot*

6.49. Idishdagi *m=21 g* massali azot gazni qattiq qizdirilganda molekulalarining *1/3* qismi atomlarga parchalandi. Idishda nechta zarra (molekula va atom) hosil bo‘ldi?

Javob: $N=\frac{4}{3}\frac{m}{M}N_A=6\cdot10^{23}ta$

6.50. Suv molekulasining diametri taxminan *d=0,28 nm* ga teng. Suv molekulalari orasidagi o‘rtacha masofa $<\ell>$ molekula diametridan necha marta katta? J: *1,1 marta*

6.51. Massasi *1,187 kg* bo‘lgan qalay bo‘lagida qancha atom bor? Qalayning molyar massasi *M =118,7 g/mol*, $N_A=6\cdot10^{23}mol$. **Javob:**

6.52. Diametri *1 mm* li suv tomchisida nechta molekula bor? $N_A=6\cdot10^{23}mol$. **Javob:**

6.53. Ugleroddan tashkil topgan mikroskopik chang zarrasining massasi *0,1 ng*. Zarracha necha atomdan iborat? **Javob:** $5\cdot10^{12}$ ta

6.54. Davolashda ishlatiladigan radonli vannada *1* dm^3 hajmdagi suvga $1{,}8\cdot10^6$ ta radon atomi aralashtirilgan bo‘ladi. Bunday vannada bitta radon atomiga necha dona suv molekulasi to‘g‘ri keladi? Radonning molyar massasi *M=84 g/mol*. **Javob:** $1{,}9\cdot10^9$ ta

6.55. Sirt yuzi $20cm^2$ bo‘lgan qurilmaning sirtiga *1 μm* qalinlikda oltin qatlami qoplandi. Qoplamda nechta oltin atomi bor? Avogadro doimiysi $N_A=6{,}02\cdot10^{23}mol$, oltinning atom massasi *197 m.a.b*, zichligi esa *19,3 g /sm* ^{3}. **Javob:**

6.56. Tezligi *1200 m/s* bo‘lgan kislorod molekulasining idish devoriga *60°* burchak ostida mutloq elastik urilishi natijasida idish devori olgan kuch impulsini toping (N·s). $N_A=6\cdot10^{23}mol^{-1}$. **Javob:** $6{,}4\cdot10^{-23}\text{N}\cdot\text{s}$

6.57. Dissotsatsiya darajasi *8 %* bo‘lgan *1 g* azotda qancha zarra (atom yoki molekula) bor? **Javob:** $2{,}31\cdot10^{22}$ *ta*

6.58. Idishdagi kislorod molekulalarining konsentratsiyasi $n = 6 \cdot 10^{25} m^{-3}$ bo‘lsa, gaz zichligi qanday? $N_A = 6 \cdot 10^{23} mol^{-1}$. **Javob:** $3{,}2 kg/m^3$

6.59. Temirda atomlar orasidagi o'rtacha masofa qanday (sm)? Temirning molyar massasi $M=56 \cdot 10^{-3}$ *kg/mol*, zichligi $\rho=7{,}8$ *g/sm*^{3} . **Javob:** $2 \cdot 10^{-8}$ sm

6.60. Zichligi $\rho=0{,}09$ *kg/m*^{3} bo‘lgan gaz bosimi $0{,}3 \cdot 10^5$ *Pa* bo‘lsa, gaz molekulalarining o‘rtacha kvadratik tezligi qanday bo‘ladi? **Javob:** *1000 m/s*

Massasi *10 g*, hajmi *1 l*, molekulalarining o‘rtacha kvadratik tezligi *600 m/s* bo‘lgan gazning idish devoriga beradigan bosimini hisoblang. **Javob:** *1200 kPa*

2-MAVZU: Bolsman doimiysi. Temperatura. Ideal gaz bosim va o‘rtacha kinetik energiyasining temperaturaga bog‘liqligi. Dalton qonuni. Arashma gazning molyar massasi.

Mavzuga oid muhim formulalar

$P=\frac{1}{3}m_0 n\bar{\vartheta}^2,\quad P=\frac{1}{3}\rho\bar{\vartheta}^2,\quad P=\frac{2}{3}nE$	*Molekulyar kinetik nazariyaning asosiy tenglamasi, tenglamaning turli ko‘rinishlari*
$k=1{,}380662\cdot10^{-23}\left[\frac{J}{K}\right]$	*Boltsman doimiysi*
$R=8{,}31\quad\left[\frac{J}{mol\cdot K}\right]$	*Universal-gaz doimiysi*
$P=n\,k\,T$	*Ideal gaz bosimining temperaturaga bog‘liqligi*
$E_0=\frac{3}{2}kT$	*Ideal gaz molekulalarini o‘rtacha ilgarilanma harakat kinetik energiyasi*
$P=P_1+P_2+P_3+...$	*Dalton qonuni*
$T=t+273{,}15\quad[K]$	*Absalyut va Selsiy shkalalari orasidagi bog‘lanish*
$T_F=\frac{9}{5}t+32\ [F],\quad t=\frac{5}{9}(T_F-32)$	*Fahrangeyt va Selsiy shkalalari orasidagi bog‘lanish*
$T_R=\frac{4}{5}t=0{,}8t\ [R],\qquad t=\frac{5}{4}T_R=1{,}25T_R$	*Reomyur va Selsiy shkalalari orasidagi bog‘lanish*
$M=\frac{m_1+m_2+m_3+...+m_n}{\nu_1+\nu_2+\nu_3+...+\nu_n}$ $M=\frac{\nu_1M_1+\nu_2M_2+\nu_3M_3+...+\nu_nM_n}{\nu_1+\nu_2+\nu_3+...+\nu_n}$ $M=\frac{m_1+m_2+m_3+...+m_n}{\frac{m_1}{M_1}+\frac{m_2}{M_2}+\frac{m_3}{M_3}+...+\frac{m_n}{M_n}}$	*O‘zaro ximiyaviy reaksiyaga kirishmaydigan gazlar aralashmasining molyar massasini hisoblash formulalari*

2-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. *27⁰C* dagi ideal gazning absalyut temperaturasini 2 marta oshirganda necha gradusga teng bo‘ladi?

Berilgan:

$t_1=27^0\,C$

$T_2=2T_1$

$t_2=?$

Yechilishi:

Dastlabki absalyut temperatura $T_1=t_1+273=300\,K$ ga teng edi. Keyingi absalyut temperatura esa $T_2=2T_1=600\,K$ bo‘ldi. Buni Selsiy shkalasiga o‘tkazamiz.

$$t_2=T_2-273=600-273=327^0C$$

Javob: $327^0\ C$

Masala № 2. *400 K* temperatura va *138 kPa* bosimda gaz molekulalarining konsentratsiyasi qanday bo‘ladi (m^{-3})? $k = 1{,}38 \cdot 10^{-23}\ J/K$.

Berilgan:	*Yechilishi:*
P = 1,38·10^5 Pa T = 400 K k= 1,38·10^{-23} J/ K n - ?	P = nkT, n = $\frac{P}{kT}$ n = $\frac{P}{kT}$ = $\frac{1{,}38 \cdot 10^5}{1{,}38 * 10^{-23} \cdot 400}$ = 2,5·10^{25} m^{-3}

Javob: 2,5 10^{25}

Masala № 3. Idishdagi gazning zichligi $1{,}2\ kg/m^3$ ga, bosimi *100 kPa* ga teng bo‘lsa, molekulalar harakatining o‘rtacha kvadratigi nimaga teng?

Berilgan:	*Yechilishi:*
P=100 kPa $\rho = 1{,}2\ kg/m^3$ $\overline{\vartheta} = ?$	Molekulyar kinetik nazariyaning asosiy tenglamasidan foydalanamiz. $P = \frac{1}{3}\rho\overline{\vartheta}^2,\ \rightarrow\ \overline{\vartheta} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \cdot 10^5}{1{,}2}} = 500\ m/s$

Javob: 500 m/s

Masala № 4. Massalari teng bo‘lgan kislorod va karbonat angidrid gazlari aralashmasining molyar massasi nimaga teng?

Berilgan:	*Yechilishi:*
M_1=32 g/mol *M_2=44 g/mol* $M = ?$	Massalari teng bo‘lgan aralashmaning molyar massasi $M = \frac{2M_1M_2}{M_1 + M_2}$ formuladan aniqlanadi. Unga ko‘ra aralashmaning molyar massasi quyidagicha bo‘ladi.

$$M = \frac{2M_1M_2}{M_1 + M_2} = \frac{2 \cdot 32 \cdot 44}{32 + 44} = 37\ g/mol$$

Javob: *M=37 g/mol*

Masala № 5. *V=110 ℓ* sig‘imli ballonga *m_1=0,8 g* massali vodorod va *m_2=1,6 g* massali kislorod gazlari joylangan. Temperatura *27^0C* ga teng. Gazlarning parsial konsentartsiyalarini hamda parsial bosimlarini toping. Idishdagi umumiy bosim nimaga teng?

Berilgan:	*Yechish:*
$V=110\ \ell$ $m_1=0,8\ g$ $m_2=1,6\ g$ $T=27^0C$ $n_1, n_2 - ?$ $P_1, P_2 - ?$ $P_{um} - ?$	Har bir gazning modda miqdorini aniqlaymiz. $\nu_1 = \frac{m_1}{M_1} = \frac{0,8\,g}{2\,g/mol} = 0,4\,mol,\ \nu_2 = \frac{m_2}{M_2} = \frac{1,6\,g}{32\,g/mol} = 0,05\,mol$ Har bir gazdagi molekulalar sonini aniqlaymiz. $N_1 = \nu_1 N_A = 2,4\cdot10^{23},\ N_2 = \nu_2 N_A = 3\cdot10^{22}$ Har bir gazning parsial konsentratsiyasini aniqlaymiz. $n_1 = \frac{N_1}{V} = \frac{2,4\cdot10^{23}}{0,11} = 2,182\cdot10^{24}\,m^{-3},\ n_2 = \frac{N_2}{V} = \frac{3\cdot10^{22}}{0,11} = 2,727\cdot10^{23}\,m^{-3}$

Har bir gazning parsial bosimini aniqlaymiz.

$P_1 = n_1 kT = 2,182\cdot10^{24}\cdot1,38\cdot10^{-23}\cdot300 = 9033\,Pa,\ P_2 = n_2 kT = 2,727\cdot10^{23}\cdot1,38\cdot10^{-23}\cdot300 = 1129\,Pa$

Umumiy bosimni aniqlaymiz.

$$P = P_1 + P_2 = 9033\,Pa + 1129\,Pa = 10162\,Pa$$

Javob: $n_1 = 2,182\cdot10^{24}\,m^{-3};\ n_2 = 2,727\cdot10^{23}\,m^{-3};$ $P_1 = 9033\,Pa;\ P_2 = 1129\,Pa;$ $P_{um} = 10162 Pa$

2-amaliy mashg‘ulot topshirig‘i

2.1. Gazning boshlang‘ich temperaturasi *500 K*. Bu temperatura *6 %* ga ortdi. Gazning oxirgi temperaturasi qanday (K)? **Javob:** *T = 530 K*

2.2. Mutlaq haroratning *150 K* qiymatiga Selsiy shkalasida qanday qiymat mos keladi? **Javob:** $t = -123°C$

2.3. Agar ochiq idishdagi ideal gazning absolut temperaturasi *30%* orttirilsa, gaz molekulalarining konsentratsiyasi qanday o‘zgaradi? **Javob:** *23 % kamayadi*

2.4. Idishdagi gazning Selsiy shkalasi bo‘yicha temperaturasi t_1 ga teng. Bu gazning temperaturasini k marta orttirilganda orttirilganda hosil bo‘lgan temperaturalarni Kelvin va Selsiy shkalalarida yozing. **Javob:** $T_2 = \delta(t_1 + 273)\,[K];\ t_2 = \delta t_1 + 273(\delta - 1)\,[^0C]$

2.5. 302^0F (Fahrangeyt) temperatura necha ^0C (selsiy) ga va necha *K* (Kelvin) ga teng bo‘ladi? **Javob:** $150^0C;\ 423\ K$

2.6. Qachon Fahrangeyt va Selsiy shkalalaridagi temperaturalar tenglashadi? **Javob:** $t_C = -40^0 C;\ t_F = -40^0 F$

2.7. Ryomer shkalasi *XVIII* va *XIX* asrlarda Yevropada keng qo‘llanilgan temperatura o‘lchash shkalasidir. Bu shkalaga ko‘ra suvning muzlash temperaturasi 0^0R (*nol Ryomer*) va qaynash temperaturasi esa 80^0R (*80 Ryomer*) ga teng. Selsiy shkalasidagi $t=25^0C$ xona temperaturasi Ryomer shkalasida nimaga teng? **Javob:** $T_R=20^0R$

2.8. Normal sharoitda 10^6 ta ideal gaz molekulasidan tashkil topgan kubning qirrasi uzunligi nimaga teng? **Javob:** *a=3,35 nm*

2.9. Temperaturasi *127°C* va bosimi *1,38 MPa* bo‘lgan gaz molekulalarining konsentratsiyasini hisoblang. Bolsman doimiysi $k=1,38\ 10^{-23}\ J/K$. **Javob:** $2,5\ 10^{26}\ m^{-3}$

2.10. Harorati *300 K* bo‘lgan gaz molekulalarining ilgarilanma harakat kinetik energiyasi necha joul bo‘ladi? Bolsman doimiysi $k = 1,38 \cdot 10^{-23}\ J/K$. **Javob:** $E_k = 6,21 \cdot 10^{-21}\ J$

2.11. Bosimi $4 \cdot 10^5\ Pa$ bo‘lgan $1\ m^3$ bir atomli ideal gaz molekulalarining kinetik energiyasini toping. **Javob:** $E_k = 6 \cdot 10^5$ J

2.12. Hozirgi zamon texnikasi yordamida *1 pPa* vakuum hosil qilish mumkin. Ana shunday $1\ sm^3$ vakuumda *300 K* temperaturada nechta gaz molekulasi qoladi? **Javob:** 240

2.13. Normal atmosfera bosimi sharoitida ochiq idishdagi gaz 27^0C dan 327^0C gacha qizdirildi. Bunda idish ichidagi hajmda gaz konsentratsiyasi qanchaga kamaygan? **Javob:** $\Delta n = 1,25 \cdot 10^{25}\ m^{-3}$

2.14. Hajmi $3\ dm^3$ bo‘lgan idishda *4 mg* geliy, *70 mg* azot va $5 \cdot 10^{21}$ ta vodorod molekulasi bor. Aralashmaning harorati 27^0C bo‘lsa, uning bosimi qanday bo‘ladi? **Javob:** *9,8 kPa*

2.15. Hajmi $2\ dm^3$ bo‘lgan idishda gaz *500 kPa* bosim ostida turibdi. Gaz molekulalari ilgarilanma harakatining kinetik energiyasini toping. **Javob:** *1,5 kJ*

2.16. $m_1 = 80\ g$ kislorod va $m_2 = 88\ g$ karbonat angidrid gazlari aralashmasining molyar massasini aniqlang. **Javob:** *37,33 g/mol*

2.17. Yonuvchi gaz aralashmasi metan (CH_4) va propan (C_2H_6) gazlaridan iborat bo‘lib, ularning massalari *2:1* nisbatda. Aralashmaning molyar massasini aniqlang. **Javob:** *18,95 g/mol*

2.18. Gaz aralashmasi massalari teng bo‘lgan uchta ideal gaz – is gazi (CO), kislorod (O_2) va karbonat angidrid (CO_2) gazlaridan iborat. Aralashmaning molyar massasini aniqlang. **Javob:** *33,45 g/mol*

2.19. Gaz aralashmasi miqdorlari teng bo‘lgan uchta ideal gaz – is gazi (CO), kislorod (O_2) va karbonat angidrid (CO_2) gazlaridan iborat. Aralashmaning molyar massasini aniqlang. **Javob:** *34,67 g/mol*

2.20. $V = 110\ l$ sig‘imli ballonga $m_1 = 0,8\ g$ massali vodorod va $m_2 = 1,6\ g$ massali kislorod gazlari joylangan. Temperatura 27^0C ga teng. Gazlarning parsial konsentartsiyalarini hamda parsial bosimlarini toping. Idishdagi umumiy bosim nimaga teng? **Javob:** $n_1 = 2,182 \cdot 10^{24}\ m^{-3}$; $n_2 = 2,727 \cdot 10^{23}\ m^{-3}$; $P_1 = 9033\ Pa$; $P_2 = 1129\ Pa$; $P_{um} = 10162\ Pa$

3-MAVZU: Ideal gaz uchun holat (Mendeleyev-Klapeyron) tenglamasi. Loshmidt soni. Birlashgan gaz qonuni. Izojarayonlar. Adiabatik va politropik jarayon uchun P=P(V), P=P(T) hamda V=V(T) bog‘lanishlar.

Mavzuga oid muhim formulalar

$PV=\frac{m}{M}RT \quad yoki \quad PV=\nu RT$	*Ideal gaz holat (Mendeleev-Klapeyron) tenglamasi*
$\frac{p_1V_1}{T_1}=\frac{p_2V_2}{T_2}=\frac{p_3V_3}{T_3}=...=\frac{p_nV_n}{T_n}=\nu R=const$	*Birlashgan gaz qonuni*
$\frac{p_1V_1}{m_1T_1}=\frac{p_2V_2}{m_2T_2}=\frac{p_3V_3}{m_3T_3}=...=\frac{p_nV_n}{m_nT_n}=\frac{R}{M}=const$	*O‘zgaruvchan massali gaz uchun formula*
$n_0=\frac{N_A}{V_0}=\frac{6,02\cdot10^{23}}{22,4\cdot10^{-3}}=2,7\cdot10^{25}\,m^{-3}$	*Loshmidt soni*
$R=8,31\ \left[\frac{J}{mol\cdot K}\right]$	*Universal-gaz doimiysi*
$P_1V_1=P_2V_2 \quad yoki \quad \frac{P_1}{P_2}=\frac{V_2}{V_1}$ $P=\frac{P_1V_1+P_2V_2+P_3V_3...+P_nV_n}{V_1+V_2+V_3+...+V_n}$	*Izotermik jarayon uchun formulalar*
$\frac{V_1}{T_1}=\frac{V_2}{T_2} \quad yoki \quad \frac{T_2}{T_1}=\frac{V_2}{V_1}$ $V=V_0(1+\alpha t)$	*Izobarik jarayon uchun formulalar*
$\frac{P_1}{T_1}=\frac{P_2}{T_2} \quad yoki \quad \frac{T_2}{T_1}=\frac{P_2}{P_1}$ $P=P_0(1+\beta t)$	*Izoxorik jarayon uchun formulalar*
$\frac{P_2}{P_1}=\left(\frac{V_1}{V_2}\right)^{\gamma}, \quad \frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{\gamma-1}, \quad \frac{P_2}{P_1}=\left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$ $\gamma_1=5/3,\ \gamma_2=7/5,\ \gamma_1=4/3,$	*Adiabatik jarayon uchun formulalar*
$\frac{P_2}{P_1}=\left(\frac{V_1}{V_2}\right)^{n}, \quad \frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{n-1}, \quad \frac{P_2}{P_1}=\left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}$ $-\infty<n<\infty$	*Politropik jarayon uchun formulalar*

3-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Aerostatning hajmi normal sharoitda *4200* m^3 edi. Aerostatning *4320 m* balandlikdagi hajmi necha m^3? Havoning bu balandlikdagi temperaturasi *260 K*. p_n=760 mm.sim.ust.

Berilgan:	*Yechish:*
$V_1 = 4200\ m^3$ $P_1 = 760\ mm.sim.ust$ $h = 4320\ m$ $T_1 = 273\ K$ $T_2 = 260\ K$ V_2- ?	Mendeleev- Klapeyron tenglamasidan temperaturani topamiz. $\frac{PV}{T} = \nu R$, $T = \frac{PV}{\nu R}$ Endi esa har bir holat uchun tenglamasini yozamiz $V_1 = \frac{\nu R T_1}{P_1}$, $V_2 = \frac{\nu R T_2}{P_2}$ Modda miqdori teng bo'ladi

V = const atmosfera bosimi har 12 m da 1 mm.sim.ust ga kamayadi keyingi bosim 360 mm.sim.ust ga kamayadi

$$\frac{V_2}{V_1} = \frac{\frac{\nu R T_2}{P_2}}{\frac{\nu R T_1}{P_1}} = \frac{P_1 T_2}{P_2 T_1} = \frac{760 \cdot 260}{400 \cdot 273} = 1{,}8, V_2 = 1{,}8 V_1,\ V_2 = 7600\ m^3$$

Javob: $7600\ m^3$

Masala № 2. Idishdagi gazning *30%* i chiqib ketishi natijasida tempe-ratura *320 K* dan *290 K* gacha sovigan bo'lsa, bosim necha marta kamaygan?

Berilgan:	*Yechilishi:*
$\Delta m = 0{,}3 m_1$ $T_1 = 320\,K$ $T_2 = 290\,K$ $P_1 / P_2 = ?$	Birlashgan gaz qonunidan foydalanamiz. $\frac{p_1 V_1}{m_1 T_1} = \frac{p_2 V_2}{m_2 T_2}, \rightarrow \frac{p_1}{p_2} = \frac{m_1}{m_2} \cdot \frac{T_1}{T_2} = \frac{m_1}{m_1 - 0{,}3 m_1} \cdot \frac{320}{290} \approx 1{,}58$ Demak, bosim 1,58 marta kamaygan.

Javob: *1,58 marta*

Masala № 3. Yulduzlararo kosmik bo'shliqdagi gaz bulutida temperatura 50K, bosim $10^{-8}\ Pa$ ga teng. Bunda har $1 sm^3$ hajmda nechta gaz molekulasi bor?

Berilgan:	*Yechilishi:*
T=50 K $P = 10^{-8}\ Pa$ $V = 10^{-6} m^3$ $N = ?$	Bunda $P = nkT = \frac{N}{V} kT$ formuladan foydalanamiz. $N = \frac{PV}{kT} = \frac{10^{-8} \cdot 10^{-6}}{1{,}38 \cdot 10^{-23} \cdot 50} = 1{,}45 \cdot 10^7\ ta$

Javob: $1{,}45 \cdot 10^7\ ta$

Masala № 4. Idishdagi gaz temperaturasini 5^0C ga qizdirilganda uning bosimi 1% ga oshgan bo'lsa, dastlabki temperatura necha gradus bo'lgan?

Berilgan:	*Yechilishi:*
$V = const$ $\Delta T = 5K$ $P_2 = 1{,}01P_1$	Izoxorik jarayon uchun yozilgan tenglamalardan foydalanamiz. $\frac{P_1}{T_1} = \frac{P_2}{T_2}, \rightarrow \frac{P_1}{T_1} = \frac{1{,}01P_1}{T_1 + 5}, \rightarrow T_1 + 5 = 1{,}01T_1, \rightarrow T_1 = 500\,K$
$T_1 = ?$	$t_1 = T_1 - 273 = 223^0 C$

Javob: 223^0 C

Masala № 5. *V=10 l* hajmli ballonda *T=293 K* temperaturali vodorod gazi *P=10 MPa* bosim ostida turibdi. Bu gazni yoqilganda m_2*=0,5 kg* massali suv hosil bo‘ldi. Necha gramm vodorod yonmasdan havoga uchib ketgan?

Berilgan:	*Yechilishi:*
T=293 K *P=10 MPa* *T=293 K* m_2*=0,5 kg*	Vodorod yonishidagi ximiyaviy reaksiyani yozamiz. $2H_2 + O_2 \rightarrow 2H_2O$ Ximiyaviy reaksiyadan ko‘rinib turibdiki, *2 mol* vodorod yonganda yana *2 mol* suv hosil bo‘lar ekan, ya’ni vodorod va suvning modda miqdorlari o‘zaro teng bo‘lar ekan. $\nu(H_2) = \nu(H_2O)$
$\Delta m = ?$	

Bundan esa yongan vodorod massasini aniqlash mumkin.

$$\nu = \frac{m_1}{M_1} = \frac{m_2}{M_2}, \quad \rightarrow \quad m_1 = \frac{M_1}{M_2} m_2 = \frac{2 \cdot 10^{-3}}{18 \cdot 10^{-3}} \cdot 0{,}5 = 55{,}56 \cdot 10^{-3}\, kg = 55{,}56\, g$$

Bunda $\begin{cases} m_1 = m(H_2) \\ m_2 = m(H_2O) \end{cases}, \begin{cases} \nu_1 = \nu(H_2) \\ \nu_2 = \nu(H_2O) \end{cases}, \begin{cases} M_1 = M(H_2) \\ M_2 = M(H_2O) \end{cases}$ bo‘ladi.

Endi esa dastlab balonda bo‘lgan vodorod massasini Mendeleyev-Klapeyron tenglamasidan aniqlaymiz.

$$PV = \frac{m_0}{M_1} RT, \quad \rightarrow \quad m_0 = \frac{PVM_1}{RT} = \frac{10^7 \cdot 10^{-2} \cdot 2 \cdot 10^{-3}}{8{,}31 \cdot 293} \approx 82{,}14 \cdot 10^{-3}\, kg = 82{,}14\, g$$

Yonishda ishtirok etmasdan havoga uchib ketgan massa esa quyidagicha bo‘ladi:

$$\Delta m = m_0 - m_1 = 82{,}14 - 55{,}56 = 26{,}58\, g \approx 26{,}6\, g$$

Javob: *Δm=26,6 g*

Masala № 6. Adiabatik kengayishda gazning hajmi *2* marta oshganda uning temperaturasi *1,32* marta kamaydi. Bu gaz molekulasining erkinlik darajasini toping.

Berilgan:	*Yechilishi:*
$PV^\gamma = const$ $V_2 = 2V_1$ $T_2 = T_1 / 1{,}32$	Adiabatik jarayon haqida batafsil keyingi mavzularimizda tanishamiz. Lekin bu mavzuda bu jarayonda makroparametrlar orasidagi bog‘lanish haqida so‘z boradi. Adiabatik jarayonda bosim va hajm orasidagi
$i = ?$	

$$PV^{\gamma} = const$$

bog‘lanish Puasson koeffitsiyenti (yoki adiabata ko‘rsatkichi)deb ataluvchi γ koeffitsiyent orqali bog‘lanadi. Yuqoridagi tenglamani Puasson tenglamasi deyiladi. Puasson tenglamasini ushbu

$$\frac{PV}{T} = const$$

birlashgan gaz qonuniga bo‘lish orqali hajm va temperatura orasidagi bog‘lanishni aniqlaymiz.

$$TV^{\gamma-1} = const \quad \text{yoki} \quad \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

Bundan esa adiabata ko‘rsatkichini aniqlaymiz.

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}, \rightarrow \frac{1}{1{,}32} = \left(\frac{1}{2}\right)^{\gamma-1}, \rightarrow 1{,}32 = 2^{\gamma-1}, \rightarrow \gamma = \log_2 1{,}32 + 1 = 1{,}4$$

Puasson koeffitsiyenti esa erkinlik darajasi (gaz molekulasining mustaqil harakatlarini ifodalovchi mustaqil tenglamalar soni) deb ataluvchi son orqali quyidagicha bog‘lanadi (bu bog‘lanishni ham keyingi mavzularimizda keltirib chiqaramiz):

$$\gamma = \frac{i+2}{i}$$

Bundan esa erkinlik darajasini aniqlaymiz.

$$\gamma = \frac{i+2}{i} = 1{,}4, \rightarrow i + 2 = 1{,}4i, \rightarrow 0{,}4i = 2, \rightarrow i = \frac{2}{0{,}4} = 5$$

degan natija kelib chiqadi.

Javob: $i=5$

3-amaliy mashg‘ulot topshirig‘i

3.1. $V=12\ l$ sig‘imli ballonda karbonat angidrid gazi bor. Gazning bosimi $P=1\ MPa$, temperaturasi $T=300\ K$ ga teng. Ballondagi gaz massasini aniqlang. **Javob:** $0{,}212\ kg$

3.2. $V=2\ m^3$ sig‘imli qozonda $T=500\ K$ haroratli $m=10\ kg$ massali o‘ta qizdirilgan suv bug‘lari bor. Qozondagi bug‘ning bosimi P ni aniqlang. **Javob:** $1{,}16\ Mpa$

3.3. Harorati $T=309\ K$ va bosimi $P=700\ kPa$ bo‘lgan gaz $\rho=12\ kg/m^3$ zichlikka ega. Gazning nisbiy molekulyar massasi M_r aniqlansin. **Javob:** $M_r=44$

3.4. $150\ kPa$ bosim va $27°C$ temperaturadagi azotning zichligini toping. $M=28\ g/mol$, $R=8{,}3\ J/(mol\cdot K)$. **Javob:** $1{,}68\ kg/m^3$

3.5. Venera sirtida temperatura va atmosfera bosimi mos ravishda $750\ K$ va $9120\ kPa$. Planeta sirtidagi atmosfera zichligini toping. Bunda uni karbonat angidrid gazidan iborat deb hisoblang. **Javob:** $64{,}4\ kg/m^3$

3.6. Idishda *6 atm* bosim ostida gaz bor. Agar idishdagi gazning 3/8 qismi chiqarib yuborilsa, unda qanday bosim qaror topadi? Harorat o‘zgarmas. **Javob:** *1,8 atm*

3.7. Yopiq idishda temperaturasi *87°C*, bosimi *4,5 MPa* bo‘lgan gaz bor. Gazning *1/5* qismi chiqarib yuborilganda, temperatura *27°C* gacha pasaygan bo‘lsa, qaror topgan bosim qanday? **Javob:** *3 MPa*

3.8. Ballonda 15^0 *C* temperaturali gaz bor. Agar gazning *40 %* i ballondan chiqsa va bunda temperatura *8° C* ga kamaysa, gazning bosimi necha marta kamayadi? **Javob:** *1,71 marta*

3.9. *V=10 l* hajmli ballonda *T=293 K* temperaturali vodorod gazi *P=10 MPa* bosim ostida turibdi. Bu gazni yoqilganda m_2*=0,5 kg* massali suv hosil bo‘ldi. Necha gramm vodorod yonmasdan havoga uchib ketgan? **Javob:** Δm*=26,6 g*

3.10. *V=30 l* hajmli ballonda *T=300 K* temperaturada va *P=828 kPa* bosimda vodorod va geliy gazlari aralashmasi saqlanadi. Aralashmaning massasi *m=24 g*. Vodorodning massasi m_1 hamda geliyning massasi m_2 aniqlansin. **Javob:** m_1*=16g;* m_2*=8g*

Izojarayonlar. Izografiklar

3.11. *3 m* chuqurlikdagi suvda suzib yurgan havo pufakchasining xajmi *10* mm^3 ga teng.Agar tashqi bosim normal atmosfera bosimiga teng bo‘lsa, suv betiga qalqib chiqqan havo pufakchasining hajmi qanday bo‘ladi? **Javob:** *13* mm^3

3.12. Ideal gaz V_1 hajmdan V_2 gacha izotermik siqilganda, bosim Δp ga ortdi. Boshlang‘ich p bosimni toping. **Javob:** $p = \frac{V_1+V_2}{V_1-V_2}\Delta p$

3.13. Sig‘imi *15* dm^3 bo‘lgan ballonda *200 kPa* bosimli gaz bor, ikkinchi ballonda esa xuddi shunday gaz *1 MPa* bostida turibdi. Haroratlari bir xil bo‘lgan ikkala ballon jo‘mrakli naycha orqali birlashtirildi. Jo‘mrak ochilsa, har ikkala ballondagi bosimlar *400 kPa* ga teng bo‘lib qoldi. Ikkinchi ballonning sig‘imi qanday? **Javob:** *5* dm^3

3.14. Uzunligi ℓ*=1,6 m* bo‘lgan va $P_0 = 101{,}3 kPa$ ga teng normal atmosfera bosimidagi havo bilan to‘ldirilgan slindr ichiga yuzasi *S=200* sm^2 bo‘lgan porshenni sekin kiritila boshlandi. Agar porshen slindr tubidan *h=10 sm* masofada to‘xtatilsa, porshenning ichki yuziga ta’sir etuvchi *F* kuch aniqlansin. Bunda porshenga ta’sir etuvchi natijaviy kuch F_{nat} qanday? **Javob:** $F = \frac{\ell}{h}P_0S = 32,4\,kN;\ F_{nat} = \left(\frac{\ell}{h}-1\right)P_0S = 30,39\,kN$

3.15. Hajmi *V=2,5* dm^3 bo‘lgan bo‘sh futbol to‘pini damlab, undagi bosimni atmosfera bosimidan *4* marta orttirish uchun unga porshenli nasos bilan necha marta dam berish zarur? Har bir dam berishda nasos atmosferadan V_0*=200* sm^3 bo‘lgan havoni so‘rib oladi. To‘pning harorati o‘zgarmas deb oling. Agar dastlab to‘pning ichi bo‘sh

bo‘lmasdan, unda atmosfera bosimiga teng bo‘lgan havo bo‘lgan bo‘lsa, bosimni *4* marta oshirish uchun nechta dam urish kerak bo‘ladi? **Javob:** *50 marta; 38 marta*

3.16. Hajmi $V=2,5\ dm^3$ ballondgi bosimni $k=100$ marta kamaytirish uchun porshenli nasos necha marta havo so‘rib olishi kerak? Nasos kamerasining hajmi $V_0=100\ sm^3$ ga teng. Gazni so‘rib olish paytida temperatura o‘zgarishini hisobga olmang. **Javob:** $n=\dfrac{\ln k}{\ln\dfrac{V+V_0}{V}}=118$

3.17. Gaz o‘zgarmas bosimda $27°C$ dan $51°C$ gacha isitilganda hajmi necha foizga ortadi? **Javob:** *8 %*

3.18. Ideal gaz o‘zgarmas bosim ostida $\Delta T=1\ K$ ga qizdirilganda uning hajmi dastlabki hajmning *1/350* qismiga ortdi. Gazning boshlang‘ich harorati necha gradus bo‘lgan? **Javob:** 77^0C

3.19. Ichida havosi bo‘lgan $0,4\ dm^3$ hajmli og‘zi ochiq shisha kolba 127^0C gacha isitilgan. Isitilgan kolbani bo‘g‘zi bilan suvga botirilib, uni 27^0C gacha sovitilsa, kolbaga kirgan suv qancha hajm egallaydi? **Javob:** $0,1\ dm^3$

3.20. Shar shaklidagi aerostatning hajmi $V=1500\ m^3$. Agar aerostatdagi gaz $T_0=273\ K$ dan $T=293\ K$ gacha isitilsa, aerostatning ko‘tarish kuchi qanchaga o‘zgaradi? Qobiqdagi gazning hamda atrofdagi havoning bosimi o‘zgarmas bo‘lib, normal atmosfera bosimiga teng. **Javob:** $\Delta F=\dfrac{T-T_0}{T}\rho_0 Vg=1,294\,kN$

3.21. Ballonda $t_1=100^0C$ haroratli gaz bor. Gazning bosimi ikki marta ortishi uchun uni qanday t_2 haroratgacha qizdirish kerak? **Javob:** $t_2=473^0C$

3.22. Ideal gazning temperaturasi izoxorik ravishda $4°C$ ga oshirilganda gaz bosimi dastlabki qiymatining *1/100* qismiga oshadi. Gazning dastlabki temperaturasi necha kelvin bo‘lgan? **Javob:** *400 K*

Adiabatik va politropik jarayonlarda makroparametrlar orasidagi bog‘lanishlar

3.23. Adiabatik kengayishda gazning hajmi *2* marta oshganda uning temperaturasi 1,32 marta kamaydi. Bu gaz molekulasining erkinlik darajasini toping. **Javob:** $i=5$

3.24. Kislorod gazi adiabatik jarayonda kengayib hajmi *5* marta oshgan bo‘lsa, bosim va temperatura necha marta o‘zgaradi? **Javob:** *bosim 9,52 marta kamayadi; temperatura 1,9 marta kamayadi*

3.25. Yuqoridagi masala shartini karbonat angidrid (CO_2) gazi uchun yeching. **Javob:** *bosim 8,55 marta kamayadi; temperatura 1,71 marta kamayadi*

3.26. Tashqi kuchlar idishga qamalgan geliy gazini adiabatik ravishda siqib absalyut temperaturasini *2,5* marta oshirgan bo‘lsa, gazning bosimi va hajmi necha marta o‘zgargan? **Javob:** *bosim 2,77 marta ortadi; hajm 1,84 marta kamayadi*

3.27. Yuqoridagi masalani azot gazi uchun yeching. **Javob:** *bosim 1,67 marta ortadi; hajm 1,44 marta kamayadi*

3.28. Idishga qamalgan ideal gazning bosim va hajmi $PV^2=const$ qonuniyat bilan o‘zgaradi. Bu gazning hajmi *3* marta ortganda temperaturasi necha marta o‘zgaradi. **Javob:** *bosim 9 marta kamayadi; temperatura 3 martakamayadi*

3.29. Idishga qamalgan ideal gazning bosim va hajmi $PV^3=const$ qonuniyat bilan o‘zgaradi. Bu gazning bosimi *8* marta kamayganda hajm va temperaturasi necha marta o‘zgaradi. **Javob:** *hajm 2 marta ortadi; temperatura 4 martakamayadi*

3.30. Idishga qamalgan ideal gazning bosim va temperaturasi $P/T^2=const$ qonuniyat bilan o‘zgaradi. Bu gazning bosimi *4* marta kamayganda temperatura va hajm necha marta o‘zgaradi. **Javob:** *temperatura 2 marta kamayadi; hajm 2 marta ortadi*

3.31. Idishga qamalgan ideal gazning bosim va temperaturasi $V/T^3=const$ qonuniyat bilan o‘zgaradi. Bu gazning hajmi *8* marta ortganda temperatura va bosim necha marta o‘zgaradi. **Javob:** *temperatura 2 marta ortadi; bosim 4 marta kamayadi*

3.32. Idishga qamalgan ideal gazning bosim va temperaturasi $V/\sqrt{T}=const$ qonuniyat bilan o‘zgaradi. Bu gazning temperaturasi *9* marta ortganda gazning hajmi va bosimi necha marta o‘zgaradi. **Javob:** *hajm 3 marta ortadi; temperatura 3 marta ortadi*

3.33. Idishga qamalgan ideal gazning bosim va temperaturasi $P^2V^3=const$ qonuniyat bilan o‘zgaradi. Bu gazning hajmi *4* marta ortganda bosim va temperatura necha marta o‘zgaradi. **Javob:** *bosim 8 marta kamayadi; temperatura 2 marta kamayadi*

4-MAVZU: Boltsmann taqsimot funksiyasi. Izotermik atmosfera uchun barometrik formulalar. Sun'iy gravitatsion maydon uchun barometrik formula.

Mavzuga oid muhim formulalar

$P = P_0 e^{-\frac{Mgh}{RT}}$, $P = P_0 e^{-\frac{m_0 gh}{k_B T}}$, $P = P_0 e^{-\frac{U}{k_B T}}$	*Atmosfera bosimining balandlikka bog'liqlik formulalari (barometrik formula)*
$n = n_0 e^{-\frac{Mgh}{RT}}$, $n = n_0 e^{-\frac{m_0 gh}{k_B T}}$, $n = n_0 e^{-\frac{U}{k_B T}}$	*Atmosferadagi havo konsentratsiyasining balandlikka bog'liqlik formulalari*
$\rho = \rho_0 e^{-\frac{Mgh}{RT}}$, $\rho = \rho_0 e^{-\frac{m_0 gh}{k_B T}}$, $\rho = \rho_0 e^{-\frac{U}{k_B T}}$	*Atmosferadagi havo zichligining balandlikka bog'liqlik formulalari*
$P = P_0 \left(1-\alpha h\right)^{\frac{Mg}{\alpha R T_0}}$ $n = \frac{P_0}{k_B T_0}\left(1-\alpha h\right)^{\left(\frac{Mg}{\alpha R T_0}-1\right)} = n_0\left(1-\alpha h\right)^{\left(\frac{Mg}{\alpha R T_0}-1\right)}$ $\rho = \frac{P_0 M}{R T_0}\left(1-\alpha h\right)^{\left(\frac{Mg}{\alpha R T_0}-1\right)} = \rho_0\left(1-\alpha h\right)^{\left(\frac{Mg}{\alpha R T_0}-1\right)}$	*Temperatura balandlik bo'yicha ushbu* $T = T_0\left(1-\alpha h\right)$ *qonunga ko'ra chiziqli kamayadigan atmosfera uchun bosim, konsentratsiya va zichliknig balandlikka bog'liq formulalari*
$P = P_0 \left(1+\alpha h\right)^{-\frac{Mg}{\alpha R T_0}}$ $n = \frac{P_0}{k_B T_0}\left(1+\alpha h\right)^{-\left(\frac{Mg}{\alpha R T_0}+1\right)} = n_0\left(1+\alpha h\right)^{-\left(\frac{Mg}{\alpha R T_0}+1\right)}$ $\rho = \frac{P_0 M}{R T_0}\left(1+\alpha h\right)^{-\left(\frac{Mg}{\alpha R T_0}-1\right)} = \rho_0\left(1+\alpha h\right)^{-\left(\frac{Mg}{\alpha R T_0}-1\right)}$	*Temperatura balandlik bo'yicha ushbu* $T = T_0\left(1+\alpha h\right)$ *qonunga ko'ra chiziqli ortadigan atmosfera uchun bosim, konsentratsiya va zichliknig balandlikka bog'liq formulalari*
$P = P_0 e^{-\frac{Max}{RT}}$, *yoki* $P = P_0 e^{-\frac{m_0 ax}{k_B T}}$	*To'g'ri chiziqli tekis o'zgaruvchan harakat qilayotgan slindrik ballon ichidagi bosimning uzunlikka bog'liqligi*
$P(r) = n_0 \frac{m_0\omega^2 R^2/2}{e^{\frac{m_0\omega^2 R^2}{2k_B T}}-1} e^{\frac{m_0\omega^2 r^2}{2k_B T}}$	*O'qi atrofida tekis aylanayotgan slindrik idishdagi gaz bosimining o'qgacha masofaga bog'liqligi*
$P(R) = n_0 \frac{m_0\omega^2 R^2}{2}\left[1-e^{-\frac{m_0\omega^2 R^2}{2k_B T}}\right]^{-1}$	*O'qi atrofida tekis aylanayotgan gaz qamalgan slindrik idishning ichki devoridagi gaz bosimi*
$P(R) = n_0 \frac{m_0\omega^2 R^2}{2}\cdot\frac{2k_B T}{m_0\omega^2 R^2} = n_0 k_B T$	*Sekin aylanayotgan slindrik idishning ichki devoridagi gaz bosimi*
$P(R) = \frac{N_0}{\pi R^2 H}\frac{m_0\omega^2 R^2}{2} = N_0\frac{F_q}{S_{yon}} = \frac{F_{q.umum}}{S_{yon}}$	*Tez aylanayotgan slindrik idishning ichki devoridagi gaz bosimi*
$P = P_0 e^{-\frac{m_0 g_0 R_{Yer}}{k_B T}\left(1-\frac{R_{Yer}}{R_{Yer}+h}\right)}$	*Planeta sirtidan ancha yuqori balandliklarda atmosfera bosimi*

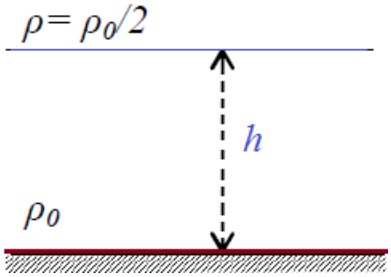
$P = P_0 e^{-\frac{m_0 g_0 R_{Yer}}{k_B T}}$	*Planeta sirtidan cheksiz uzoqlikda atmosfera bosimi*

4-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Qanday *h* balandlikdagi havo zichligi dengiz sathidagi bosimdan 2 marta kichik bo‘ladi (km)? Havo temperaturasini hamma joyda bir xil *T=273 K* deb hisoblang.

Berilgan:
T=273 K
M=29 g/mol
g=9,81 m/s²
h=?

Yechilishi:
T=const bo‘lgani sabab, izotermik jarayon uchun barometrik formuladan foydalanamiz.



$$P = P_0 \cdot e^{-\frac{Mgh}{RT}}$$

Bu yerda: P=ρRT/M – h balandlikdagi bosim; P₀=ρ₀RT/μ – dengiz sirtidagi bosim.

$$\frac{\rho RT}{M} = \frac{\rho_0 RT}{M} \cdot e^{-\frac{\mu gh}{RT}}; \quad \rightarrow \quad \rho = \rho_0 \cdot e^{-\frac{Mgh}{RT}}; \quad \rightarrow \quad \frac{\rho}{2} = \rho_0 \cdot e^{-\frac{Mgh}{RT}}; \quad \rightarrow \quad e^{\frac{Mgh}{RT}} = 2$$

$$e^{\frac{Mgh}{RT}} = 2, \quad \rightarrow \quad \frac{Mgh}{RT} = \ln 2, \rightarrow \; h = \frac{RT \ln 2}{Mg} = \frac{8{,}31 \cdot 273 \cdot \ln 2}{0{,}029 \cdot 9{,}81} = 5527\, m$$

Javob: *S=5,53 km*

Masala № 2. Samolyot kabinasidagi barometr doimiy bosimni ko‘rsatadi, shu sababdan uchuvchi *h* balandlikda uchyapman deb o‘ylaydi. Agar havo temperaturasi *ΔT=1 K* ga o‘zgarsa, balandlikni hisoblashda qancha xatolikka yo‘l qo‘yiladi? Temperaturani o‘zgarishdan oldin va keyin balandlik bo‘yicha bir xil deb oling. Yer sirtida atmosfera bosimi.

Berilgan:
P=80kPa
P₀=100 kPa
ΔT=1 K
υ₀=?

Yechilishi:
Barometrik formuladan foydalanamiz.

$$P = P_0 \cdot e^{-\frac{Mgh}{RT}}$$

Samolyotdagi barometr turli T_1 va T_2 temperaturalarda o‘zgarmas *P* bosimni ko‘rsatishimumkin, lekin bort tashqarisida bu bosimni turli h_1 va h_2 balandliklarda ko‘rsatadi. Bu balandliklar uchun barometrik formulalarni yozamiz.

$$P = P_0 \cdot e^{-\frac{Mgh_1}{RT_1}} \quad \text{va} \quad P = P_0 \cdot e^{-\frac{Mgh_2}{RT_2}}$$

Yuqoridagi formulalardan P₀/P nisbatlarni topib, ularni logarifmlaymiz.

$$\ln\frac{P_0}{P} = \frac{Mgh_1}{RT_1} \quad \text{va} \quad \ln\frac{P_0}{P} = \frac{Mgh_2}{RT_2}$$

Endi balandliklar farqini aniqlaymiz.

$$\Delta h = h_2 - h_1 = \frac{RT_2}{Mg}\cdot\ln\frac{P_0}{P} - \frac{RT_1}{Mg}\cdot\ln\frac{P_0}{P} = \frac{R}{Mg}\cdot\ln\frac{P_0}{P}\cdot(T_2 - T_1) = \frac{R\Delta T}{Mg}\ln\frac{P_0}{P}.$$

$$\Delta h = \frac{8{,}31\cdot 1}{0{,}029\cdot 9{,}8}\cdot\ln\frac{100000}{80000} = 29{,}24\cdot\ln 1{,}25 = 6{,}52\,m.$$

Javob: *Δh=6,52 m*

Masala № 3. Dengiz sathidan *h* balandlikda (taxminan *10 km* balandlikkacha) havo temperaturasi $T=T_0(1-\alpha h)$ qonunga bo'ysunadi. Bunda α – doimiy konstanta. Havoning bosimi va zichligi balandlik bo'yihca qanday o'zgaradi? Yer sirtidagi bosim P_0 ga teng.

Berilgan:	*Yechilishi:*
h,	Balandlik dh ga o'zgarganda bosim dP ga o'zgaradi.
P_0	$dP = -\rho g\,dh$
$T=T_0(1-\alpha h)$	Mendeleyev-Klapeyron tenglamasiga asosan
t=?	$\rho = \frac{PM}{RT}$

ni e'tiborga olsak, bosim o'zgarishi

$$dP = -\frac{PM}{RT}g\,dh = -\frac{PMg\,dh}{RT_0(1-\alpha h)}$$

bo'ladi. Yuqoridagi ifodani matematik almashtirib va integrallab bosimni balandlikka bog'lanishini topamiz.

$$\int_{P_0}^{P}\frac{dP}{P} = -\frac{Mg}{RT_0}\int_0^h\frac{dh}{1-\alpha h}, \quad \rightarrow \quad \ln\frac{P}{P_0} = \frac{Mg}{\alpha RT_0}\ln(1-\alpha h)$$

$$P = P_0(1-\alpha h)^{\frac{Mg}{\alpha RT_0}}$$

Bundan zichlikni balandlikka bog'liqlik ifodasini topamiz ($1>\alpha h$).

$$\rho = \frac{P_0M}{RT}(1-\alpha h)^{\frac{Mg}{\alpha RT_0}} = \frac{P_0M}{RT_0(1-\alpha h)}(1-\alpha h)^{\frac{Mg}{\alpha RT_0}} = \frac{P_0M}{RT_0}(1-\alpha h)^{\left(\frac{Mg}{\alpha RT_0}-1\right)}$$

Javob: $P = P_0(1-\alpha h)^{\frac{Mg}{\alpha RT_0}}$; $\rho = \frac{P_0M}{RT_0}(1-\alpha h)^{\left(\frac{Mg}{\alpha RT_0}-1\right)}$.

Masala № 4. *ℓ=3,6 m* uzunlikdagi gorizontal slindrik berk idish *T=300 K* temperaturadagi azot (N_2) gazi bilan to'ldirildi. Bu idishga *Ox* o'qi bo'yicha $a=30\ m/s^2$ tezlanish berildi. Slindrik idishning qarama-qarshi asoslaridagi bosimlari necha marta farq qiladi?

Berilgan:	*Yechilishi:*
ℓ=3,6 m	Idishga bog‘langan noinersial sanoq sistemasida gaz
T=300 K	molekulalariga inersiya kuchi ta’sir qiladi.
M=28 g/mol	$\vec{F}_{in} = -m\vec{a}$
$P_0/P=?$	Ox o‘qini slindrning harakat yo‘nalishida yo‘naltiramiz va

slindrning chap asosini sanoqbishi deb olamiz. Shartli ravishda chap asosidagi potensial energiyani *U(0)=0* deb olib, shunga nisbatan idish ichidagi ixtiyoriy nuqtadagi potensial energiyani topamiz.

$$U = -\int \vec{F} d\vec{r} = ma\,x$$

Chap asosdan x masofada posim quyidagicha bo‘ladi:

$$P = P_0 e^{-\frac{Max}{RT}}$$

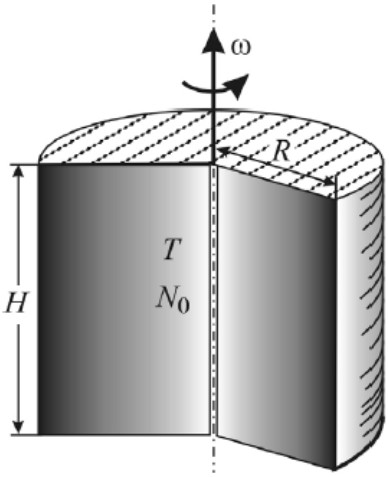
Bundan so‘ralgan nisbatni aniqlaymiz.

$$\frac{P_0}{P} = e^{\frac{Ma\ell}{RT}} = e^{\frac{0{,}028 \cdot 30 \cdot 3{,}6}{8{,}31 \cdot 300}} \approx 1{,}0011$$

Javob: *1,0011 mrta farq qiladi.*

Masala № 5. Vertikal o‘q atrofida doimiy ω burchak tezlik bilan aylanayotgan slindrik idishda *T* temperaturali ideal gaz turibdi. Slindrning balandligi *H* ga, radiusi esa *R* ga teng. Slindrik idishning radiusi bo‘ylab bosimning taqsimlanishini hamda slindr yon devorlariga ko‘rsatiladigan bosimni aniqlang.

Berilgan:	*Yechilishi:*
T	Slindr bilan birga aylanayotgan noinersial
R	sanoq sistemasidagi m_0 massali gaz
H	molekulasiga miqdori molekuladan aylanish
ω	o‘qigacha bo‘lgan *r* masofaga proporsional
p(r)=?	bo‘lgan markazdan qochuvchi inersiya
p(R)=?	kuchi ta’sir qiladi.



$$F_q = m_0\omega^2 r$$

Aylanish o‘qidan r masofada turgan molekulaning potensial energiyasi miqdoran markazdan qochuvchi kuchning molekulani berilgan *r* nuqtadan aylanish o‘qi *r=0* nuqtaga ko‘chirishda bajargan ishiga teng. Bunda shartli ravishda *r=0* da molekulaning potensial energiyasi *u(r=0)=0* deb olinadi.

$$U = \int_r^0 \vec{F}_q \cdot d\vec{r} = \int_r^0 m_0\omega^2 r \cdot dr \cdot \cos\pi = -\frac{1}{2} m_0\omega^2 r^2$$

Molekulani $dV = 2\pi rH\,dr$ (radiusi *r* va *r+dr*) elementar hajmda topish ehtimolligi Bolsmann taqsimotidan aniqlanadi.

$$dP_B(r) = Ae^{-\frac{U}{k_BT}}dV = Ae^{\frac{m_0\omega^2r^2}{2k_BT}} \cdot 2\pi rH\,dr$$

Normalash shartidan *A* konstantani topamiz.

$$\int_0^R Ae^{\frac{m_0\omega^2r^2}{2k_BT}} \cdot 2\pi rH\,dr = 1, \;\rightarrow\; 2\pi AH\int_0^R e^{\frac{m_0\omega^2r^2}{2k_BT}} r\,dr = 1, \;\rightarrow\; 2\pi AH\frac{k_BT}{m_0\omega^2}e^{\frac{m_0\omega^2r^2}{2k_BT}}\Bigg|_0^R =$$

$$= 2\pi AH\frac{k_BT}{m_0\omega^2}\left(e^{\frac{m_0\omega^2R^2}{2k_BT}} - 1\right) = 1, \quad \rightarrow \quad A = \frac{m_0\omega^2}{2\pi Hk_BT}\left(e^{\frac{m_0\omega^2R^2}{2k_BT}} - 1\right)^{-1}.$$

Yuqoridagi formulada $a = \frac{m_0\omega^2R^2}{2k_BT}$ deb belgilash kiritsak, u holda

$$A = \frac{a}{\pi R^2H}\left(e^a - 1\right)^{-1} = \frac{a}{\pi R^2H\left(e^a - 1\right)}$$

formulaga ega bo‘lamiz.

r va *r+dr* koordinataga ega bo‘lgan molekulalar soni ehtimollik qoidasi bo‘yicha quyidagicha bo‘ladi:

$$\frac{dN(r)}{N_0} = dP_B(r), \quad dN(r) = N_0 \cdot dP_B(r)$$

Aylanish o‘qidan *r* masofadagi konsentratsiyani topish uchun dN(r) ni elementar hajm $dV(r) = 2\pi rH\,dr$ ga bo‘lamiz.

$$n(r) = \frac{dN(r)}{dV} = \frac{N_0 \cdot dP_B(r)}{2\pi rH\,dr} = N_0Ae^{\frac{m_0\omega^2r^2}{2k_BT}} = n_0\left(\pi R^2H\right)Ae^{\frac{m_0\omega^2r^2}{2k_BT}} = n_0\frac{a}{\left(e^a - 1\right)}e^{\frac{m_0\omega^2r^2}{2k_BT}}$$

Bu yerda: $n_0 = \frac{N_0}{\pi R^2H}$ – slindrning butun hajmidagi molekulalar o‘rtacha konsentratsiyasi.

Aylanish o‘qidan r masofada bosim

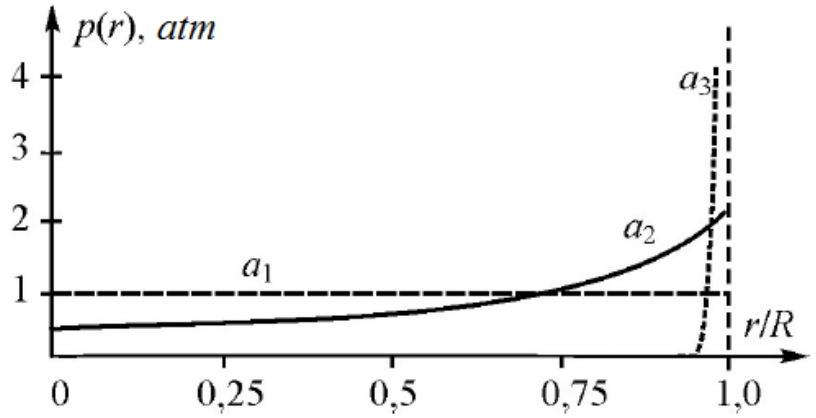
$$P(r) = n(r)k_BT = N_0k_BT\,Ae^{\frac{m_0\omega^2r^2}{2k_BT}} = \left(n_0\pi R^2H\right)k_BT\left[\frac{m_0\omega^2}{2\pi Hk_BT}\left(e^{\frac{m_0\omega^2R^2}{2k_BT}} - 1\right)^{-1}\right]e^{\frac{m_0\omega^2r^2}{2k_BT}} =$$

$$= n_0\frac{m_0\omega^2R^2/2}{e^{\frac{m_0\omega^2R^2}{2k_BT}} - 1}e^{\frac{m_0\omega^2r^2}{2k_BT}}$$

ni tashkil etadi.

Shunday qilib, slindrning ixtiyoriy r nuqtasidagi bosim quyidagicga bo‘lar ekan:

$$P(r) = n_0 \frac{m_0\omega^2 R^2 / 2}{e^{\frac{m_0\omega^2 R^2}{2k_BT}} - 1} e^{\frac{m_0\omega^2 r^2}{2k_BT}}$$



Yuqoridagi rasmda idishdagi gaz bosimining *r* masofaga bog‘liqlik grafiklari keltirilgan. Bunda $n_0 k_B T = 1atm$ va $n_0 = \frac{N_0}{\pi R^2 H}$. Bu egri chiziqlar slindr aylanishining har xil chastotalariga mos hisob-kitob qilingan a ning turli qiymatlari uchun berilgan: $a_1 = 0,015; a_2 = 1,5; a_3 = 75$.

Yuqorida keltirib chiqarilgan formulaga *r=R* ni qo‘yib slindr ichki devorlaridagi bosimni aniqlash mumkin.

$$P(R) = n_0 \frac{m_0\omega^2 R^2}{2} \left[1 - e^{-\frac{m_0\omega^2 R^2}{2k_BT}}\right]^{-1}$$

Bosimning slindr devoriga beradigan bosimning temperaturaga bog‘lanishini aniqlaylik.

1) Yuqori temperaturalarda (yoki slindrning sekin aylanishlarida) $a = \frac{m_0\omega^2 R^2}{2k_BT} << 1$ va a ning bunday kichik qiymatida funksiyani Teylor qatoriga yoyishda $e^{-a} \approx 1 - a$ ni qo‘llash mumkin. Bunda quyidagini olamiz:

$$P(r) = n_0 \frac{m_0\omega^2 R^2}{2} \cdot \frac{2k_BT}{m_0\omega^2 R^2} = n_0 k_B T$$

Olingan natija shuni ko‘rsatadiki, yuqori temperaturalarda (yoki slindrning sekin aylanishlarda) slindr devori yaqinidagi konsentartsiya xuddi aylanish bo‘lmagandagi kabi o‘rtacha konsentratsiyaga teng bo‘lar ekan. Shunga ko‘ra bunday hollarda markazdan qochuvchi kuchni hisobga olmaslik mumkin ekan.

1) Past temperaturalarda (yoki slindrning tez aylanishlarida) $a = \frac{m_0\omega^2 R^2}{2k_BT} >> 1$ va bosim quyidagicha bo‘ladi

$$P(r) = n_0 \frac{m_0\omega^2R^2}{2} = \frac{N_0}{\pi R^2 H}\frac{m_0\omega^2R^2}{2} = N_0\frac{F_q}{S}$$

Bunda: $S=2\pi RH$ – slindr yon devorining sirti; $F_q = m_0\omega^2R -$ bitta molekulaga ta'sir qiluvchi markazdan qochma inersiya kuchi.

Bundan shunday xulosa qilish mumkinki, past temperaturalarda (yoki slindrning tez aylanishlarda) bosim slindrning ichki yon devori yaqiniga to'plangan barcha molekulalardan hosil bo'ladi. Bu holda molekulalarning issiqlik harakatini hisobga olmaslik mumkin ekan.

Javob: $P(r) = n_0 \dfrac{m_0\omega^2R^2/2}{e^{\frac{m_0\omega^2R^2}{2k_BT}}-1} e^{\frac{m_0\omega^2r^2}{2k_BT}}$; $P(R) = n_0\dfrac{m_0\omega^2R^2}{2}\left[1-e^{-\frac{m_0\omega^2R^2}{2k_BT}}\right]^{-1}$

Masala № 6. Atmosfera temperaturasi balandlik bo'yicha o'zgarmas (izotermik atmosfera), atmosfera tarkibi esa turli ideal gazlar aralashmasidan tarkib topgan deb hisoblab, quyidagilarni aniqlang:

1) doimiy *T* temperaturada balandlik bo'yicha havo tarkibi o'zgarishini:

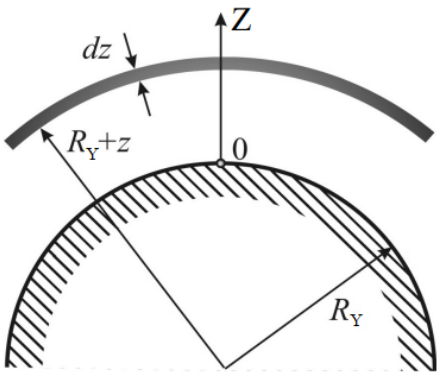
2) og'irlik kuchi maydoni o'zgarmas bo'lgan sharoitda izotermik Yer atmosferasidagi gaz molekulalarning <U> o'rtacha potensial energiyasini;

3) izotermik atmosferadagi umumiy molekulalar sonini;

4) Yer sirtida havo zichligi n_0 ga teng doimiy zichlik bo'lganda izotermik atmosfera qatlam qalinligini.

Yechilishi:

1) *Z* o'qini Yer sirtiga tik holda yuqoriga yo'naltiramiz va sanoq boshini rasmdagi kabi Yer sirtida tanlaymiz.



Ideal gaz qo'llanishi doirasida *m* massali molekulalarning balandlik bo'yicha taqsimoti boshqa massali molekalaning mavjudligiga bog'liq emas. Molekulalarning *z* balandlik bo'yicha taqsimlanishi Boltsmann taqsimotidan aniqlanadi.

$$dP_m(z) = Ae^{-\frac{mgz}{k_BT}}dV = Ae^{-\frac{mgz}{k_BT}}\cdot 4\pi\left(R_Y+z\right)^2dz \qquad (*)$$

Agar m massali molekulalarning jami soni NAgar m massali molekulalarning jami soni N_{0m} bo'lsa, u holda z balandlikdagi dz qalinlikdagi qatlamda $dN_m(z) = N_{0m}dP_m(z)$ ga teng molekulalar bo'ladi. Konsentratsiya esa

$$n_m(z) = \frac{dN_m(z)}{dV} = \frac{dN_m(z)}{4\pi\left(R_Y+z\right)^2dz} = N_{0m}Ae^{-\frac{mgz}{k_BT}} = n_m(0)e^{-\frac{mgz}{k_BT}}$$

Yuqoridagi tenglamada eksponenta oldidagi $n_m(0)$ koeffitsiyenti Yer sirtidagi m massali molekulalar konsentratsiyasini anglatadi.

$$n_m(0) = N_{0m}A$$

Molekulalar taqsimotidagi A konstantani aniqlashdan oldin Boltsmanning (*) taqsimotidagi eksponentaning daraja ko‘rsatkichiga diqqat qaratylik.

$$-\frac{mgz}{k_BT} = -\left(\frac{mgR_Y}{k_BT}\right)\frac{z}{R_Y}$$

$T=273\ K$ temperaturadagi havo molekulalarining o‘rtacha molyar massasi $M=0{,}029\ kg/mol$ uchun quyidagini olamiz:

$$\frac{mgR_Y}{k_BT}\frac{z}{R_Y} = \frac{MgR_Y}{RT}\frac{z}{R_Y} \approx \frac{29\cdot10^{-3}\cdot9{,}8\cdot6{,}37\cdot10^{6}}{8{,}31\cdot273}\cdot\frac{z}{R_Y} \approx 800\cdot\frac{z}{R_Y}$$

Bu shuni bildiradiki, faqat $z<<R_Y$ bo‘lgan hol uchun ehtimollik aniq qiymatga ega va bunda quyidagicha taxmin qilish mumkin:

$$\left(R_Y + z\right)^2 \approx R_Y^2$$

(*) taqsimot ushbu ko‘rinishga o‘tadi:

$$dP_m(z) \approx Ae^{-\frac{mgz}{k_BT}}\cdot 4\pi R_Y^2 dz$$

A konstatntani $\int_0^\infty dP_m(z) = 1$ normirovka shartidan aniqlanadi. Undan tashqari $x = \frac{mgz}{k_BT},\ dz = \frac{k_BT}{mg}dx$ belgilash kiritib hamda integrallashda $\int_0^\infty e^{-x}dx = 1$ ekanini hisobga olamiz.

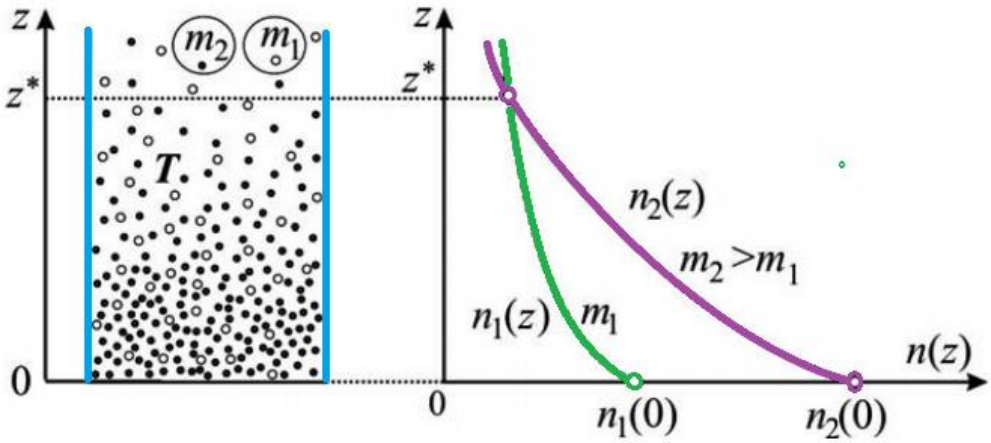
$$A\int_0^\infty e^{-\frac{mgz}{k_BT}}\cdot 4\pi R_Y^2 dz = 1,\ \rightarrow\ -A\cdot 4\pi R_Y^2\cdot\frac{k_BT}{mg}\int_0^\infty e^{-x}dx = 1,\ \rightarrow\ A = \frac{mg}{4\pi R_Y^2 k_BT}$$

Nihoyat, ehtimollik va konsentratsiyalar uchun quyidagilarni olamiz:

$$dP_m(z) \approx \frac{mg}{k_BT}e^{-\frac{mg\,z}{k_BT}}dz\,, \qquad n_m(z) \approx n_m(0)\,e^{-\frac{mg\,z}{k_BT}} = n_m(0)\,e^{-\frac{Mg\,z}{RT}} \qquad (**)$$

Yer atmosferasiga kiruvchi turli gaz molekulalari konsentratsiyasining balandlikka bog‘liqligi turlichadir. Molekulalar qanchalik og‘ir bo‘lsa, ularning balandlik bo‘yicha konsentratsiyasi shuncha tez kamayib boradi. Rasmda turli m_1 va m_2 ($m_1<m_2$) massaga ega bo‘lgan molekulalarning balandlikka bog‘liq konsentartsiyalari tasvirlangan.

$$n_1(z) \approx n_1(0)\,e^{-\frac{m_1g\,z}{k_BT}}, \qquad n_2(z) \approx n_2(0)\,e^{-\frac{m_2g\,z}{k_BT}}$$



Agar konsentratsiyalarning Yer sirtidagi nisbatini $\xi(0)=\frac{n_2(0)}{n_1(0)}$ deb, biror z balandlikdagi nisbatini esa $\xi(z)=\frac{n_2(z)}{n_1(z)}$ deb belgilasak, u holda molekulalar massalar farqi $\Delta m=m_2-m_1\left(\Delta M=M_2-M_1\right)$ bo‘lgan gazlar uchun quyidagi ifoda o‘rinli.

$$\xi(z)\approx\xi(0)\cdot e^{-\frac{\Delta m\,g\,z}{k_BT}} \qquad \text{yoki} \qquad \xi(z)\approx\xi(0)\cdot e^{-\frac{\Delta M\,g\,z}{RT}}$$

Doimiy *T* temperaturada balandlik oshishi bilan havodagi og‘r molekulalarning siyraklashishi sodir bo‘ladi. Agar atmosferaning Yer sirtida azot (*N2*) va geliy (*He*) gazlarining ulushi mos holda $\alpha_1=5,2\cdot10^{-4}$ va $\alpha_2=0,78$ ga teng bo‘lsa, qanday *z** balandlikda ularning konsentratsiyalari tenglashishini aniqlaylik.

Normal sharoitda *1 m³* gazda *NL* Loshmidt soniga teng molekulalar bo‘lishini hisobga olib, azot va geliyning Yer sirtida konsentratsiyasini aniqlaymiz.

$$n_1(0)=\alpha_1N_L, \qquad n_2(0)=\alpha_2N_L$$

Masala shartiga ko‘ra *z** balandlikda $\xi(z)=\frac{n_2(z)}{n_1(z)}=1$ bo‘lish kerak.

$$\xi(z)=\xi(0)\cdot e^{-\frac{\Delta m\,g\,z^*}{k_BT}}=\frac{n_2(0)}{n_1(0)}\cdot e^{-\frac{\Delta m\,g\,z^*}{k_BT}}=\frac{\alpha_2}{\alpha_1}\cdot e^{-\frac{\Delta M\,g\,z^*}{RT}}=1$$

$$z^*=\frac{RT}{\left(M_2-M_1\right)}\ln\frac{\alpha_2}{\alpha_1}=\frac{8,31\cdot300}{(28-4)\cdot10^{-3}\cdot9,8}\ln\frac{78}{5,2\cdot10^{-4}}\approx126\,km.$$

2) bitta molekulaning o‘rtacha potensial energiyasini bizga ma’lum bo‘lgan o‘rta qiymatlar uchun ehtimollikning taqsimoti $dP_m(z)$ formulasiga ko‘ra aniqlanadi:

$$<W_p>=\int_0^\infty mgz\,dP_m(z)=\int_0^\infty mg\,\frac{mg}{k_BT}\,ze^{-\frac{mg\,z}{k_BT}}dz=\frac{m^2g^2}{k_BT}\int_0^\infty ze^{-\frac{mg\,z}{k_BT}}dz$$

$\frac{mgz}{k_BT} = x,\ dz = \frac{k_BT}{mg}dx$ almashtirishlarni e'tiborga olamiz.

$$< W_p >= \frac{m^2g^2}{k_BT}\int_0^\infty z e^{-\frac{mgz}{k_BT}} dz = \frac{m^2g^2}{k_BT}\int_0^\infty \frac{k_BT}{mg} x \cdot e^{-z} \cdot \frac{k_BT}{mg} dx = k_BT \int_0^\infty x e^{-x} dx =$$

$$= k_BT\left(-xe^{-x} - e^{-x}\right)\Big|_0^\infty = k_BT.$$

3) Izotermik atmosferadagi jami molekulalarning umumiy sonini baholab ko'raylik. Hisoblashda barcha molekulalarni o'rtacha M molyar massali bir xil deb olamiz. U holda (**) tenglamadan foydalanish mumkin.

$$N_0 = \int_0^\infty n(z)\,dV = 4\pi\int_0^\infty n(0)\cdot e^{-\frac{mgz}{k_BT}}\cdot(R_Y+z)^2\,dz = 4\pi R_Y^2\int_0^\infty n(0)\cdot e^{-\frac{mgz}{k_BT}}\cdot\left(1+2\frac{z}{R_Y}+\ldots\right)dz \approx$$

$$\approx n(0)\cdot 4\pi R_Y^2 \cdot z_0.$$

Bu yerda: $z_0 = \frac{k_BT}{mg} = \frac{RT}{Mg} = \frac{8{,}31\cdot 273}{0{,}029\cdot 9{,}8} \approx 8000\,m$ – bu konsentratsiya *e* marta kamayadigan balandlik.

Yer sirtida havo konsentratsiyasi Loshmidt soniga tengligini e'tiborga olib jami molekulalarni hisoblaymiz.

$$N_0 = n(0)\cdot 4\pi R_Y^2 \cdot z_0 = 2{,}7\cdot 10^{25}\cdot 4{\cdot},14\cdot\left(6{,}37\cdot 10^6\right)^2\cdot 8\cdot 10^3 \approx 10^{44}$$

4) Izotermik qatlam qalinligi (n(0) konsentratsiya o'zgarmas bo'lgandagi havo qatlami) quyidagicha:

$$z_0 = \frac{k_BT}{mg} = \frac{RT}{Mg} = \frac{8{,}31\cdot 273}{0{,}029\cdot 9{,}8} \approx 8000\,m$$

Javob: 1) $n_m(z) \approx n_m(0)\,e^{-\frac{mgz}{k_BT}} = n_m(0)\,e^{-\frac{Mgz}{RT}}$

2) $< W_p > k_BT$

3) $N_0 = n(0)\cdot 4\pi R_Y^2 \cdot z_0 \approx 10^{44}$

4) $z_0 = \frac{RT}{Mg} \approx 8000\,m$

4-amaliy mashg'ulot topshirig'i

4.1. Yer sirtidagi kuzatuvchi *h=500 m* balandlikdagi tepalikka chiqqanda *100 kPa* atmosfera bosimi qanchaga kamayadi? Havo harorati balandlikka bog'liq emas va *310K* ga teng. $g=9{,}8\ m/s^2$. **Javob:** $\Delta P=5367\ Pa$

4.2. Havoda muallaq turgan chang zarralari $m=10^{-21}$ *kg* massaga ega. Balandlik $\Delta h=1$ *m* ga ortganda ularning konsentratsiyasi *n* necha marta kamayadi? Havoning harorati $T=300$ *K*. $g=9,8$ *m/s*^{2}. **Javob:** $e^{2,36}=10,6$ *marta*

4.3. Har birining massasi $m=10^{-12}$ *g* dan bo‘lgan bir xil zarralar kuchlanganligi $G=0,2$ *μN/kg* bo‘lgan bir jinsli gravitatsion maydonda taqsimlangan. Bir-biridan $\Delta z=20$ *m* uzoqlikda bo‘lgan ekvipotensial sathlaridagi zarralar konsentratsiyasining nisbati n_1/n_2 aniqlansin. Harorat barcha qatlamlarda bir xil va $T=290$ *K* deb hisoblansin. **Javob:** *2,72* marta

4.4. Uchayotgan vertolyot kabinasidagi barometr $P=85$ *kPa* bosimni ko‘rsatmoqda. Agar uchish maydonchasidagi bosim *100 kPa* bosimni ko‘rsatgan bo‘lsa, vertolyot qanday balandlikda uchmoqda. Havoning harorati *280 K* va balandlik bo‘yicha bir xil. $g=9,8$ *m/s*^{2} **Javob:** $h=1330$ *m*

4.5. *1* m^3 havoning Yer sirtida va $h=4$ *km* balandlikdagi og‘irliklarini aniqlang. Havo temperarurasini balandlik bo‘yicha bir xil 0^0C deb oling. Yer sirtida atmosfera bosimi 100 kPa ga teng. **Javob:** *12,53 N; 7,59 N*

4.6. $h=1$ *km* chuqurlikdagi shaxtaning tubida bosim nimaga teng. Shaxtaning chuqurligi bo‘yicha havo temperaturasi $t=32^0C$ va erkin tushish tezlanishi $g=9,8$ *m/s*^{2} qiymatlar bir xil saqlanadi. Yer sirtidagi havo bosimi P=100 kPa ga teng. **Javob:** $P=111,87$ *kPa*

4.7. *1 km* chuqurlikdagi va *1 km* balandlikdagi havo bosimlari nisbati nimaga teng? Temperaturani barcha nuqtalarda bir xil va t=0^0C deb oling. **Javob:** *1,285*

4.8. Yer sirti yaqinida azot molekulalari konsentratsiyasiga nisbatan geliy atomlari konsentratsiyasi 10^8 marta, vodorod molekulalari konsentratsiyasi esa 10^6 marta kam. Mos holda qanday h_1 va h_2 balandliklarda azot molekulalari konsentratsiyasi geliy va vodorod konsentratsiyalariga teng bo‘ladi? Balandlikning barcha nuqtalarida atmosfera temperaturasi bir xil va 0^0C ga teng deb oling. **Javob:** *174 km; 121 km*

4.9. Yer sirtidan *3 km* balandlikda har *1* sm^3 havoda 10^2 ta, Yer sirtida esa 10^5 ta chang zarrasi bor. Chang zarrasining o‘rtacha massasini aniqlang. Agar chang zarrasining zichligi *1,5* g/sm^3 ga teng bo‘lsa, bitta chang zarrasining o‘lchamini baholang. Havo temperaturasi $t=27^0C$ ga teng. J: $m_0 \approx 10^{-24}$ *kg;* $d \sim 10^{-9}$ *m*

4.10. Bosimning $\Delta P=100$ *Pa* ga teng o‘zgarishiga mos keluvchi balandliklar farqi Δh ushbu iki holat uchun topilsin: 1) temperatura $T_1=290$ *K* va bosim $P_1=100$ *kPa* bo‘lgan Yer sirti yaqinida; 2) temperatura $T_2=220$ *K* va bosim $P_2=25$ *kPa* bo‘lgan biror balandlikda. $g=9,8$ *m/s*^{2} . **Javob:** *1) 8,5 m; 2) 25,8 m*

4.11. Dengiz sathidan *h* balandlikda (taxminan *10 km* balandlikkacha) havo temperaturasi $T=T_0(1-\alpha h)$ qonunga bo‘ysunadi. Bunda α – doimiy konstanta. Havoning

bosimi va zichligi balandlik bo‘yihc qanday o‘zgaradi? Yer sirtidagi bosim P_0 ga teng.

Javob: $P = P_0\left(1-\alpha h\right)^{\frac{Mg}{\alpha RT_0}}$; $\rho = \frac{P_0 M}{RT_0}\left(1-\alpha h\right)^{\left(\frac{Mg}{\alpha RT_0}-1\right)}$

4.12. Molyar massasi M bo‘lgan ideal gaz erkin tushish tezlanishi g bo‘lgan bir jinsli og‘irlik kuchi maydonida turibdi. Bosimni balandlik h ning funksiyasi sifatida ifodalang. Yer sirtidagi bosim P_0 ga teng. Temperatura balandlik bo‘yicha $T=T_0(1+\alpha h)$ qonunga bo‘ysunadi. **Javob:** $P = P_0\left(1+\alpha h\right)^{-\frac{Mg}{\alpha RT_0}}$

4.13. *Sentrifuganing rotori ω burchak tezlik bilan aylanmoqda. Bolsmanning taqsimot funksiyasidan foydalanib, sentrifuga rotoriga m_0 massali zarralar konsentartsiyasi n ning taqsimoti aylanish o‘qidan uzoqlik r ning funksiyasi sifatida aniqlanin. **Javob:** $n = n_0 e^{\frac{m_0\omega^2 r^2}{rk_B T}}$

4.14. *Rotorining radiusi $R=0,5\ m$ bo‘lgan sentrifugada molyar massasi $1\ kg/mol$ bo‘lgan $T=300$ K temperaturadagi gazsimon modda bor. Agar rotor $v=50\ Gs$ chastota bilan aylanayotgan bo‘lsa, rotor devorlari yonidagi va radius o‘rtasidagi molekulalar konsentratsiyalarining nisbati $\frac{n_R}{n_{R/2}}$ aniqlansin. **Javob:** *5,91*

4.15. *Sentrifugada $271\ K$ temperaturadagi biror gaz bor. Bu sentriguganing $R=0,4\ m$ radiusli rotori $\omega=500\ rad/s$ burchak tezlik bilan aylanmoqda. Agar rotor devori yonidagi P bosim markazdagi P_0 bosimidan $2,1$ marta katta bo‘lsa, u holda gazning molyar massasi M ni aniqlang. **Javob:** *$M=84\ g/mol$, bu kripton elementi*

4.16. *Faraz qilaylik, Yer sirtida suv bug‘i va vododrodning konsentratsiyalari bir xil. Balandlik bo‘yicha $T=280\ K$ temperatura o‘zgarmaydi. $h=1000\ m$ balandlikda suv bug‘i konsentartsiyasi vodorod konsentartsiyadan necha marta kam bo‘ladi? $h=4000\ m$ balandlikda-chi? $g=9,8\ m/s^2$. **Javob:** *1,07 marta; 1,31 marta*

4.17. *Yer sirti yaqinida azot molekulalari konsentarsiyasining kislorod molekulalari konsentratsiyasiga nisbati $n_{01}/n_{02}=4,25$ ga teng bo‘lsa, bu nisbat $h=2\ km$ balandlikida nimaga teng bo‘ladi? Temperatura balandlik bo‘yicha bir xil va $T=273\ K$. Azot va kislorodning molyar massalari mos holda $M_1=28\ g/mol$ va $M_2=32\ g/mol$ ga teng. $g=9,8\ m/s^2$. **Javob:** $\frac{n_1}{n_2} = \frac{n_{01}}{n_{02}} \cdot e^{\frac{(M_2-M_1)gh}{RT}} = 4,4\ marta$

5-MAVZU: Maksvellning molekulalar tezliklar taqsimoti. Molekulalarning tezliklar komponentasi bo‘yicha hamda tezliklar bo‘yicha taqsimot funksiyasi. Eng katta ehtimoliy tezlik. O‘rta kvadratik tezlik. O‘rtacha tezlik.

Mavzuga oid muhim formulalar

$\bar{\vartheta}=\sqrt{\frac{3kT}{m_0}}$ *yoki* $\bar{\vartheta}=\sqrt{\frac{3RT}{M}}$	*O‘rta kvadratik tezlik*
$\vartheta=\frac{2\pi\nu}{\varphi}(R-r)$	*Shtern formulasi*
$\langle\vartheta\rangle=\sqrt{\frac{8kT}{\pi m_0}}$ *yoki* $\langle\vartheta\rangle=\sqrt{\frac{8RT}{\pi M}}$	*O‘rtacha (o‘rta arifmetik) tezlik*
$\vartheta_e=\sqrt{\frac{2kT}{m_0}}$ *yoki* $\vartheta_e=\sqrt{\frac{2RT}{M}}$	*Eng katta ehtimoliy tezlik*
$\Delta n=n f(\vartheta)\Delta\vartheta$	*Molekulalar soni nimalarga bog‘liqligi*
$\frac{\Delta n}{n}=f(\vartheta)\Delta\vartheta$ *yoki* $\frac{dn}{n}=f(\vartheta)d\vartheta$	*Extimollik*
$f(\vartheta_z)=Ae^{-\frac{m_0\vartheta_z^2}{2k_BT}}$, $A=\left(\frac{m_0}{2\pi k_BT}\right)^{1/2}$ $dn=nAe^{-\frac{m_0\vartheta_z^2}{2k_BT}}d\vartheta_z$, $\rightarrow\frac{dn}{n}=Ae^{-\frac{m_0\vartheta_z^2}{2k_BT}}d\vartheta_z$ $f(\vartheta_z)=\frac{dn}{nd\vartheta_z}=\left(\frac{m_0}{2\pi k_BT}\right)^{1/2}e^{-\frac{m_0\vartheta_z^2}{2k_BT}}$	*Molekulalarning tezlikar komponentasi bo‘yicha taqsimot funksiyasi*

Molekulalarning tezlikar bo‘yicha taqsimot funksiyasini kelib chiqishi

$$dn_{xyz}=nA^3e^{-\frac{m_0\vartheta^2}{2k_BT}}d\vartheta_xd\vartheta_yd\vartheta_z=n\left(\frac{m_0}{2\pi k_BT}\right)^{3/2}e^{-\frac{m_0\vartheta^2}{2k_BT}}d\vartheta_xd\vartheta_yd\vartheta_z=n\left(\frac{m_0}{2\pi k_BT}\right)^{3/2}e^{-\frac{m_0\vartheta^2}{2k_BT}}d\omega-\text{Dekartda}$$

$$dn=n\left(\frac{m_0}{2\pi k_BT}\right)^{3/2}e^{-\frac{m_0\vartheta^2}{2k_BT}}d\Omega=4\pi n\left(\frac{m_0}{2\pi k_BT}\right)^{3/2}\vartheta^2e^{-\frac{m_0\vartheta^2}{2k_BT}}d\vartheta-\text{sferikda}$$

Extimollik va molekulalarning tezlikar bo‘yicha taqsimot funksiyasi

$$\frac{dn}{n}=4\pi\left(\frac{m_0}{2\pi k_BT}\right)^{3/2}\vartheta^2e^{-\frac{m_0\vartheta^2}{2k_BT}}d\vartheta,\qquad f(\vartheta)=\frac{dn}{nd\vartheta}=4\pi\left(\frac{m_0}{2\pi k_BT}\right)^{3/2}\vartheta^2e^{-\frac{m_0\vartheta^2}{2k_BT}}$$

$$\frac{dn}{n}=4\pi\left(\frac{M}{2\pi RT}\right)^{3/2}\vartheta^2e^{-\frac{M\vartheta^2}{2RT}}d\vartheta,\qquad f(\vartheta)=\frac{dn}{nd\vartheta}=4\pi\left(\frac{M}{2\pi RT}\right)^{3/2}\vartheta^2e^{-\frac{M\vartheta^2}{2RT}}$$

Extimollik va molekulalarning ilgarilanma harakat kinetik energiyasi bo‘yicha taqsimot funksiyasi

$$\frac{dn}{n}=\frac{2}{\sqrt{\pi}}(k_BT)^{-3/2}\varepsilon^{1/2}e^{-\varepsilon/(k_BT)}d\varepsilon,\qquad f(\varepsilon)=\frac{2}{\sqrt{\pi}}(k_BT)^{-3/2}\varepsilon^{1/2}e^{-\varepsilon/(k_BT)}$$

Extimollik va molekulalarning impulsi bo'yicha taqsimot funksiyasi $\frac{dn}{n}=\frac{4}{\sqrt{\pi}}\left(2\pi m_0 k_B T\right)^{-3/2} p^2 e^{-p^2/(2m_0 k_B T)}dp,\quad f(p)=\frac{4}{\sqrt{\pi}}\left(2\pi m_0 k_B T\right)^{-3/2} p^2 e^{-p^2/(2m_0 k_B T)}$	
$u_z=\frac{\vartheta_z}{\vartheta_e},\quad f(u_z)=\frac{dn}{n\,du_z}=\frac{1}{\sqrt{\pi}}e^{-u_z^2}$	*Nisbiy tezlik komponentasi, molekulalarning nisbiy tezlik komponentasi bo'yicha taqsimot funksiyasi*
$u=\frac{\vartheta}{\vartheta_e},\quad f(u)=\frac{dn}{n\,du}=\frac{4}{\sqrt{\pi}}u^2e^{-u^2}$	*Nisbiy tezlik, molekulalarning nisbiy tezlik bo'yicha taqsimot funksiyasi*
$\frac{n_{>u}}{n}=\frac{4}{\sqrt{\pi}}\int_u^\infty u^2e^{-u^2}du$	*u nisbiy tezlikdan katta tezlikda harakatlanuvchi molekulalar sonini aniqlash*

5-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Azot gazining xona temperaturasidagi tezligiga teng bo'lishi uchun karbonat angidrid gazining temperaturasi necha gradus bo'lishi kerak?

Berilgan:

$t_1=20^0C$

$M_1=28\,g/mol$

$M_2=44\,g/mol$

$E_{k.\max}=?$

Yechilishi:

Birincha gazning absalyut temperaturasi $T_1=t_1+273=293K$

Har bir gaz uchun o'rta kvadratik tezlik formulasidan foydalanamiz va ularni yenglashtiraamiz.

$$\begin{cases}\overline{\vartheta}_1=\sqrt{\frac{3RT_1}{M_1}} & (1)\\ \overline{\vartheta}_2=\sqrt{\frac{3RT_2}{M_2}} & (2)\end{cases};\quad \Rightarrow (2)=(1)\ \rightarrow\ \sqrt{\frac{3RT_1}{M_1}}=\sqrt{\frac{3RT_2}{M_2}},\ \rightarrow$$

$$T_2=\frac{M_2}{M_1}T_1=\frac{44\cdot10^{-3}}{28\cdot10^{-3}}\cdot293=460\,K.$$

Endi topilgan qiymatni Selsiy shkalasiga o'tkazamiz.

$$t_1=T_1-273=460-273=187^0C$$

Javob: 187^0C

Masala № 2. Shteyner tajribasini laboratoriya sharoitida o'quvchi bajarib ko'rmoqchi. Bunda radiuslari *R=16 sm* va *r=10 sm* bo'lgan konsentrik slindrlardan foyadalandi. Tajribada slindrlar *100 Hz* chastotagacha tezlashtirildi. Tajribadan so'ng katta slindrdagi kumush bug'lari hosil qilgan dog'i kichik slindr tirqishidan $\Delta\ell=2\,sm$ masofaga surilgani aniqlandi. Kumush atomlari qanday tezlikda harakatlangan?

Berilgan:

R=16 sm

r=10 sm

$\Delta\ell = 2\,sm$

$\nu = 100\,Hz$

$\vartheta = ?$

Yechilishi:

Dastlab siljish burchaginbi aniqlaymiz.

$$\Delta\varphi = \frac{\Delta\ell}{R} = \frac{2}{16} = 0{,}125\ rad$$

Shtern formulasidan foydalanib tezlikni aniqlaymiz.

$$\vartheta = \frac{2\pi\nu}{\Delta\varphi}(R-r) = \frac{2\cdot 3{,}14\cdot 100}{0{,}125}(0{,}16-0{,}1) = 301 m/s$$

Javob: *301 m/s*

Masala № 3. Azot oksidi (NO) ning temperaturasi T=300 K. Bu gaz molekulalarining qanday qismi $\left(\frac{\Delta N}{N_0}\right)$ tezliklari ϑ_1*=820 m/s* dan ϑ_2*=830 m/s* gacha intervalda yotadi? Gazning molyar massasi *M=30 g/mol*.

Berilgan:

T=300 K

ϑ_1*=820 m/s*

ϑ_2*=830 m/s*

M=30 g/mol

$\frac{\Delta N}{N_0} = ?$

Yechilishi:

Maksvellning molekulalar tezliklar taqsimoti formulasidan foydalanamiz.

$$f(\vartheta) = 4\pi\left(\frac{m_0}{2\pi kT}\right)^{3/2}\vartheta^2 e^{-\frac{m_0\vartheta^2}{2k_BT}} = 4\pi\left(\frac{M}{2\pi RT}\right)^{3/2}\vartheta^2 e^{-\frac{M\vartheta^2}{2RT}}$$

Bu taqsimot funksiyasi tezliklar ϑ dan $\vartheta+d\vartheta$ oraliqda yotgan molekulalar hissasini anglatadi.

$$f(\vartheta) = \frac{dN_\vartheta}{N_0 d\vartheta} = 4\pi\left(\frac{M}{2\pi RT}\right)^{3/2}\vartheta^2 e^{-\frac{M\vartheta^2}{2RT}}$$

Endi hisob-kitoblarni bajaramiz.

$$\frac{\Delta N_\vartheta}{N_0} = f(\vartheta)\Delta\vartheta = 4\pi\left(\frac{M}{2\pi RT}\right)^{3/2}\vartheta_1^2 e^{-\frac{M\vartheta_1^2}{2RT}}\Delta\vartheta = 4\cdot 3{,}14\cdot\left(\frac{0{,}03}{2\cdot 3{,}14\cdot 8{,}31\cdot 300}\right)^{3/2}\cdot 820^2\cdot$$

$$\cdot e^{-\frac{0{,}03\cdot 820^2}{2\cdot 8{,}31\cdot 300}}\cdot 10 = 12{,}56\cdot 2{,}652\cdot 10^{-9}\cdot 672400\cdot 0{,}0175\cdot 10 \approx 0{,}00392 = 0{,}392\%.$$

Javob: $\frac{\Delta N}{N_0} = 3{,}92\cdot 10^{-3} = 0{,}392\%$

Masala № 4. Ideal gazning nisbiy tezliklar bo‘yicha taqsimot qonunidan foydalanib *t=0°C* da turgan karbonat angidrid gazining qanday qismi *100 m/s* dan *110 m/s* gacha oraliqda yotishini hisoblang. Gazning molyar massasi *M=44 g/mol*.

Berilgan:

$t=0^0C$

$\vartheta_1=100\ m/s$

$\vartheta_2=110\ m/s$

$M=44\ g/mol$

$\frac{\Delta N}{N_0}=?$

Yechilishi:

Ideal gazn molekulalari $u=\frac{\vartheta}{\vartheta_e}$ nisbiy tezliklar bo‘yicha taqsimot qonuni quyidagi ko‘rinishga ega:

$$f_{nis}(u)=\frac{4}{\sqrt{\pi}}u^2e^{-u^2}$$

Bunda eng katta extimoliy tezlik

$$\vartheta_e=\sqrt{\frac{2RT}{M}}=\sqrt{\frac{2\cdot 8,31\cdot 273}{0,044}}=321m/s$$

bo‘ladi. Endi nisbiy tezlik intervali chegaralarini aniqlaymiz.

$$u_1=\frac{\vartheta_1}{\vartheta_e}=\frac{100}{321}=0,3115,\quad u_2=\frac{\vartheta_2}{\vartheta_e}=\frac{110}{321}=0,3427$$

Bu nisbiy tezliklar farqi va yarimyig‘indisi quyidagicha:

$$\Delta u=u_2-u_1=0,0312,\quad \frac{u_2+u_1}{2}=0,3271$$

Nisbiy tezliklarning shu oraliqdagi taxminiy ulushini hisoblaymiz.

$$\frac{\Delta N}{N_0}\approx f_{nis}\left(\frac{u_1+u_2}{2}\right)\Delta u$$

Hisoblashlar quyidagi natijani beradi:

$$\frac{\Delta N}{N_0}\approx\frac{4}{\sqrt{\pi}}\cdot(0,3271)^2\cdot e^{-(0,3271)^2}\cdot 0,0312=2,2567\cdot 0,107\cdot 0,8985\cdot 0,0312=6,769\cdot 10^{-3}\approx 0,6769\%$$

Topilgan bu qiymat taxminiy qiymat bo‘lib, aniq qiymat esa integrallash amali orqali chiqarilish kerak.

$$\frac{dN}{N_0}=\int_{u_1}^{u_2}f_{nis}(u)du$$

Buni Maple dasturi yordamida hisoblab

$$\frac{dN}{N_0}=\int_{u_1}^{u_2}f_{nis}(u)du=\frac{4}{\sqrt{\pi}}\int_{0,3115}^{0,3427}u^2e^{u^2}du=0,67717\%$$

natijani olamiz. Bu esa oldingi javobga juda yaqindir.

Javob: $\frac{\Delta N}{N_0}\approx 0,677\ \%$

Masala № 5. $T_1=T$ va $T_2=2T$ bo‘lgan hollar uchun Maksvell taqsimot funksiyasi egri chiziqlari ϑ tezlikning qanday qiymatida kesishadi? Egri chiziqlar necha marta kesishadi?

Berilgan:	*Yechilishi:*
$T_1=T$ $T_2=2T$ $f_1(\vartheta)=f_2(\vartheta)$ $\vartheta=?$	Masala shartiga ko‘ra Maksvell taqsimotining ikkita egri chizig‘i kesishish kerak. Kesishganda esa funksiyalar tenglashadi.

$$f_1(\vartheta)=f_2(\vartheta),\ \rightarrow\ \frac{4}{\sqrt{\pi}}\left(\frac{m}{2k_BT_1}\right)^{3/2}\vartheta^2e^{-\frac{m\vartheta^2}{2k_BT_1}}=\frac{4}{\sqrt{\pi}}\left(\frac{m}{2k_BT_2}\right)^{3/2}\vartheta^2e^{-\frac{m\vartheta^2}{2k_BT_2}},$$

$$\rightarrow\left(\frac{1}{T_1}\right)^{3/2}e^{-\frac{m\vartheta^2}{2k_BT_1}}=\left(\frac{1}{T_2}\right)^{3/2}e^{-\frac{m\vartheta^2}{2k_BT_2}},\ \rightarrow\ e^{-\frac{m\vartheta^2}{2k_B}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}=\left(\frac{1}{T_1}\right)^{3/2},\ \rightarrow$$

$$\vartheta^2=\frac{3k_B}{m}\frac{T_1T_2}{T_2-T_1}\ln\frac{T_2}{T_1}=\frac{3k_BT}{m}\cdot\ln2=\frac{3RT}{M}\cdot\ln2,\ \rightarrow\ \vartheta=\sqrt{\frac{3RT}{M}\cdot\ln2}=$$

$$=\sqrt{\frac{2R(2T)}{M}\cdot\frac{3}{2}\cdot\ln2}=\sqrt{1{,}5\ln2}\cdot\vartheta_{e.2}$$

Javob: $\vartheta=\sqrt{1{,}5\ln2}\cdot\vartheta_{e.2}$; *faqat bir marta*

5-amaliy mashg‘ulot topshirig‘i

5.1. Qanday T temperaturada geliy atomining o‘rtacha kvadratik tezligi 2-kosmik tezlik $\vartheta_{II}=11{,}2$ *km/s* ga teng bo‘ladi? **Javob:** $T=20100$ *K*

5.2. Havoda muallaq suzib yurgan mayda chang zarralari go‘yoki juda katta molekulalar kabi harakatlanadi. Agar havoning harorati $T=300$ K bo‘lsa, $m=10^{-13}$ *kg* massali chang zarrachasining o‘rta kvadratik tezligi aniqlansin. **Javob:** *0,352 mm/s*

5.3. Kislorod molekulasining o‘rta kvadratik tezligi $\bar{\vartheta}$ kislorod molekulalari orasida harakatlanib yurgan $m=10^{-12}$ *kg* massali chang zarrachasining o‘rta kvadratik tezligidan necha marta katta? **Javob:** $1{,}37\cdot10^6$ *marta*

5.4. Agar gaz molekulasining o‘rta kvadratik tezligi $\bar{\vartheta}=1000\ m/s$ ga teng bo‘lsa, u holda o‘rta arifmetik tezlik $\langle\vartheta\rangle$ hamda eng katta ehtimoliy tezlik ϑ_e nimaga teng bo‘ladi? **Javob:** $\langle\vartheta\rangle=921$ *m/s;* $\vartheta_e=816$ *m/s*

5.5. *300 mm sim.ust.* bosimida zichligi *0,3 g/l* bo‘lgan gaz molekulalarining o‘rta arifmetik, o‘rta kvadratik va ehyimolligi eng katta tezlikni aniqlang. **Javob:** $\langle\vartheta\rangle=579$ *m/s;* $\bar{\vartheta}=628\,m/s$; $\vartheta_e=513$ *m/s*

5.6. Qanday temperaturada azot molekulalarining o‘rta kvadratik tezligi ularning ehtimolligi eng katta tezligidan *50 m/s* ga ortiq bo‘ladi. **Javob:** -190^0C

5.7. Vodorodning o‘rta kvadratik tezligi uning eng katta ehtimoliy tezligidan $\Delta\vartheta=400$ *m/s* ga katta. Gazning temperaturasini toping. **Javob:**

$$T=\frac{M(\Delta\vartheta)^2}{\left(\sqrt{3}-\sqrt{2}\right)R}=330\,K$$

5.8. 0^0C da kislorod molekulalarining qancha qismi *100 m/s* dan *105 m/s* gacha oraliqdagi tezliklarga ega bo'ladi. **Javob:** *0,2 %*

5.9. 150^0C temperaturada azot molekulalarining qancha qismi *300 m/s* dan *325 m/s* gacha oraliqdagi tezliklarga ega bo‘ladi. **Javob:** *2,8 %*

5.10. 0^0C da vodorod molekulalarining qancha qismi *2000 m/s* dan *2100 m/s* gacha oraliqdagi tezliklarga ega bo‘ladi. **Javob:** *4,5%*

5.11. Ideal gaz muayyan molekulasining $\vartheta_e / 2$ tezlikdan ko‘pi bilan *1 %* ga farq qiladigan tezlikka ega bo‘lish ehtimolligi qanday? **Javob:** *0,439 %*

5.12. Ideal gaz muayyan molekulasining $2\vartheta_e$ tezlikdan ko‘pi bilan *1 %* ga farq qiladigan tezlikka ega bo‘lish ehtimolligi qanday? **Javob:** *0,663 %*

5.13. *Tezliklari ϑ dan $\vartheta + \Delta\vartheta$ oraliqda yotgan molekulalarning ΔN_1 soni tezliklari ϑ_e dan $\vartheta_e + \Delta\vartheta$ oraliqda yotgan molekulalarning ΔN_2 sonidan necha marta kichik? **Javob:** *Ixtiyoriy gaz uchun* $\frac{\Delta N_2}{\Delta N_1} = 1{,}1$ *bo‘ladi.*

5.14. *Ballonda *5 g* kislorod bor. Tezliklari o‘rta kvadratik tezlikdan katta bo‘lgan kislorod molekulalarining soni topilsin. **Javob:** $N_x = 3{,}75 \cdot 10^{22}$ *ta*.

5.15. *Idishda *1600 K* temperaturali *4 g* kislorod bor. Ilgarilanma harakatining kinetik energiyasi $W_k = 6{,}65 \cdot 10^{-20}\ J$ dan yuqori bo‘lgan kislorod molekulalarining soni topilsin. **Javob:** $N_x = 9 \cdot 10^{21}$ *ta*

5.16. *Molekulalar umumiy sonining qanday qismi : 1) ehtimolligi eng katta tezlikdan katta tezliklarga; 2) ehtimolligi eng katta tezlikdan kichik tezliklarga ega bo‘ladi? **Javob:** *57,2%; 42,8%*

5.17. **150^0C temperaturada azot molekulalarining qancha qismi *300 m/s* dan *800 m/s* gacha oraliqdagi tezliklarga ega bo‘ladi. **Javob:** *70 %*

5.18. *Normal sharoitda vodorod *1* sm^3 hajmni egallab turibdi. Shu hajmda *1 m/s* tezlikdan kichik tezlikka ega bo‘lgan nechta molekula bor? **Javob:** $6 \cdot 10^9$ *ta*

5.19. **Bir xil haroratda energiyasi molekula ilgarilanma harakat o‘rtacha kinetik energiyasidan *1 %* dan ko‘p farq qilmaydigan ideal gaz molekulalarining ulushi aniqlansin. **Javob:** *0,93 %*

5.20. **Energiyalari *0* dan *0,01kT* gacha oraliqda joylashgan molekulalarning ulushi aniqlansin. **Javob:** 0,0753%

5.21. **Energiyalari *0* dan biror *E* gacha oraliqda joylashgan molekulalarning soni molekulalar umumiy sonining *0,1 %* ini tashkil qiladi. *E* ning kattaligini *kT* ulushlarida aniqlang. **Javob:** $8{,}28 \cdot 10^{-3}\ kT$

5.22. *$T_1=T$ va $T_2=2T$ bo‘lgan hollar uchun Maksvell taqsimot funksiyasi egri chiziqlari ϑ tezlikning qanday qiymatida kesishadi? Egri chiziqlar necha marta kesishadi? **Javob:** $\vartheta=\sqrt{1{,}5\ln 2}\cdot\vartheta_{e.2}$; *faqat bir marta*

5.23. Qanday temperaturada vodorod molekulasining tezliklar bo‘yicha taqsimot funksiyasi xona temperaturasidagi (20^0C) azot molekulasining tezliklar bo‘yicha taqsimot funksiyasi bilan ustma-ust tushadi. **Javob:** *21 K*

5.24. Ideal gaz molekulalarining energiyalar bo‘yicha taqsimot funksiyasidan foydalanib eng katta ehtimoliy energiyani keltirib chiqaring. **Javob:** $\varepsilon_e=\frac{1}{2}k_BT$

5.25. *Bir atomli ideal gazning o‘rta kvadratik tezligi 2 marta oshish uchun bu gazni adiabatik ravishda necha marta siqish kerak bo‘ladi? **Javob:** *8 marta*

5.26. *Maksvellning tezliklar bo‘yicha taqsimot funksiyasidan foydalanib, eng katta ehtimoliy tezlikni keltirib chiqaring. **Javob:** $\vartheta_e=\sqrt{\frac{2k_BT}{M}}$

5.27. *Maksvellning tezliklar bo‘yicha taqsimot funksiyasidan foydalanib, o‘rtacha tezlikni keltirib chiqaring. **Javob:** $\vartheta_e=\sqrt{\frac{8k_BT}{\pi M}}$

5.28. **Maksvellning tezliklar bo‘yicha taqsimot funksiyasidan foydalanib, o‘rtacha tezlikni keltirib chiqaring. **Javob:** $\vartheta_e=\sqrt{\frac{3k_BT}{M}}$

5.29. *Maksvellning tezliklar bo‘yicha taqsimot funksiyasidan foydalanib, ilgarilanma impuls orqali ifodalangan taqsimot funksiyasini keltirib chiqaring. **Javob:** $f(p)=\frac{n}{n\,dp}=\frac{4}{\sqrt{\pi}}\left(2\pi m_0k_BT\right)^{-3/2}p^2e^{-p^2/(2m_0k_BT)}$

5.30. *Maksvellning tezliklar bo‘yicha taqsimot funksiyasidan foydalanib, ilgarilanma kinetik energiya orqali ifodalangan taqsimot funksiyasini keltirib chiqaring. **Javob:** $f(\varepsilon)=\frac{n}{n\,d\varepsilon}=\frac{2}{\sqrt{\pi}}\left(k_BT\right)^{-3/2}\varepsilon^{1/2}e^{-\varepsilon/(k_BT)}$

5.31. *Maksvellning tezliklar bo‘yicha taqsimot funksiyasidan foydalanib, nisbiy tezliklar orqali ifodalangan taqsimot funksiyasini keltirib chiqaring. **Javob:** $f(u)=\frac{n}{n\,du}=\frac{4}{\sqrt{\pi}}u^2e^{-u^2}$

5.32. *Maksvellning tezliklar komponentasi bo‘yicha taqsimot funksiyasidan foydalanib, nisbiy tezliklar komponentasi orqali ifodalangan taqsimot funksiyasini keltirib chiqaring. **Javob:** $f(u_x)=\frac{n}{n\,du_x}=\frac{1}{\sqrt{\pi}}e^{-u_x^2}$

6-MAVZU: Gaz molekulalarining erkin yugurish yo‘li. Gaz molekulalarining o‘rtacha to‘q nashishlar soni. Ichki ishqalanish. Puzeyl formulasi. Reynolds soni

Mavzuga oid muhim formulalar

$F_{ish} = -\eta \frac{\Delta \vartheta}{\Delta \ell} S$	*Ichki ishqalanish uchun Nyuton formulasi*
$F_{ish} = 6\pi\eta r\vartheta$ $\eta = \frac{2t}{9h}(\rho - \rho_s) g r^2$	*Qovushqoq muhitda harakatlanayotgan sharga ta’sir qiluvchi ishqalanish kuchi – Stoks formulasi*
$F_{qar} = C_x S \frac{\rho \vartheta^2}{2}$	*Nisbatan katta tezliklarda peshona qarshilik kuchi*
$\vartheta = \frac{p_1 - p_2}{4\eta\ell}(R^2 - r^2)$	*Qovusqoq suyuqlikning slindrik trubada oqish tezligi*
$\vartheta_{\max} = \frac{(p_1 - p_2)R^2}{4\eta\ell}$	*Suyuqlikning slindrik truba o‘qidagi tezligi*
$Q = \frac{\pi R^4}{8\eta} \frac{p_1 - p_2}{\ell}, \quad Q = \frac{\pi R^4}{8\eta} \frac{dp}{d\ell}$	*Slindrik trubada oqayotgan qovushqoq suyuqlikning suyuqlik sarfi*
$\Delta V = \frac{\pi R^4}{8\eta} \frac{dp}{d\ell} \Delta t$	*Biror vaqtda slindrik trubadan oqib o‘tgan suyuqlik hajmi*
$\vartheta_{o'rt} = \frac{R^2}{8\eta} \frac{dp}{d\ell}$	*Qovusqoq suyuqlikning slindrik trubadagi o‘rtacha oqim tezligi*
$X = \frac{8\eta\ell}{\pi R^4}$	*Gidravlik qarshilik*
Ketma-ket va parallel ulangan trubalar sistemasining umumiy gidravlik qarshiligi $X = X_1 + X_2 + X_3 + ... + X_n, \qquad \frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + ... + \frac{1}{X_n}$	
$\nu = \frac{\eta}{\rho_s}$	*Kinematik qovushqoqlik*
$\mathrm{Re} = \frac{\rho_s \vartheta d}{\eta}, \qquad \mathrm{Re} = \frac{\vartheta d}{\nu}$	*Reynolds soni*
$<\lambda> = \frac{<\vartheta>}{<\nu>} = \frac{1}{\sqrt{2}\pi d_{eff}^2 n} = \frac{1}{\sqrt{2}\sigma_{eff} n}$	*Gaz molekulalarining erkin yugurish yo‘li*
$<\nu> = \sqrt{2}\pi d_{eff}^2 n <\vartheta> = \sqrt{2}\sigma_{eff} n <\vartheta>$	*Gaz molekulalarining bir sekund vaqtdagi to‘qnashishlar soni*
$<\tau> = \frac{1}{<\nu>} = \frac{1}{\sqrt{2}\pi d_{eff}^2 n <\vartheta>} = \frac{1}{\sqrt{2}\sigma_{eff} n <\vartheta>}$	*Gaz molekulalarining erkin yugurish vaqti*
$<\vartheta> = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8k_B T}{\pi m_0}}$	*Gaz molekulalarining o‘rtacha (o‘rta arifmetik) tezligi*

Birlik hajmdagi molekulalarningbirlik vaqtdagi jami to‘qnashishlar soni

$$< z >= \frac{1}{2} n < v > \quad yoki \quad < z >= \frac{\sqrt{2}}{2} \sigma_{eff} n^2 < \vartheta >= \frac{\sqrt{2}}{2} \pi d_{eff}^2 n^2 < \vartheta >$$

Gaz molekulalarining erkin yugurish yo‘li, erkin yugurish vaqti va birlik vaqtdagi to‘qnashishlar sonining gaz bosimi va temperaturasiga bog‘liq formulalari

$$< \lambda >= \frac{k_B}{\sqrt{2}\pi d_{eff}^2} \cdot \frac{T}{P}, \quad < \tau >= \frac{\sqrt{k_B m_0}}{4\sqrt{\pi} d^2} \cdot \frac{\sqrt{T}}{P}, \quad < v >= \frac{4\sqrt{\pi} d^2}{\sqrt{k_B m_0}} \cdot \frac{P}{\sqrt{T}}$$

6-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. *P=100 kPa* bosim va *T=273 K* temperaturada vodorod molekulalarining erkin yugurish yo‘li *λ=100 nm* ga teng. Bu molekulalarning diametri d ning kattaligini baholang.

Berilgan:

P=100 kPa

T=273 K

λ=100 nm

d=?

Yechilishi:

Molekulaning diametrini baholash sifatida uning effektiv qiymatini qabul qilamiz.

$$< \lambda >= \frac{1}{\sqrt{2}\pi d^2 n}$$

Bu yerda: d – molekulaning effektiv diametri, n – molekulalar konsentratsiyasi.

P=nkT formuladan foydalansak, konsentratsiya uchun uhbu $n = \frac{P}{k_B T}$ almashtirish bajaramiz.

$$< \lambda >= \frac{1}{\sqrt{2}\pi d^2 n} = \frac{k_B T}{\sqrt{2}\pi d^2 P}, \quad \rightarrow \quad d = \sqrt{\frac{k_B T}{\sqrt{2}\pi < \lambda > P}} =$$

$$= \sqrt{\frac{1{,}38 \cdot 10^{-23} \cdot 273}{1{,}41 \cdot 3{,}14 \cdot 10^{-7} \cdot 10^5}} \approx 2{,}9 \cdot 10^{-10} m = 0{,}29 nm$$

Javob: *d=0,29 nm*

Masala № 2. Agar ideal gazning zichligi *k_1=3* marta oshirilsa, tempera-turasi esa *k_2=4* marta kamaytirilsa, molekulalarning birlik vaqtdagi to‘qnashuvlar soni necha marta o‘zgaradi?

Berilgan:

$\rho_2 = k_1 \rho_1$

$T_2 = \frac{T_1}{k_2}$

Yechilishi:

Molekulalarning birlik vaqtdagi o‘rtacha to‘qnashuvlar soni

$$< z >= \sqrt{2}\pi d^2 n < \vartheta >$$

formuladan aniqlanadi.

Bu yerda: d – molekulaning effektiv diametri; n – molekulalar

$\frac{<z_2>}{<z_1>}=?$

konsentratsiyasi bo‘lib $n=\rho/m_0$ formuladan aniqlanadi; $<\vartheta>$ – molekulalarning o’rtacha harakat tezligi bo‘lib u quyidagi formuladan aniqlanadi:

$$<\vartheta>=\sqrt{\frac{8k_BT}{\pi m_0}}$$

$<\vartheta>$ va n uchun yozilgan formulalarni birlik vaqtdagi molekulalarning o‘rtacha to‘qnashuvlar sonini topish formulasiga qo‘yamiz.

$$<z>=\sqrt{2}\,\pi d^2 n<\vartheta>=\sqrt{2}\,\pi d^2\frac{\rho}{m_0}\sqrt{\frac{8k_BT}{\pi m_0}}=4d^2\frac{\rho}{m_0}\sqrt{\frac{\pi k_BT}{m_0}}$$

Yuqoridagi formulani zichlik va temperatura o‘zgarishdan oldingi va keyingi hol uchun yozamiz.

$$<z_1>=4d^2\frac{\rho_1}{m_0}\sqrt{\frac{\pi k_BT_1}{m_0}}$$

$$<z_2>=4d^2\frac{\rho_2}{m_0}\sqrt{\frac{\pi k_BT_2}{m_0}}=4d^2\frac{k_1\rho_1}{m_0}\sqrt{\frac{\pi k_BT_1}{m_0k_2}}=\frac{k_1}{\sqrt{k_2}}\left(4d^2\frac{\rho_1}{m_0}\sqrt{\frac{\pi k_BT_1}{m_0}}\right)=\frac{k_1}{\sqrt{k_2}}<z_1>$$

Endi so‘ralgan nisbatni aniqlaymiz.

$$\frac{<z_2>}{<z_1>}=\frac{k_1}{\sqrt{k_2}}=\frac{3}{\sqrt{4}}=1{,}5$$

Javob: *1,5 marta ortadi*

Masala № 3. Karbonad angidrid (CO_2) gazining effektiv diametrini *d=0,35 nm* ga teng deb olib uning erkin yugurish yo‘lini aniqlang. Gazning bosimi *P=1 mm.sm.ust.*, temperaturasi $t=50^0C$. Bu sharoitda erkin yugurish yo‘li molekula o‘lchamidan necha marta katta?

Berilgan:

M=44 g/mol
d=0,35 nm
P=133,3 Pa
T=323 K

$<\lambda>=?$
$<\lambda>/d=?$

Yechilishi:

Gaz bosimi uchun $P=nk_BT$ formuladan foydalanib, konsentartsiya n ni erkin yugurish yo‘li formulasiga qo‘yamiz.

$$<\lambda>=\frac{1}{\sqrt{2}\,\pi d^2 n}=\frac{k_BT}{\sqrt{2}\,\pi d^2 P}=\frac{1{,}38\cdot10^{-23}\cdot323}{1{,}41\cdot3{,}14\cdot\left(3{,}5\cdot10^{-10}\right)^2\cdot133{,}3}=$$

$$=6{,}165\cdot10^{-5}m=61{,}65\,\mu m.$$

Endi erkin yugurish yo‘li va molekula diametrining necha marta farq qilishini aniqlaymiz.

$$\frac{<\lambda>}{d}=\frac{6{,}165\cdot10^{-5}m}{3{,}5\cdot10^{-10}m}=1{,}76\cdot10^5$$

Javob: $<\lambda>=61,65\,\mu m;\ \dfrac{<\lambda>}{d}=1,76\cdot10^{5}$

Masala № 4. Ideal gaz molekulasiniong o‘rtacha erkin yugurish yo‘li <λ>, o‘rtacha erkin yugurish vaqti τ, birlik vaqtdagi o‘rtacha to‘qnashishlar soni <z> kattaliklarining bosim P va temperatura T ga bog‘liqlik ifodalarini aniqlang.

Berilgan:	*Yechilishi:*
<λ>	Avvalo <λ>, <z> va τ kattaliklarining formulalarini yozamiz.
<z>	
τ	
$<\lambda>=\lambda(T,P)-?$	$<\lambda>=\dfrac{1}{\sqrt{2}\,\pi d^{2}n}$ (1)
$\tau=\tau(T,P)-?$	$\tau=\dfrac{1}{\sqrt{2}\,\pi d^{2}n<\vartheta>}$ (2)
$<z>=z(T,P)-?$	$<z>=\sqrt{2}\,\pi d^{2}n<\vartheta>$ (3)

Yuqoridagi formulalarga $n=\dfrac{P}{k_B T}$ hamda $<\vartheta>=\sqrt{\dfrac{8k_B T}{\pi m_0}}=\sqrt{\dfrac{8RT}{\pi M}}$ formulalarni qo‘yish orqali so‘ralgan bog‘lanishlarni olamiz.

$$<\lambda>=\frac{1}{\sqrt{2}\,\pi d^{2}n}=\frac{k_B T}{\sqrt{2}\,\pi d^{2}P}=\frac{k_B}{\sqrt{2}\,\pi d^{2}}\cdot\frac{T}{P} \qquad (1')$$

$$\tau=\frac{1}{\sqrt{2}\,\pi d^{2}n<\vartheta>}=\frac{k_B T}{\sqrt{2}\,\pi d^{2}P}\sqrt{\frac{\pi m_0}{8k_B T}}=\frac{\sqrt{k_B m_0}}{4\sqrt{\pi}d^{2}}\cdot\frac{\sqrt{T}}{P} \qquad (2')$$

$$<z>=\sqrt{2}\,\pi d^{2}n<\vartheta>=\sqrt{2}\,\pi d^{2}\frac{P}{k_B T}\sqrt{\frac{8k_B T}{\pi m_0}}=\frac{4\sqrt{\pi}d^{2}}{\sqrt{k_B m_0}}\cdot\frac{P}{\sqrt{T}} \qquad (3)$$

Javob: $<\lambda>=\dfrac{k_B}{\sqrt{2}\,\pi d^{2}}\cdot\dfrac{T}{P};\ <\tau>=\dfrac{\sqrt{k_B m_0}}{4\sqrt{\pi}d^{2}}\cdot\dfrac{\sqrt{T}}{P};\ <z>=\dfrac{4\sqrt{\pi}d^{2}}{\sqrt{k_B m_0}}\cdot\dfrac{P}{\sqrt{T}}$

Masala № 5. Havodagi chang zarrachasining o‘chami *0,2μm* dan *5μm* gacha oraliqda bo‘ladi. Zarrachaning zichligini *2500 kg/m³* deb, sahkilini esa *R=1μm* radiusli sharsimon deb hisoblab, uning balandligi *3m* balandlikdan tushish vaqtini baholang. Havoni qo‘zg‘almas deb hisoblang. Broun harakatini hisobga olmang. Havoning qovushqoqligi *1,7·10⁻⁵ Pa·s*, zichligi *1,3 kg/m³*.

Berilgan:

$\rho = 2500\,kg/m^3$

$h = 3m$

$\rho_h = 1,3\,kg/m^3$

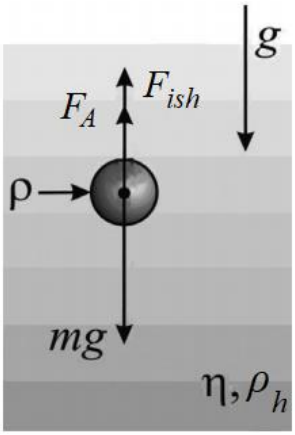
$R = 10^{-6}\,m$

$\eta = 1,7\cdot10^{-5}\,Pa\cdot s$

$t = ?$

Yechilishi:

Havodagi chan zarrachasiga Arximed kuchi va ishqalanish kuchi ta'sir etadi.



$$F_A = \rho_h V g = \frac{4}{3}\pi R^3 \rho_h g, \quad F_{ish} = 6\pi\eta R\vartheta$$

Chang zarrachasi tekis tushayotganda og'irlik kuchi Arximed kuchi va ishqalanish kuchlar bilan balanslashadi.

$$F_{og'} = F_A + F_{ish}, \quad \rightarrow \quad \frac{4}{3}\pi R^3 \rho g = \frac{4}{3}\pi R^3 \rho_h g + 6\pi\eta R\vartheta$$

Bundan zarrachaning tekis tushish tezligini aniqlaymiz.

$$\vartheta = \frac{2R^2 g(\rho - \rho_h)}{9\eta} = \frac{2\cdot10^2\cdot9,8\cdot(2500-1,3)}{9\cdot1,7\cdot10^{-5}} = 3,3\cdot10^{-4}\,m/s$$

h=3m balandlikdan tushish vaqti quyidagicha bo'ladi:

$$t = \frac{h}{\vartheta} = \frac{3}{3,3\cdot10^{-4}} \approx 9\cdot10^4\,s = 2,5\,soat$$

Javob: 2,5 soat.

6-amaliy mashg'ulot topshirig'i

6.1. Ikkita bir xil uzunlikdagi trubalar uchlarida bir xil bosimlar farqi qayd etiladi. Trubalardan dinamik qovushqoqliklari 5 marta farq qiladigan suyuqliklar oqmoqda. Agar har ikkala truba kesimlari orqali bir xil vaqtda bir xil hajmdagi suyuqliklar oqib o'tgan bo'lsa, u holda trubalar diametrlari necha marta faqr qiladi? **Javob:** *1,495 marta*

6.2. Radiusi *r=1 mm*, uzunligi *ℓ=10 sm* bo'lgan slindrik idishning *t=20⁰C* temperaturadagi gidravlik qarshiligini ushbu hollar uchun aniqlang. Trubadan: a) havo oqmoda; b) suv oqmoqda; c) qon oqmoqda. Suv uchun *20⁰C* da dinamik qovushqoqlik *η=1 mPa·s* ga teng. Shu temperaturada havoning qovushqoqligi suvnikidan *50* marta kichik, qonniki esa *5* marta katta deb oling. **Javob:**

$a)\ X = 5,6\cdot10^6\,\frac{kg}{m^4 s};\ b)\ X = 2,6\cdot10^8\,\frac{kg}{m^4 s};\ c)\ X = 1,3\cdot10^9\,\frac{kg}{m^4 s}$

6.3. Shamollaganda nafas olish yo'llarida qisqarishlar sodir bo'ldi va natijada kesim radiusi 2 marta kishraydi. Kasal bo'lishiga qaramasdan odamning nafas olish sarfi o'zgaramagan deb hisoblab, bunda Reynolds soni necha marta o'zgarganini aniqlang. Agar shamollashgacha nafas yo'li uchun Reynolds soni *1500* ga teng bo'lgan bo'lsa, u holda shamollagan o'pka yo'lidagi havo harakatini turbulent deb aytish mumkiinmi? **Javob:** *2 marta oshadi; turbulent deyish mumkin*

6.4. Zichligi *ρ=2500 kg/m³* ga, radiusi *r=2 μm* ga teng bo'lgan sferik zarrachaning *ℓ=3 sm* balandlikdagi suv qatlamiga cho'kish tezligi hamda cho'kish vaqti quyidagi ikki hol uchun topilsin: *a)* og'irlik kuchi ta'sirida; *b) R=10 sm* radiusli sentrifugada *n=500 Gs*

chastota bilan aylanganda (bunda og‘irlik kuchini hisobga olmang). $t=20^0C$ da suvning qovushqoqligi $\eta=1\ mPa\cdot s$ ga teng. **Javob:** *a)* $t=2{,}25\cdot10^3\ s$; $\vartheta=1{,}33\cdot10^{-5}\ m/s$; b) $t=2{,}25\cdot10^{-2}$ s; $\vartheta=1{,}33\ m/s$

6.5. Radiusi $r=1\ mm$ ga teng bo‘lgan sharik suvda $\vartheta=2\ m/s$ tezlik bilan harakatlanmoqda. Suvning bir qismi sharik yuzasiga ilashib qoladi va qatlamlarning nisbiy harakati yuzaga keladi. Suvning nisbiy oqimi qaysi turga (laminar yoki turbulent) mansub? **Javob:** $Re=4000>Re_{kr}$, *turbulent oqim*

6.6. Radiusi $d=1\ mm$ ga teng bo‘lgan trubada qovushqoq suyuqlik oqmoqda. Bunda Reynolds soni $Re=1000$. Truba kesimi qisqarib boshlaydi va suyuqlikning hajmiy oqish tezligi (suyuqlik sarfi) saqlanib qoladi. Trubaning qanday d_x diametrida turbulentli oqimi paydo bo‘ladi? $Re_{kr}=2300$. **Javob:** $d_x=0{,}87\ mm$

6.7. Ko‘ndalang kesim yuzasi $S=1\ m^2$ bo‘lgan sun’iy yo‘ldosh $h=200\ km$ balandlikda $\vartheta=7900\ m/s$ tezlik bilan orbitada harakatlanmoqda. Bu balandlikda temperatura $T=1226\ K$, havo bosimi esa $P=1{,}37\cdot10^{-4}\ Pa$ ga teng. Yo‘ldoshning havo molekulalari bilan birlik vaqtda to‘qnashishlar sonini aniqlang. **Javob:** s^{-1}

6.8. Normal sharoitdagi havodagi diametri $d=3{,}7\cdot10^{-10}\ m$ bo‘lgan molekulalarning o‘rtacha erkin yugurish yo‘lini aniqlang. **Javob:** $<\lambda>=62\ nm$

6.9. Normal sharoitdagi havodagi azot molekulalarning o‘rtacha erkin yugurish yo‘lini aniqlang. Azot va kislorod molekulalarining diametrini $d=0{,}18\ nm$ deb qabul qiling. **Javob:** $<\lambda>=65\ nm$

6.10. Sig‘imi $V=2{,}53\ l$ bo‘lgan ballonda $T=400\ K$ temperatura va $P=1{,}3\ Pa$ bosimdagi karbonat angidrid (CO_2) gazi bor. $t=1\ s$ vaqt ichida molekulalar orasida qancha z to‘qnashuvlar sodir bo‘ladi? **Javob:** $z=9{,}3\cdot10^9$ ta

6.11. 0^0C temperaturada turgan kislorod molekulasining o‘rtacha erkin yugurish yo‘lini aniqlang. $1s$ vaqtdagi o‘rtacha to‘qnashishlar soni $z=3{,}7\cdot10^9$ ga teng. **Javob:** $<\lambda>=115\ nm$

6.12. $P=0{,}1\ Pa$ bosim va $T=100\ K$ haroratda vodorod molekulalari erkin yugurish yo‘lining o‘rtacha uzunligini toping. **Javob:** *6,4 sm*

6.13. Agar gazning harorati $T=300\ K$ bo‘lsa, qanday P bosimda azot molekulalarining erkin yugurish yo‘lining o‘rtacha qiymati $<\lambda>=1\ m$ bo‘ladi? **Javob:** *3,5 mPa*

6.14. T=280 K haroratda azot saqlanayotgan $d=20\ sm$ diametrli kolbada hosil qilingan $P=100\ \mu Pa$ bosimli vakuumni yuqori vakuum deb hisoblash mumkinmi? **Javob:** *mumkin, chunki* $<\lambda>=97\ m$

6.15. Normal sharoitda $t=1s$ vaqt davomida kislorod molekulasiga urilishlarning o‘rtacha soni $<z>$ ni aniqlang. **Javob:** $<z>=3{,}7\cdot10^9\ s^{-1}$

6.16. Normal sharoitda $V=5\ mm^3$ hajmdagi vodorodning barcha molekulalari orasida $t=2\ s$ davomida bo‘ladigan barcha urilishlar soni N aniqlansin. **Javob:** $N=1,57\cdot10^{22}$ ta

6.17. $T=250\ K$ harorat va $P=100\ Pa$ bosim ostidagi kislorod molekulasi erkin yugurish yo‘lining o‘rtacha davomiyligi $<\tau>$ qancha? **Javob:** $<\tau>=288$

7-MAVZU: Gazlarda diffuziya hodisasi. Fik qonuni. Ideal gazlar uchun qovushqoqlik va issiqlik o‘tkazuvchanlik koeffitsiyentlari.

Mavzuga oid muhim formulalar

$G=\frac{1}{3}<\vartheta><\lambda>\frac{dH}{dx}S\Delta t$	*Ko‘chki tenglamasi*
$\Delta N^{*}=\frac{\Delta N}{S\tau}=-\frac{1}{3}\langle\lambda\rangle\langle\vartheta\rangle\frac{dn}{dx}$	*Birlik vaqtda birlik yuzadan o‘tgan molekulalar soni*
$\Delta N=\Delta N^{*}S\tau=-\frac{1}{3}\langle\lambda\rangle\langle\vartheta\rangle\frac{dn}{dx}S\tau$	*S yuzadan τ vaqtda ko‘chib o‘tgan molekulalar soni*
$\Delta M^{*}=-\frac{1}{3}<\lambda><\vartheta>\frac{d\rho}{dx}$	*Birlik vaqtda birlik yuzadan o‘tgan massa*
$\Delta M=\Delta M^{*}S\tau=-\frac{1}{3}<\lambda><\vartheta>\frac{d\rho}{dx}S\tau$	*S yuzadan τ vaqtda ko‘chib o‘tgan massa*
$D=\frac{1}{3}<\lambda><\vartheta>,\quad \Delta M^{*}=-D\frac{d\rho}{dx}$	*Diffuziya koeffitsiyenti*
$D=\frac{2k_BT\sqrt{k_BT}}{3\pi d_{eff}^{2}\sqrt{\pi m_0}\,P}$	*Diffuziya koeffitsiyentining temperatura va bosimga bog‘liqligi*
$F_{ishq}=-\frac{1}{3}\rho<\vartheta><\lambda>S\frac{du}{dx}$	*Yondosh qatlamlar orasidagi ichki ishqalanish kuchi*
$\eta=\frac{1}{3}\rho<\vartheta><\lambda>,\quad \eta=\rho D$	*Ichki ishqalanish (qovushqoqlik) koeffitsiyenti*
$\eta=\frac{2}{3}\frac{k_B}{\pi d_{eff}^{2}}\sqrt{\frac{MT}{\pi R}}$	*Ichki ishqalanish koeffitsiyentining temperaturaga bog‘liqligi*
$\Delta Q^{*}=\frac{\Delta Q}{S\tau}=-\frac{1}{3}n<\lambda><\vartheta>\frac{dE}{dx}$ $\Delta Q^{*}=-\frac{1}{3}\rho<\lambda><\vartheta>c_V\frac{dT}{dx}$ $\Delta Q^{*}=-\chi\frac{dT}{dx}=-\chi\,gradT$	*Birlik vaqtda birlik yuzadan o‘tgan energiyani aniqlash formulalari*
$\Delta Q=\Delta Q^{*}S\tau=-\frac{1}{3}\rho<\lambda><\vartheta>c_V\frac{dT}{dx}S\tau$	*S yuzadan τ vaqtda o‘tgan energiya*
$\chi=\frac{1}{3}\rho<\lambda><\vartheta>c_V,\quad c_V=\frac{i}{2}\frac{R}{M}$ $\chi=\eta c_V=\chi=\rho D c_V$	*Ideal gazlar uchun issiqlik o‘tkazish koeffitsiyenti*
$\chi=\frac{i}{3}\frac{k_B}{\pi d_{eff}^{2}}\sqrt{\frac{RT}{\pi M}}$	*Issiqlik o‘tkazish koeffitsiyentining temperaturaga bog‘liqligi*

7-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. *P=101,3 kPa* bosim va $t=10^{0}C$ temperaturadagi havoning diffuziya koeffitsiyentini va qovushqoqligini aniqlang. Havo molekulasining

effektiv diametri $d=3,8\cdot10^{-10}$ *m* ga teng.

Berilgan:	*Yechilishi:*
$P=101,3$ *kPa* $t=10^0C$ $d=3,8\cdot10^{-10}$ *m*	Diffuziya koeffitsiyentini aniqlash formulasi $D=\frac{1}{3}<\lambda><\vartheta>$
D=? η=?	ga $<\lambda>=\frac{1}{\sqrt{2}\pi d^2 n}$, $n=\frac{P}{k_B T}$ va $<\vartheta>=\sqrt{\frac{8k_B T}{\pi m_0}}$ formulalarni

qo‘yamiz.

$$D=\frac{1}{3}<\lambda><\vartheta>=\frac{1}{3}\frac{1}{\sqrt{2}\pi d^2 n}\sqrt{\frac{8k_B T}{\pi m_0}}=\frac{1}{3}\frac{k_B T}{\sqrt{2}\pi d^2 P}\sqrt{\frac{8RT}{\pi M}}=\frac{2k_B T}{3\pi d^2 P}\sqrt{\frac{RT}{\pi M}}=$$

$$=\frac{2\cdot1,38\cdot10^{-23}\cdot283}{3\cdot3,14\cdot\left(3,8\cdot10^{-10}\right)^2\cdot101300}\cdot\sqrt{\frac{8,31\cdot283}{3,14\cdot0,029}}=9,11\cdot10^{-6}\,m^2/s.$$

Qovushqoqlik koeffitsiyentini

$$D=\frac{\eta}{\rho}$$

bog‘lanishdan aniqlash mumkin. Bunda zichlikni Mendeleyev-Klapeyron tenglamasi $P=\frac{\rho RT}{M}$ dan foydalanib aniqlash mumkin.

$$\eta=\rho D=\frac{PM}{RT}D=\frac{101300\cdot0,029}{8,31\cdot283}\cdot9,11\cdot10^{-6}=1,138\cdot10^{-5}\,Pa\cdot s$$

Javob: $D=9,11\cdot10^{-6}\,m^2/s;\ \eta=1,138\cdot10^{-5}\,Pa\cdot s$.

Masala № 2. Azot uchun molekulalarning o‘rtacha erkin yugurish yo‘lini *<λ>*, diffuziya koeffitsiyentini *D*, qovushqoqlikni *η* va issiqlik o‘tkazuvchanlikni χ aniqlang. Temperatura $t=17^0C$, bosim $p=100$ *kPa*. Azot uchun effektiv diametr $d_{eff}=0,32$ *nm* ga teng.

Berilgan:	*Yechilishi:*
$p=100$ *kPa* $t=17^0C$ $d_{eff}=3,2\cdot10^{-10}$ *m*	Erkin yugurish masofasini aniqlaymiz. $<\lambda>=\frac{k_B T}{\sqrt{2}\pi d_{eff}^2 P}=\frac{1,38\cdot10^{-23}\cdot290}{1,41\cdot3,14\cdot\left(3,2\cdot10^{-10}\right)^2\cdot10^5}=8,83\cdot10^{-8}m=88,3nm$
<λ>=?, D=? η=?, χ=?	Molekulalarning o‘rtacha tezligini topamiz. $<\vartheta>=\sqrt{\frac{8RT}{\pi M}}=\sqrt{\frac{8\cdot8,31\cdot290}{3,14\cdot28\cdot10^{-3}}}=468m/s$

Diffuziya koeffitsiyentini aniqlaymiz.

$$D=\frac{1}{3}<\lambda><\vartheta>=\frac{1}{3}\cdot8,83\cdot10^{-8}\cdot468=1,378\cdot10^{-5}\,m^2/\text{s}.$$

Azotning zichligini aniqlaymiz.

$$\rho = \frac{PM}{RT} = \frac{10^5 \cdot 28 \cdot 10^{-3}}{8{,}31 \cdot 290} = 1{,}162\, kg/m^3$$

Dinamik qovushqoqlikni aniqlaymiz.

$$\eta = \rho D = 1{,}162 \cdot 1{,}378 \cdot 10^{-5} = 1{,}6 \cdot 10^{-5}\, Pa \cdot s = 16\, \mu Pa \cdot s$$

Endi issiqlik o‘tkazuvchanlik koeffitsiyentini aniqlaymiz.

$$\chi = \eta c_V = \eta \frac{i}{2}\frac{R}{M} = 1{,}6 \cdot 10^{-5} \cdot \frac{5}{2} \cdot \frac{8{,}31}{28 \cdot 10^{-3}} = 1{,}187 \cdot 10^{-2} W/(\mathrm{m \cdot K}) = 11{,}87\ mW/(\mathrm{m \cdot K})$$

Javob:

$$<\lambda> = 8{,}83 \cdot 10^{-8} m;\ D = 1{,}378 \cdot 10^{-5}\, m^2/s;\ \ \eta = 1{,}6 \cdot 10^{-5}\, Pa \cdot s;\ \chi = 1{,}187 \cdot 10^{-2} W/(\mathrm{m \cdot K}).$$

Masala № 3. Uzunlikari $\ell = 10\ sm$ dan bo‘lgan ikkita yupqa devorli koaksial slindrlar umumiy o‘qlari atrofida erkin aylanishadi. Katta slindrning radiusi *R=5 sm*. Slindrlar orasida *Δr=2 mm* bo‘lgan bo‘shliq bor. Ikkala slindr ham normal sharoitdagi havoda turibdi. Ichki slindrni o‘zgarmas $\nu_1 = 20\ Gs$ chastota bilan aylantirildi. Tashqi slindr ushlab turilibdi. Tashqi slindr qo‘yib yuborilgandan boshlab qancha vaqt o‘tgach $\nu_2 = 1\ Gs$ chastota bilan aylanadi? Hisob ishlarida slindrlarning nisbiy tezliklari o‘zgarishi e’tiborga olinmasin. Tashqi slindr massasi *m=100 g*. Havoning dinamik qovushqoqligi $\eta = 1{,}72 \cdot 10^{-5}\ Pa \cdot s$ ga teng.

Berilgan:

$\ell = 10\, sm$
$R = 5\, sm$
$\Delta r = 2\, mm$
$\nu_1 = 20\, Gs$
$\nu_2 = 1 Gs$
$m = 0{,}1 kg$
$\eta = 17{,}2\, \mu Pa \cdot s$

$t = ?$

Yechilishi:

Ichki slindr aylanganda slindrga yopishgan havo qatlami unga ergashadi va $\vartheta = 2\pi\nu_1 (R - \Delta r)$ tezlik bilan aylana boshlaydi. Ammo, *Δr<<R* ekanligidan $\vartheta \approx 2\pi\nu_1 R$ deyish mumkin. Ichki ishqalanish tufayli impuls momenti gazning qo‘shni qatlamlariga uzatiladi.

Biror *Δt* vaqt davomida tashqi slindr *ΔL=Δp·R* ga teng impuls momentini oladi. Bunda *Δp* – tashqi slindr *Δt* vaqt davomida olgan impuls. Bu impuls o‘garishlari boshqa tomondan

$$\Delta p = F \cdot \Delta t = \eta \frac{d\vartheta}{dr} S \cdot \Delta t = \eta \frac{\vartheta}{\Delta r} S \cdot \Delta t$$

ekanini inobatga olsak, *Δt* vaqt uchun ushbu ifodani olamiz.

$$\Delta t = \frac{\Delta p}{\eta \frac{\vartheta}{\Delta r} S} = \frac{\Delta L}{\eta \frac{\vartheta}{\Delta r} S R} = \frac{I\,\Delta\omega}{\eta \frac{\vartheta}{\Delta r} S R} = \frac{mR^2 \cdot 2\pi\nu_2}{\eta \frac{\vartheta}{\Delta r} (2\pi R \ell) R} = \frac{m\nu_2 \Delta r}{\eta \vartheta \ell} = \frac{m\nu_2 \Delta r}{2\pi\eta R \ell}$$

Endi hisob-kitob ishlarini bajarib so‘ralgan natijani olamiz.

$$\Delta t = \frac{m\nu_2 \Delta r}{2\pi\eta\nu_1 R\ell} = \frac{0{,}1 \cdot 1 \cdot 2 \cdot 10^{-3}}{2 \cdot 3{,}14 \cdot 1{,}72 \cdot 10^{-5} \cdot 20 \cdot 5 \cdot 10^{-2} \cdot 0{,}1} = 18{,}5\, s$$

Javob: *Δt =18,5 s*

Masala № 4. O‘qlari mos tushadigan ikkita bir xil disk bir-biridan *h* masofada turibdi. Ularning radiuslari *a* ga teng bo‘lib, bunda *a >>h*. Disklar

molyar massasi *M* ga, bosimi *P* ga, temperaturasi *T* ga teng bo‘lgan kuchli razryadlangan gazga joylashtirildi. Disklardan biri uncha katta bo‘lmagan ω burchak tezlik bilan aylantiriladi. Ikkinchi disk aylanmasdan tinch turishi uchun uni qanday kattalikdagi M_0 burovchi moment bilan ushlab turish kerak bo‘ladi?

Berilgan:	*Yechilishi:*
$a>>h$ M, P, T ω	Molekulalar aylanayotgan diskka urilganda impuls momentini ikkinchi diskka uzatadi. Molekulalarning tekis sirt birlik yuzasiga urilishlar chastotasi quyidagich:
$\varepsilon = ?$	$$\nu = \frac{1}{4} n < \vartheta > = \frac{1}{4} n \sqrt{\frac{8k_B T}{m_0}}$$

Aylanuvchi diskda *r* radiusli va *dr* qalinlikdagi xalqani fikran ajrataylik. Bu xalqaga har sekundda

$$dN = \nu \cdot 2\pi r\, dr = \frac{1}{4} n < \vartheta > \cdot 2\pi r\, dr$$

sondagi molekulalar uriladi va qaytadi. Bunda har bir molekula $L = m_0 r^2 \omega$ ga teng impuls moment oladi. Natijada, har bir molekula shu impuls momentlarni ikkinchi diskka urilganda unga uzatadi. Birlik vaqtda ikkinchi disk urilgan molekulalardan olgan to‘la impuls momenti quyidagicha bo‘ladi:

$$\frac{dL_{um}}{dt} = \int_0^a \frac{1}{4} n < \vartheta > \cdot 2\pi r \cdot m_0 \omega r^2 dr = \frac{\pi}{8} m_0 n \omega < \vartheta > a^4$$

$\frac{dL}{dt} = M$ formulaga ko‘ra ikkinchi diskka birlik vaqtda urilib qaytadigan molekulalar

$$M_0 = \frac{\pi}{8} m_0 n \omega < \vartheta > a^4$$

ga teng burovchi momentni keltirib chiqarar ekan. $< \vartheta > = \sqrt{\frac{8k_B T}{m_0}} = \sqrt{\frac{8RT}{M}}$ va $n = \frac{P}{k_B T}$ ekanini e’tiborga olib, yuqoridagi formulani quyidagicha yozamiz:

$$M_0 = \frac{\pi}{8} m_0 n \omega < \vartheta > a^4 = \frac{\pi}{8} \frac{M}{N_A} \frac{P}{k_B T} \omega \sqrt{\frac{8RT}{\pi M}} a^4 = P \omega a^4 \sqrt{\frac{\pi}{8RT}}$$

Javob: $M_0 = P\omega a^4 \sqrt{\frac{\pi}{8RT}}$

Masala № 5 . Karbonat angidrid va azot gazi bir xil bosim va tempera-turada turibdi. Bu gazlar uchun quyidagi kattaliklar nisbatlarini aniqlang: a) diffuziya koeffitsiyentlarining; b) qovushqoqlik koefitsiyentlarining; c) issiqlik o‘tkazuv-chanlikning. Bu gazlarning molekulalarining effektiv diametrlarini bir xil deb oling.

Berilgan:

$M_1 = 44 \cdot 10^{-3} \frac{kg}{mol}$

$M_2 = 28 \cdot 10^{-3} \frac{kg}{mol}$

$P_1 = P_2; T_1 = T_2$

$d_1 = d_2$

a) $D_1 / D_2 = ?$

b) $\eta_1 / \eta_2 = ?$

c) $\chi_1 / \chi_2 = ?$

Yechilishi:

a) Diffuziya koeffitsiyentlari nisbatini aniqlash uchun avval uning formulasini keltirib chiqaramiz, so‘ngra so‘ralgan nisbatni aniqlaymiz.

$$D = \frac{1}{3} < \lambda >< \vartheta >= \frac{1}{3} \frac{1}{\sqrt{2}\pi d^2 n} \sqrt{\frac{8k_B T}{\pi m_0}} = \frac{1}{3} \frac{k_B T}{\sqrt{2}\pi d^2 P} \sqrt{\frac{8RT}{\pi M}} = \frac{2k_B T}{3\pi d^2 P} \sqrt{\frac{RT}{\pi M}}$$

$$\frac{D_1}{D_2} = \left(\frac{2k_B T_1}{3\pi d_1^2 P_1} \sqrt{\frac{RT_1}{\pi M_1}} \right) : \left(\frac{2k_B T_2}{3\pi d_2^2 P_2} \sqrt{\frac{RT_2}{\pi M_2}} \right) = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{28}{44}} = 0,798$$

b) Dinamik qovushqoqlik koeffitsiyentlari nisbatini aniqlash uchun avval uning formulasini keltirib chiqaramiz, so‘ngra so‘ralgan nisbatni aniqlaymiz.

$$\eta = \rho D = \rho \cdot \left(\frac{1}{3} < \lambda >< \vartheta > \right) = \frac{PM}{RT} \cdot \frac{1}{3} \frac{1}{\sqrt{2}\pi d^2 n} \sqrt{\frac{8RT}{\pi M}} = \frac{PM}{RT} \cdot \frac{1}{3} \frac{k_B T}{\sqrt{2}\pi d^2 P} \sqrt{\frac{8RT}{\pi M}} =$$

$$= \frac{M}{R} \cdot \frac{2}{3} \frac{k_B}{\pi d^2} \sqrt{\frac{RT}{\pi M}} = \frac{2}{3} \frac{k_B}{\pi d^2} \sqrt{\frac{MT}{\pi R}}$$

$$\frac{\eta_1}{\eta_2} = \left(\frac{2}{3} \frac{k_B}{\pi d_1^2} \sqrt{\frac{M_1 T_1}{\pi R}} \right) : \left(\frac{2}{3} \frac{k_B}{\pi d_2^2} \sqrt{\frac{M_2 T_2}{\pi R}} \right) = \sqrt{\frac{M_1}{M_2}} = \sqrt{\frac{44}{28}} = 1,253$$

c) Issiqlik o’tkazuvchanlik koeffitsiyentlari nisbatini aniqlash uchun avval uning formulasini keltirib chiqaramiz, so‘ngra so‘ralgan nisbatni aniqlaymiz.

$$\chi = \eta \cdot c_V = \rho D \cdot \frac{i}{2} \frac{R}{M} = \rho \cdot \left(\frac{1}{3} < \lambda >< \vartheta > \right) \cdot \frac{i}{2} \frac{R}{M} = \frac{PM}{RT} \cdot \frac{1}{3} \frac{1}{\sqrt{2}\pi d^2 n} \sqrt{\frac{8RT}{\pi M}} \cdot \frac{i}{2} \frac{R}{M} =$$

$$= \frac{i}{3} \frac{P}{T} \frac{k_B T}{\pi d^2 P} \sqrt{\frac{RT}{\pi M}} = \frac{i}{3} \frac{k_B}{\pi d^2} \sqrt{\frac{RT}{\pi M}}$$

$$\frac{\chi_1}{\chi_2} = \left(\frac{i_1}{3} \frac{k_B}{\pi d_1^2} \sqrt{\frac{RT_1}{\pi M_1}} \right) : \left(\frac{i_2}{3} \frac{k_B}{\pi d_2^2} \sqrt{\frac{RT_2}{\pi M_2}} \right) = \frac{i_1}{i_2} \sqrt{\frac{M_2}{M_1}} = \frac{6}{5} \sqrt{\frac{28}{44}} = \frac{6}{5} \sqrt{\frac{7}{11}} = 0,957$$

Javob: $\frac{D_1}{D_2} = \sqrt{\frac{M_2}{M_1}} = 0,798;\ \frac{\eta_1}{\eta_2} = \sqrt{\frac{M_1}{M_2}} = 1,253;\ \frac{\chi_1}{\chi_2} = \frac{i_1}{i_2} \sqrt{\frac{M_2}{M_1}} = 0,957$

7-amaliy mashg‘ulot topshirig‘i

7.1. Kislorod gazining $t=0^0C$ dagi diffuziya koeffitsiyenti $D=0,19\ sm^2/s$ ga teng. Bu gaz molekulasining o‘rtacha erkin yugurish yo‘lini aniqlang. **Javob:** $<\lambda>=12,5\ nm$

7.2. Azotning normal sharoitdagi ichki ishqalanish koeffitssiyenti η ni aniqlang. Azotning diffuziya koeffitsiyenti $D=0,142\ sm^2/s$ ga teng. **Javob:** $\eta=18,2\ \mu Pa \cdot s$

7.3. Agar ideal gazning $t=50^0C$ dagi ichki ishqalanish koeffitsiyenti $\eta=28,4\ \mu Pa \cdot s$ ga teng bo‘lsa, bu qaysi gaz? Effektiv diametr $d_{eff}=0,27\ nm$. **Javob:** $M=40\ g/mol$, *argon*

7.4. Kislorod gazining $t=100^0C$ dagi issiqlik o‘tkazuvchanlik koeffitsiyenti $\chi = 32,5 mW/(\text{m}\cdot\text{K})$ ga teng. Bu gazning shu temperaturadagi qovushqoqlik koeffitsiyenti η ni aniqlang. **Javob:** $\eta=50\ \mu Pa\cdot s$

7.5. 280 K temperatura va biror hajmda joylashgan azotning issiqlik o‘tkazuvchanlik koeffitsiyentini aniqlang. Azot molekulasining effektiv diametrini $d_{eff}=0,27\ nm$ deb oling. **Javob:** $\chi = 8,25 mW/(\text{m}\cdot\text{K})$

7.6. Normal sharoitda geliy atomlari erkin yugurish yo‘lining o‘rtacha uzunligi $<\lambda>=180nm$. Geliyning diffuziyasi D aniqlansin. **Javob:** $D=7,23\cdot10^{-6}\ m^2/s$.

7.7. $t=0^0C$ haroratda kislorodning diffuziyasi $D=0,19\ sm^2/s$. Kislorod molekulalari erkin yugurish yo‘lining o‘rtacha uzunligi $<\lambda>$ aniqlansin. J: $<\lambda>=135nm$

7.8. Argon molekulasining effektiv diametri $d_{eff}=0,27\ nm$ ga teng. $t=50^0C$ temperaturada argon gazi uchun ichki ishqalanish koeffitsiyenti nimaga teng. **Javob:** $\eta=28,4\ \mu Pa\cdot s$

7.9. $P=101,3\ kPa$ bosim va $t=10^0C$ temperaturadagi havoning diffuziya koeffitsiyentini va qovushqoqligini aniqlang. Havo molekulasining effektiv diametri $d=3,8\cdot10^{-10}\ m$ ga teng. **Javob:** $D = 9,11\cdot10^{-6}\ m^2/s;\ \eta = 1,138\cdot10^{-5} Pa\cdot s$

7.10. Azot uchun molekulalarning o‘rtacha erkin yugurish yo‘lini $<\lambda>$, diffuziya koeffitsiyentini D, qovushqoqlikni η va issiqlik o‘tkazuvchanlikni χ aniqlang. Temperatura $t=17^0C$, bosim $p=100\ kPa$. Azot uchun effektiv diametr $d_{eff}=0,32\ nm$ ga teng. **Javob:** $<\lambda> = 8,83\cdot10^{-8} m;\ D = 1,378\cdot10^{-5}\ m^2/s;\ \eta = 1,6\cdot10^{-5} Pa\cdot s;$ $\chi = 1,187\cdot10^{-2} W/(\text{m}\cdot\text{K})$

7.11. 1) Izobarik; 2) izoxorik jarayonlar uchun diffuziya D ning harorat T ga bog‘liqligi aniqlansin. **Javob:** $D\sim T^{3/2};\ D\sim T^{1/2}$

7.12. 1) Izotermik; 2) izoxorik jarayonlar uchun diffuziya D ning harorat P ga bog‘liqligi aniqlansin. **Javob:** $D\sim P^{-1};\ D\sim P^{1/2}$

7.13. Dinamik qovushqoqligi $\eta=17\ \mu Pa\cdot s$ bo‘lgan azot molekulalari erkin yugurish yo‘lining o‘rtacha uzunligi $<\lambda>$ aniqlansin. **Javob:**

7.14. Normal sharoitda geliyning diffuziyasi $D=1,06\cdot10^{-4}\ m^2/s$. Shu sharoitlarda geliyning dinamik qovushqoqligi η topilsin. **Javob:** .

7.15. 1) Izobarik; 2) izoxorik jarayonlar uchun diffuziya D ning harorat T ga bog‘liqligi aniqlansin. **Javob:** 1) $\eta\sim T^{1/2}$; 2)

7.16. 1) Izotermik; 2) izoxorik jarayonlar uchun diffuziya D ning harorat P ga bog‘liqligi aniqlansin. J: 1) bog‘liq emas; 2) $\eta\sim P^{1/2}$.

7.17. Normal sharoitdagi geliyning issiqlik o‘tkazuvchanligi aniqlansin. **Javob:** *38,6 Mw/(m·K)*

7.18. Oralaridagi masofa $d=5mm$ bo‘lgan ikkita katta parallel plastina orasidagi bo‘shliq geliy bilan to‘ldirilgan. Bitta plastinaning harorati $T_1=290\ K$, ikkinchisiniki $T_2=310\ K$ o‘zgarmas saqlab turiladi. Issiqlik oqimining zichligi |q| hisoblansin. Hisoblash ishlari geliyning P bosimi 1) $0,1\ mPa$ ga; 2) $1\ mPa$ ga teng bo‘lgan hollar uchun bajarilsin. **Javob:** $196\ W/m^2;\ 35\ mW/m^2$

7.19. Bir-biridan $L=5\ mm$ masofada turgan va har biri $S=150\ sm^2$ yuzaga ega bo‘lgan ikkita parallel plastina orasidagi fazo normal sharoitdagi kislorod gazi bilan to‘ldirilgan. Plastinalardan biri $t_1=27^0C$ da, ikkinchisi esa $t_2=17^0C$ da ushlab turilibdi. Issiqlik o‘tkazuvchanlik tufayli 1-plastinadan 2-siga $t=5\ min$ vaqtda oqib o‘tadigan issiqlik miqdori Q ni aniqlang. Kislorod gazi molekulasi uchun effektiv diametrni $d_{eff}=0,36\ nm$ deb oling. **Javob:** $Q=76,6\ J$

7.20. Uzunlikari $\ell=10\ sm$ dan bo‘lgan ikkita yupqa devorli koaksial slindrlar umumiy o‘qlari atrofida erkin aylanishadi. Katta slindrning radiusi $R=5\ sm$. Slindrlar orasida $\Delta r=2\ mm$ bo‘lgan bo‘shliq bor. Ikkala slindr ham normal sharoitdagi havoda turibdi. Ichki slindrni o‘zgarmas $\nu_1=20\ Gs$ chastota bilan aylantirildi. Tashqi slindr ushlab turilibdi. Tashqi slindr qo‘yib yuborilgandan boshlab qancha vaqt o‘tgach $\nu_2=1\ Gs$ chastota bilan aylanadi? Hisob ishlarida slindrlarning nisbiy tezliklari o‘zgarishi e’tiborga olinmasin. Tashqi slindr massasi $m=100\ g$. Havoning dinamik qovushqoqligi $\eta=1,72\cdot10^{-5}$ $Pa\cdot s$ ga teng. **Javob:** $\Delta t=\dfrac{m\nu_2\Delta r}{2\pi\eta\nu_1 R\ell}=18,5\,s$

7.21. O‘qlari mos tushadigan ikkita bir xil disk bir-biridan h masofada turibdi. Ularning radiuslari a ga teng bo‘lib, bunda $a>>h$. Disklar molyar massasi M ga, bosimi P ga, temperaturasi T ga teng bo‘lgan kuchli razryadlangan gazga joylashtirildi. Disklardan biri uncha katta bo‘lmagan ω burchak tezlik bilan aylantiriladi. Ikkinchi disk aylanmasdan tinch turishi uchun uni qanday kattalikdagi M_0 burovchi moment bilan ushlab turish kerak bo‘ladi? **Javob:** $M_0=P\omega a^4\sqrt{\dfrac{\pi}{8RT}}$

8-MAVZU: Issiqlik miqdori, issiqlik sig‘imlari. Erkinlik darajasi. Ichki energiya.

Mavzuga oid muhim formulalar

Issiqlik miqdorining turli ko‘rinishlari

$$Q = qm, \quad Q = \lambda m, \quad Q = rm, \quad Q = cm(t_2 - t_1) = cm\Delta t$$

$$Q = C(t_2 - t_1) = C\Delta t, \quad Q = c^* \nu (t_2 - t_1) = c^* \nu \Delta t$$

Solishtirma yonish, solishtirma erish, solishtirma bug‘lanish issiqliklari

$$q = \frac{Q}{m}\left[\frac{J}{kg}\right], \quad \lambda = \frac{Q}{m}\left[\frac{J}{kg}\right], \quad r = \frac{Q}{m}\left[\frac{J}{kg}\right]$$

Issiqlik sig‘imi hamda solishtirma issiqlik sig‘imi

$$C = \frac{Q}{\Delta t}\left[\frac{J}{K}\right], \quad c = \frac{Q}{m \cdot \Delta t}\left[\frac{J}{kg \cdot K}\right]$$

Issiqlik sig‘imi, solishtirma issiqlik hamda molyar issiqlik sig‘imlari orasidagi bog‘lanishlar

$$C = cm, \quad C = c^*\nu, \quad c^* = cM$$

Erkinlik darajasiga oid formulalar

$$i = i_{ilg} + i_{ayl} + 2i_{teb}, \quad i_{ilg} + i_{ayl} + i_{teb} = 3N, \quad i_{teb} = 3N - (i_{ilg} + i_{ayl})$$

$$i = 6N - (i_{ilg} + i_{ayl})$$

Ideal gazning ichki energiyasi

$$U = \frac{i}{2}\frac{m}{M}RT = \frac{i}{2}\nu RT = \frac{i}{2}PV$$

Ideal gazning ichki energiya o‘zgarishi

$$\Delta U = \frac{i}{2}\frac{m}{M}R(T_2 - T_1) = \frac{i}{2}\nu R(T_2 - T_1) = \frac{i}{2}(P_2V_2 - P_1V_1)$$

Izobarik va izoxorik jarayonlarda ichki energiya o‘zgarishi

$$\Delta U_P = \frac{i}{2}P(V_2 - V_1), \quad \Delta U_V = \frac{i}{2}V(P_2 - P_1)$$

8-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Massasi *0,51 kg* bo‘lgan etil spirtini erish temperaturasidagi kristall holidan qaynash temperaturasidagi gaz holatiga keltirguncha qancha issiqlik talab etiladi? Etil spirtining solishtirma erish issiqligi $\lambda = 109 kJ/kg$ ga, solishtirma issiqlik sig‘imi $c = 2,43 kJ/kg \cdot K$ ga, solishtirma bug‘lanish issiqligi $r = 879 kJ/kg$ ga teng bo‘lib, u *-114 ^0C* da eriydi, *78 ^0C* da qaynaydi.

Berilgan:

$\lambda = 109\,kJ/kg$

$c = 2,43\,kJ/kgK$

$r = 879\,kJ/kg$

$m = 0,51\,kg$

$t_{er} = -114^0 C$

$t_q = 78^0 C$

$Q = ?$

Yechilishi:

Berilgan issiqlik muz holidagi kristaldan to qaynash temperaturasidagi gaz holatiga keltirguncha beriladigan issiqlik kristalni eritishga, suyuqlikni isitishga va bug'lashga sarg bo'ladi.

$$Q = Q_{er} + Q_{is} + Q_{bug'} = \lambda m + cm\left(t_q - t_{er}\right) + rm = 109 \cdot 0,51 +$$
$$+2,43 \cdot 0,51 \cdot \left(78 + 114\right) + 879 \cdot 0,51 = 55,59 + 237,95 +$$
$$+448,29 = 741,83\ kJ$$

Javob: *741,83 kJ*

Masala № 2. Kalorimetrga *0,485 kg* massali suv va noma'lum massali muz bo'lagi solingan bo'lib, ulardagi temperatura o'zgarishi rasmda ko'rsatilgan. Bunda suv muzga P quvvat bilan issiqlik uzatadi. Rasmda vaqt o'qidagi $t_s = 80\min$. P quvvat nimaga teng? Muzning boshlang'ich massasi nimaga teng? Necha gramm suv muzga aylangan?

Berilgan:

m=0,485 kg

$t_s = 80\min$

$c_s = 4,2\,kJ/kgK$

$c_m = 2,1kJ/kgK$

$\lambda = 330\,kJ/kg$

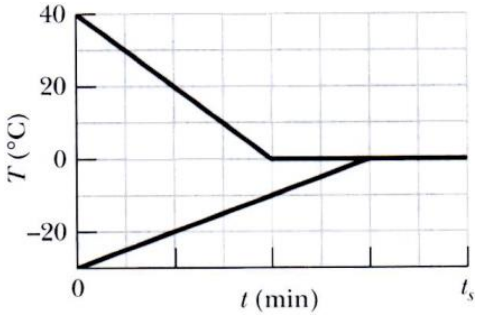
$P = ?, m_m = ?$

$\Delta m_s = ?$

Yechilishi:

Rasmdan ko'rinadiki, suv *40⁰C* dan *0⁰C* gacha *40 min* vaqtda tushgan. Bunda sovish quvvati

$$P = \frac{Q_{bergan}}{\Delta t_v} = \frac{c_s m_s \Delta t}{\Delta t_v} =$$
$$= \frac{4200 \cdot 0,485 \cdot 40}{40 \cdot 60} \approx 34\ W$$



Muz ham shu quvvatni o'ziga yutib isiydi. Muz *-30⁰C* da *0⁰C* gacha *60 min* vaqtda isiydi. Bundan muzning massasini aniqlaymiz.

$$P = \frac{Q_{olgan}}{\Delta t_v} = \frac{c_m m_m \Delta t}{\Delta t_v},\ \rightarrow m_m = \frac{P\Delta t_v}{c_m \Delta t} = \frac{34 \cdot 60 \cdot 60}{2100 \cdot 30} \approx 1,943 kg$$

60 min va *40 min* vaqtlar orasida *20 min* vaqt farq mavjud bo'lib, bu vaqtda suvning bir qismi muzga aylanadi. Ana shu muzga aylangan qismning massasini aniqlaymiz.

$$P = \frac{\Delta Q_{bergan}}{\Delta t_v} = \frac{\lambda \Delta m_s}{\Delta t_v},\ \rightarrow \Delta m_s = \frac{P\Delta t_v}{\lambda} = \frac{34 \cdot 20 \cdot 60}{330000} \approx 0,124 kg = 124\,g\ .$$

Javob: $P = 34W;\ m_m = 1,943kg;\ \Delta m_s = 124\,g$.

Masala № 3. Quyidagi ma'lumotlarga tayanib metallning solishtirma issiqlik sig'imini aniqlang. Kalorimetr *3,6 kg* massali metalldan yasalgan bo'lib, unga *15 kg* massali suv sig'adi. Dastlab 16⁰C temperaturada turgan ushbu suv to'la

kalorimetrga *180⁰C* temperaturali va *1,8 kg* massali metall parchasi tushiriladi. Shunda *18⁰C* temperatura qaror topadi.

Berilgan:

$m_k = 3,6\,kg$

$m_s = 15\,kg$

$c_s = 4,2\,kJ\,/\,kg$

$m_2 = 1,8\,kg$

$t_1 = 16^0 C$

$t_2 = 180^0 C$

$t' = 18^0 C$

$c_m = ?$

Yechilishi:

Bu issiqlik almashuv jarayonida 1-jism sifatida kalorimetr va suv qaralib, ular birgalikda isiydi.

$$Q_{olgan} = c_m m_k (t' - t_1) + c_s m_s (t' - t_1) = c_m \cdot 3,6 \cdot 2 + 4,2 \cdot 15 \cdot 2 =$$
$$= 7,2 c_m + 126\,kJ$$

Suvga tushirilgan issiq metall parchasi esa 2-jism sifatida qaralib, bu jism soviydi.

$$Q_{bergan} = c_m m_2 (t_2 - t') = c_m \cdot 1,8 \cdot 178 = 320,4 c_m$$

Ular orasidai issiqlik almashinuvi o‘zaro teng bo‘ladi.

$$Q_{olgan} = Q_{bergan}, \rightarrow 7,2 c_m + 126 = 320,4 c_m, \rightarrow c_m = \frac{126}{313,2} = 0,4\ kJ\,/\,kgK$$

Javob: 40 J/kgK

Masala № 4. Miqdori *1 mol* dan bo‘lgan bir atomli, ikki atomli va uch atomli gazlarni *1 K* temperaturaga isitganda ichki energiyalari qanchaga oshishini hisoblsng.

Berilgan:

$\nu = 1 mol$

$\Delta T = 1K$

$i_1 = 3, i_2 = 5$

$i_3 = 6$

$\Delta U = ?$

Yechilishi:

$$\Delta U = \frac{i}{2} \nu R\, \Delta T = \frac{i}{2} \cdot 1 \cdot R \cdot 1 = \frac{i}{2} R$$

$$\Delta U_1 = \frac{3}{2} R = 12,465\ J, \quad \Delta U_2 = \frac{3}{2} R = 20,775\ J,$$

$$\Delta U_1 = \frac{6}{2} R = 3R = 24,93\ J$$

Javob: $\Delta U_1 = 12,465\ J, \quad \Delta U_2 = 20,775\ J, \ \Delta U_3 = 24,93\ J$

Masala № 5. *10 g* massali kislorod gazini *25⁰C* dan *125⁰C* gacha isistilganda uning ichki energiyasi qanchaga oshadi?

Berilgan:

m=10 g

t_1 = 25⁰C

t_2 = 125⁰C

i=5

$\Delta U = ?$

Yechilishi:

Masalani yechish uchun ichki energiya formulasidan foydalanamiz.

$$\Delta U = \frac{i}{2} \frac{m}{M} R\, \Delta T = \frac{5}{2} \cdot \frac{10}{32} \cdot 8,31 \cdot 100 = 649,22\,J$$

Javob: 649,22 J

Masala № 6. Uch atomli gaz xona temperaturasida (20^0C) turibdi. Xuddi shunday miqdordagi ikki atomli gazning temperaturasi necha gradus bo'lganda ularning ichki energiyalari bir xil bo'ladi? Bir atomli gazniki-chi?

Berilgan:

$T_3 = 293K$

$i_1 = 3, i_2 = 5$

$i_3 = 6$

$\nu_1 = \nu_2 = \nu_3 = \nu$

$U_1 = U_2 = U_3 = U$

$T_2 = ?, T_3 = ?$

Yechilishi:

Dastlab ikki atomli gaz temperaturasini aniqlaymiz.

$$U_3 = U_2, \rightarrow \frac{i_3}{2}\nu RT_3 = \frac{i_2}{2}\nu RT_2, \rightarrow T_2 = \frac{i_3}{i_2}T_3 = \frac{6}{5}\cdot 293 = 351,6K$$

$$t_2 = T_2 - 273 = 78,6^0C$$

Endi bir atomli gaz temperaturasini aniqlaymiz.

$$U_3 = U_1, \rightarrow \frac{i_3}{2}\nu RT_3 = \frac{i_1}{2}\nu RT_1, \rightarrow T_1 = \frac{i_3}{i_1}T_3 = \frac{6}{3}\cdot 293 = 586K$$

$$t_1 = T_1 - 273 = 313^0C$$

Javob: $t_2 = 78,6^0C;\ t_1 = 313^0C$

8-amaliy mashg'ulot topshirig'i

Issiqlik miqdori

8.1. Issiqlik sig'imi *63 J/K* bo'lgan kalorimetrga *12° C* temperaturali *250* g moy quyildi. Moyga massasi *500 g* bo'lgan *100° C* temperaturali mis jism tushirilgandan keyin umumiy temperatura *33° C* bo'lib qoldi. Tajriba ma'lumotlariga ko'ra moyning solishtirma issiqlik sig'imi qancha bo'lishini aniqlang. **Javob:** *2,2 kJ/(kg·K)*

8.2. Temperaturasi *10° C* bo'lgan suvga *100° C* gacha qizdirilgan jism tushirilgandan keyin biroz vaqt o'tgach umumiy temperatura *40° C* bo'lib qoldi. Agar birinchi jismni suvdan chiqarib olmay, unga *100° C* gacha qizdirilgan o'shanday yana bir jism tushirilsa, suvning temperaturasi qancha bo'lib qoladi? **Javob:** *55°C*

8.3. *15° C* temperatura *1,5 kg* suv bo'lgan idishga *100° C* temperaturali *200 g* suv bug'i kiritildi. Bug' kondensatsiyalangandan keyin umumiy temperaturasi qanday bo'ladi? Suvning solishtirma issiqlik sig'imi *4,2 kJ/(kg·K)*, bug'ning solishtirma kondensatsiyalanish issiqligi *2,3 MJ/kg*. **Javob:** *89° C*

8.4. *20° C* da 2,8 *l* suv quyilgan idishga massasi *3 kg* bo'lib, *460° C* gacha qizdirilgan po'lat brusok tashlandi. Bunda suv 60° C gacha isiydi, suvning bir qismi esa bug'ga aylanadi. Bug'ga aylangan suvning massasini toping. Idishning issiqlik sig'imini hisobga olmang. **Javob:** *33 g*

8.5. *-10°C* temperaturada olingan *200 kg* qordan *20° C* temperaturali suv olish uchun F1Ki *40 %* bo'lgan pechkaga qancha o'tin yoqish kerak? Yog'ochning solishtirma yonish issiqligi *q=10 MJ/kg*. **Javob:** *22 kg*

8.6. Qalayning solishtirma erish issiqligini aniqlash uchun ichida *7° C* li *330 g* suv bo'lgan kalorimetrga qotish temperaturasida *350 g* erigan qalay quyildi. Shundan keyin kalorimetrda *32° C* temperatura qaror topdi. Kalorimetrning issiqlik sig'imi *100 J/K*. Tajriba ma'lumotlariga qarab qalayning erish solishtirma issiqligi qiymatini aniqlang. **Javob:** *60 kJ/kg*

8.7. Hajmi *200 sm*^{3} bo‘lgan piyoladagi *100°C* haroratli choy *20°C* gacha soviganda ajraladigan energiyadan foydalanib, massasi *1 tonna* bo‘lgan yukni ko‘pi bilan necha metr balandlikka ko‘tarish mumkin? Suvning solishtirma issiqlik sig‘imi 4,2 $kJ/(kg \cdot K)$, g=10 m/s^2. **Javob:** *6,7 m*

8.8. Qandaydir balandlikdan tushayotgan po‘lat jismning erga urilishidagi tezligi *50 m/s*. Agar bunda kinetik energiya to‘liq ravishda jismning ichki energiyasiga aylansa, u necha gradusga isiydi? Po‘latning solishtirma issiqlik sig‘imi 500 $J/(kg \cdot K)$ **Javob:** *2,5 K*

8.9. Qo‘rg‘oshin o‘q *200 m/s* tezlik bilan uchib kelib, qumga tiqilib qoldi. Agar o‘q energiyasi to‘la issiqlik energiyasiga aylansa, o‘qning harorati necha gradus ortadi? c=130 $J/(kg \cdot K)$. **Javob:** *154 K*

8.10. *0°C* temperaturadagi teng massali ikkita muz parchasi bir-biriga qanday bir xil tezlik bilan urilganda, to‘liq erib ketadi? Muzning solishtirma erish issiqligi λ ga teng. **Javob:** $\sqrt{2\lambda}$

8.11. Temperaturasi *20°C* bo'lgan *2 kg* massali suvga *0°C* temperaturali muz solindi. Muz butunlay erib ketishi uchun uning massasi ko'pi bilan qanday (kg) bo'lishi kerak? Muzning solishtirma erish issiqligi *336 KJ/kg*, suvning solishtirma issiqlik sig'imi *4200 J/(kg·°C)*. **Javob:** 0,5 kg

8.12. Bir soatda dvigatel *20kg* dizel yonilg’isi sarflaydi. Dvigatelning mexanik quvvati *75kW* bo’lsa, uning FIK necha foiz? Dizel yonilg'isining solishtirma yonish issiqligi *42kg* dizel yonilg'isi sarflaydi. **Javob:** 32%

8.13. Avtomobil dvigatelining harakat paytidagi o'rtacha quvvati *20 kW*, tezligi esa *90 km/soat*. Agar dvigatelning FIK *25%* bo'lsa, benzin bakining sig’imi (40 l) necha km yo'lga mo'ljallangan? Benzinning zichligi *0,7 g/cm*^{3}, *q=46 MJ/kg*. **Javob:** *402km*

Ichki energiya

8.14. Agar ideal gaz bosimi va hajmi *2* marta oshsa, uning ichki nergiyasi qanday o‘zgaradi? **Javob:** *4 marta oshadi*

8.15. *2 mol* geliy *20°C* dan *-80°C* gacha sovitilganda, uning ichki energiyasi necha kJ kamayadi? **Javob:** 2,5J kamaygan

8.16. $4 \cdot 10^{23}$ ta molekulaga ega bo‘lgan bir, ikki va uch atomli ideal gazlarning temperaturasi *100 K* ga ortganda, ularning ichki energiyalarii necha joulga o‘zgaradi? $N_A = 6 \cdot 10^{23}\ mol^{-1}$. **Javob:** *ΔU=831 J; ΔU=1385 J; ΔU=1662 J*

8.17. Temperaturasi *-73°C* va ichki energiyasi *2493 J* bo‘lgan geliy gazining massasini aniqlang (g). **Javob:** $m = 4$ g

8.18. *6 mol* miqdordagi kislorod gazini *300 K* dan to *1200 K* gacha qizdirishda ichki energiya qanchaga oshadi (*kJ*)? *1000 K* dan boshlab barcha molekulalalarda atomlarini tutib turuvchi bog‘ bo‘ylab to‘la tebranishlar sodir bo‘ladi deb hisoblang. **Javob:** *122,2 kJ*

8.19. Yuqoridagi masalada ichki energiyani oshirishga sarflangan jami energiyaning qancha qismi ilgarilanma harakatga, aylanma harakatga va tebranma harakatga sarf bo‘lganini aniqlang. **Javob:** 7/13; 14/39; 4/39

8.20. Berilliy xlorid ($BeCl_2$) gazi uch atomli bo‘lsada, bu moddaning molekulalari chiziqli strukturaga ega. Bu gaz uchun umumiy erkinlik darajasini va barcha erkinlik darajalarini aniqlang. **Javob:** *i=13, shulardan 3 ta ilgarilanma, 2 ta aylanma va 4 ta tebranma*

8.21. Yuqoridagi masalada modda ichki energiyasining qancha qismi ilgarilanma harakatga, aylanma harakatga va tebranma harakatga tegishli ekanini aniqlang. **Javob:** 3/13; 2/13; 8/13

8.22. Adiabata ko‘rsatkichi *a) γ=1,33; b) γ=1,4; c) γ=1,17* bo‘lgan hollar uchun ideal gazning erkinlik darajasining soni va xaraktarini aniqlang. **Javob:** *a) i=5, shulardan 3 ta ilgarilanma va 2 ta aylanma; b) i=6, shulardan 3 ta ilgarilanma va 3 ta aylanma; c) i=12, shulardan 3 ta ilgarilanma, 3 ta aylanma va 3 ta tebranma.*

8.23. Agar tebranma harakat erkinlik darajasi “muzlatilganda” γ adiabata ko‘rsatkichi *49/45* marta oshgan bo‘lsa, chiziqli molekula nechta atomdan tashkil topgan? **Javob:** *2 atomli*

8.24. Uch atomli chiziqli molekulalardan iborat ideal gazni o‘ta qizdirilgan hol uchun Puasson koeffitsiyentini aniqlang. Bunda aniqlangan Puasson koeffitsiyentining qiymati normal sharoitdagiga qaraganda necha marta kichik bo‘ladi? **Javob:** *γ=15/13; 91/75 marta*

8.25. Uch atomli fazoviy molekulalardan iborat ideal gazni o‘ta qizdirilgan hol uchun Puasson koeffitsiyentini aniqlang. Bunda aniqlangan Puasson koeffitsiyentining qiymati normal sharoitdagiga qaraganda necha marta kichik bo‘ladi? **Javob:** *γ=7/6; 8/7 marta*

9-MAVZU: Ideal gazni kengayishida bajargan ishi. Termodinamikaning1-qonuni va uni turli izojarayonlarga tadbiqi.

Mavzuga oid muhim formulalar

$A=\int_{V_1}^{V_2} P(V)\,dV$	*Gazning bajargan ishini ifodalovchi umumiy formula*
$A_p = P\Delta V = \nu R\Delta T$	*Gazning izobarik jarayonda bajargan ishi*
$A_T = \nu RT\ln\frac{V_2}{V_1} = \nu RT\ln\frac{P_1}{P_2}$	*Gazning izotermik jarayonda bajargan ishi*
$PV^{\gamma} = const$ *yoki* $\frac{P_2}{P_1}=\left(\frac{V_1}{V_2}\right)^{\gamma}$ $TV^{\gamma-1} = const$ *yoki* $\frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{\gamma-1}$ $\frac{P^{\gamma-1}}{T^{\gamma}} = const$ *yoki* $\left(\frac{P_2}{P_1}\right)^{\gamma-1}=\left(\frac{T_2}{T_1}\right)^{\gamma}$	*Adiabatik jarayonda makroparametrlar orasidagi bog'lanishlar*
Gazning adiabatik jarayonda bajargan ishi $A_\gamma = \frac{\nu R}{\gamma-1}T_1\left(1-\left(\frac{V_1}{V_2}\right)^{\gamma-1}\right)$ *yoki* $A_\gamma = \frac{\nu R}{\gamma-1}T_2\left(\left(\frac{V_2}{V_1}\right)^{\gamma-1}-1\right)$	
$Q=\Delta U+A',\quad$ *yoki* $\quad\delta Q = dU+\delta A'$	*Termodinamikaning 1-qonuni*
Izobarik jarayonda gazga uzatilgan issiqlikning qancha qismi ish bajarishga (kengayishga) va qancha qismi ichki energiyani oshirishga (isishga) sarf bo'lishi $A'=\frac{2}{i+2}Q,\qquad \Delta U=\frac{i}{i+2}Q$ $\begin{cases}A'_1=\frac{2}{5}Q\\ \Delta U_1=\frac{3}{5}Q\end{cases}\quad\begin{cases}A'_2=\frac{2}{7}Q\\ \Delta U_2=\frac{5}{7}Q\end{cases}\quad\begin{cases}A'_3=\frac{1}{4}Q\\ \Delta U_3=\frac{3}{4}Q\end{cases}$	
Termodinamikaning 1-qonunini izotermik jarayonga tadbiqi $Q=A'=A_T=\nu RT\ln\frac{V_2}{V_1}=\nu RT\ln\frac{P_1}{P_2},\qquad \delta Q=\delta A'_T=\mathrm{PdV}=\nu\mathrm{RT}\frac{dV}{V}$	
Termodinamikaning 1-qonunini izoxorik jarayonga tadbiqi $Q=\Delta U_V=\frac{i}{2}\frac{m}{M}R(T_2-T_1)=\frac{i}{2}V(P_2-P_1),\qquad \delta Q=dU_V=\frac{i}{2}\nu R\,dT=\frac{i}{2}V\,dP$	
Termodinamikaning 1-qonunini adiabatik jarayonga tadbiqi $A'=-\Delta U\quad$ *yoki* $\quad A=\Delta U$ $A'=A_\gamma=\frac{\nu R}{\gamma-1}T_1\left(1-\left(\frac{V_1}{V_2}\right)^{\gamma-1}\right)=\frac{\nu R}{\gamma-1}T_2\left(\left(\frac{V_2}{V_1}\right)^{\gamma-1}-1\right)$	

9-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Silindrdagi gazning o‘rtacha bosimi *1 MN/m²*. Porshenning vuzi *200 cm²*, yurish uzunligi *0,5 m*. Porshenning bir marta yurishida gaz qanday ish bajaradi (*kJ*)?

Berilgan:

$P = 1\ MPa$

$S = 200\ sm^2$

$\Delta h = 0{,}5\ m$

$A = ?$

Yechilishi:

Gaz kengayib bajargan ishi

$A = P\Delta V = PS\Delta h = 10^6 \cdot 200 \cdot 10^{-4} \cdot 0{,}5 = 10^4\ J = 10\ kJ$

Javob: $A = 10\ kJ$

Masala № 2. *10^5 Pa* bosim ostida turgan ideal gazning hajmi izobar ravishda *300 sm³* dan *500 sm³* gacha oshdi. Bunda gaz necha joul ish bajargan?

Berilgan:

$P = 10^5\ Pa$

$V_1 = 3 \cdot 10^{-4}\ m^3$

$V_2 = 5 \cdot 10^{-4}\ m^3$

$A = ?$

Yechilishi:

Gaz kengayib bajargan ishi

$A = P\Delta V = P(V_2 - V_1) = 10^5(5 \cdot 10^{-4} - 3 \cdot 10^{-4}) = 20\ J$

Javob: $A = 20\ J$

Masala № 3. *300 K* temperaturadagi miqdori *5 mol* bo‘lgan gaz *50 L* hajm egallagan. Uning hajmini dastlab o‘zgarmas bosim sharoitida, keyin esa $\frac{P}{V} = const$ sharoitida ikki marta oshirildi. Bunda bajarilgan ishlarni aniqlang. Ishlar necha marta farq qiladi?

Berilgan:

$T_1 = 300\,K$

$\nu = 5\,mol$

$V_1 = 50\,L,$

$V_2 = 100\,L$

$a)\ P = const$

$b)\ \frac{P}{V} = const$

$A_2 / A_1 = ?$

Yechilishi:

Dastlab gazning bosimini aniqlaymiz.

$$P_1V_1 = \nu RT_1, \ \rightarrow\ P_1 = \frac{\nu RT}{V_1} = \frac{5 \cdot 8{,}31 \cdot 300}{0{,}05} = 249300\,Pa = 249{,}3\,kPa.$$

a) O‘zgarmas bosimda bajarilgan ishni aniqlaymiz.

$$A = P\Delta V = 249300 \cdot (0{,}1 - 0{,}05) = 12465\,J$$

b) Endi $\frac{P}{V} = const$ sharoitida bajarilgan ishni aniqlaymiz. Bunda const sonining qiymati $const = \frac{P_1}{V_1} = \frac{249300}{0{,}05} = 4986000\ \frac{Pa}{m^3}$ bo‘ladi.

Demak, bosim $P = const \cdot V = 4986000 \cdot V$ qonunga ko‘ra o‘zgarar ekan. Integarllash orqali bajarilgan ishni aniqlaymiz.

$$A_2 = \int_{V_1}^{V_2} P(V)\,dV = \int_{0,05}^{0,1} 4986000V dV = 2493000V^2 \Big|_{0,05}^{0,1} = 2493000 \cdot \left(0,1^2 - 0,05^2\right) = 18697,5\ J$$

Endi ishlar nisbatini aniqlaymiz.

$\frac{A_2}{A_1} = \frac{18697,5}{12465} = 1,5$. Demak, ikkinchi sharoitda 1,5 marta ko‘p ish bajarilar ekan

Javob: A_1=12465 J; A_2=18698 J; A_2/A_1=1,5 marta

Masala № 4. Adiabatik kengayish $PV^\gamma = const$ qonunga bo'ysunishini yaxzhi bilamiz. *2 mol* miqdordagi ikki atomli ideal gazning temperaturasi *T=300 K* bo‘lganda uni bosimi *P=120 kPa* bo‘lgani haqida ma’lumotga tayanib, *const* qiymatni aniqlang.

Berilgan:

$PV^\gamma = const$

$i=5$

$P = 120\ kPa$

$T = 300\ K$

$const$ =?

Yechilishi

Dastlab Puasson koeffitsiyentini aniqlaymiz.

$$\gamma = \frac{i+2}{i} = \frac{5+2}{5} = 1,4$$

Endi const qiymatni aniqlaymiz.

$$const = PV^\gamma = \frac{(PV)^\gamma}{P^{\gamma-1}} = \frac{(\nu RT)^\gamma}{P^{\gamma-1}} = \frac{(2 \cdot 8,31 \cdot 300)^{1,4}}{120000^{1,4-1}} = \frac{150263,4}{107,56} = 1397\ \frac{kg \cdot m^{3,2}}{s^2}$$

Javob: $const = 1397\ \frac{kg \cdot m^{3,2}}{s^2}$

Masala № 5. Ikki atomli ideal gaz adiabatik ravishda siqilmoqda. Uning boshlang‘ich bosimi *120 kPa* va hajmi *0,2 m³* ga teng. Gazning oxiridagi bosimi *360 kPa* ga teng. Tashqi kuchlar gazni siqishda qancha ish bajargan?

Berilgan:

$P_1 = 120\ kPa$

$P_2 = 360\ kPa$

$V_1 = 0,2\ m^3$

$i = 5$

$\gamma = 4/3$

A_{tash} =?

Yechilishi:

Gaz ustida bajarilgan ish

$$A_{tash} = -A_\gamma = -\frac{\nu RT_1}{\gamma - 1}\left(1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right) = \frac{P_1V_1}{\gamma-1}\left(\left(\frac{V_1}{V_2}\right)^{\gamma-1} - 1\right) =$$

$$= \frac{P_1V_1}{\gamma-1}\left(\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right) = \frac{120000 \cdot 0,2}{4/3-1}\left(\left(\frac{360000}{120000}\right)^{\frac{4/3-1}{4/3}} - 1\right) =$$

$$= 72000 \cdot \left(\sqrt[4]{3} - 1\right) = 22757\ J$$

Javob: $A_{tash} = 22757\ J$

Masala № 6. Gazga *40 kJ* issiqlik miqdori berilganda, u *60 kJ* ish bajardi. Gaz ichki energiyasining o‘zgarishini toping (kJ).

Berilgan:

$A = 60\ kJ$

$Q = 40\ kJ$

Yechish:

Termodinamikaning birinchi qonuni

$Q = \Delta U + A$

$\Delta U = Q - A = 40 - 60 = -20\ kJ$

$\Delta U = ?$

Javob: $\Delta U = -20\ kJ$

Masala № 7. Ballondagi massasi 1 g bo‘lgan geliy gaziga 25 J issiqlik miqdori berilganda, uning temperaturasi qanchaga ortadi (K)?

Berilgan:

$m = 1\ g = 10^{-3}\ kg$

$M = 4 \cdot 10^{-3}\ kg/mol$

$Q = 25\ J$

$\Delta T = ?$

Yechish:

Termodinamikaning birinchi qonuni

$Q = \Delta U + A$

$A = P\Delta V = 0, \quad Q = \Delta U$

Ichki energiya o‘zgarishi

$$\Delta U = \frac{3}{2} \cdot \frac{m}{M} R\Delta T = Q$$

$$\Delta T = \frac{2MQ}{3mR} = \frac{2 \cdot 4 \cdot 10^{-3} \cdot 25}{3 \cdot 10^{-3} \cdot 8{,}31} = 8\ K$$

Javob: $\Delta T = 8\ K$

Masala № 8. Ideal gaz hajmi rasmdagi kabi V_0 dan $4V_0$ gacha oshganda bosim P_0 dan $P_0/4$ gacha kamayadi. Agar $V_0 = 1m^3$ va $P_0 = 40\,kPa$ ga teng bo‘lsa, A, B, C trayektoriyalar bo‘yicha kengayishda bajarilgan ishlarni aniqlang.

Berilgan:

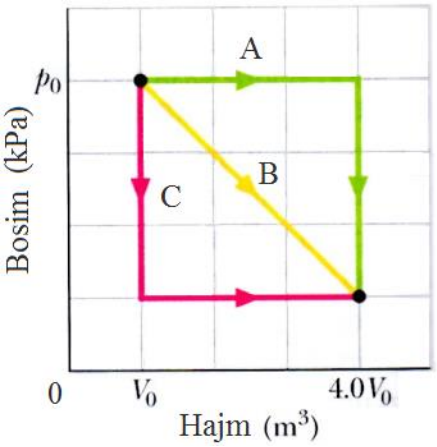
$V_0 = 1m^3$

$P_0 = 40\,kPa$

$A = ?$

Yechilishi:

Ma’lumki, P=P(V) bog‘lanishli grafikda grafik tagidagi yuza son jihatdan bajarilgan ishni beradi. Shuning uchun, uchala hol uchun ham yuzalarni aniqlaymiz.



$$A_A = \left(P_0 - \frac{P_0}{4_0}\right) \cdot \left(4V_0 - V_0\right) = \frac{9}{4} P_0 V_0 = 90\,kJ$$

$$A_B = \frac{P_0 + P_0/4}{2} \cdot \left(4V_0 - V_0\right) = \frac{15}{8} P_0 V_0 = 75\,kJ$$

$$A_C = P_0/4 \cdot \left(4V_0 - V_0\right) = \frac{3}{4} P_0 V_0 = 30\,kJ$$

Javob: $A_A = 90\,kJ;\ A_B = 75\,kJ;\ A_C = 30\,kJ$

Masala № 9. Porshen ostidagi ideal gaz bosimi rasmdagi kabi yopiq kontur bo‘yicha o‘zgaradi. AB o‘tishda sistema tomonidan uzatilgan issiqlik $Q_{AB} = 25\,kJ$ ga BC o‘tishda esa $Q_{BC} = 0$ va sikl davomida bajarilgan ish $A_{ABC} = 15\,kJ$ bo‘lsa, CA o‘tishda qancha issiqlik atrofga uzatilgan?

Berilgan:

$Q_{AB} = 25kJ$

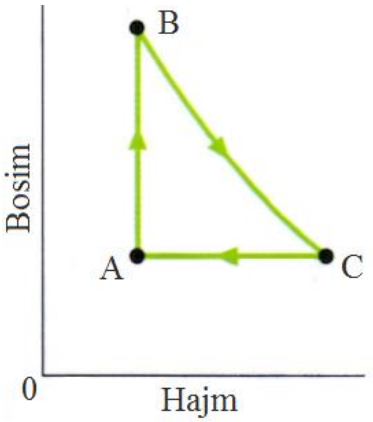
$Q_{BC} = 0$

$A_{ABC} = 15kJ$

$Q_{CA} = ?$

Yechilishi:

Termodinamikaning 1-qonuniga asosan, sistemaga uzatilgan issiqlik ish bajarishga va ichki energiyaga sarf bo'ladi. Lekin, ABC sikl berk bo'lgani uchun $\Delta U_{ABC} = 0$ bo'ladi. Shuning uchun uzatilgan issiqlik ish bajarishga va sovitkichga uzatishga sarf bo'ladi.



$$A_{ABC} = Q_{AB} + Q_{BC} - Q_{CA} = Q_{AB} - Q_{CA}$$

$$Q_{AB} = A_{ABC} + Q_{CA}, \ \rightarrow \ Q_{CA} = Q_{AB} - A_{ABC} = 25kJ - 15kJ = 10kJ$$

Javob: $Q_{CA} = 15kJ$

Masala № 10. Rasmda porshen ostidagi 1 mol bir atomli gazning sikli tasvirlangan. Temperaturalar $T_1 = 300K, T_2 = 600K, T_3 = 455K$ ga teng. 1 nuqtada bosim $P_1 = 101kPa$ ga teng. Quyidagilarni aniqlang: *a)* 2 va 3 nuqtalardagi bosimlarni *b)* $1 \rightarrow 2$ o'tishda $Q_{12}, A_{12}, \Delta U_{12}$ kattaliklarni; *c)* $2 \rightarrow 3$ o'tishda $Q_{31}, A_{31}, \Delta U_{31}$ kattaliklarni; *d)* $3 \rightarrow 1$ o'tishda $Q_{23}, A_{23}, \Delta U_{23}$ kattaliklarni; *e)* berk sikl uchun $Q, A, \Delta U$ kattaliklarni aniqlang. ?

Berilgan:

$\nu = 1mol$

$P_1 = 101kPa$

$T_1 = 300K$

$T_2 = 600K$

$T_3 = 455K$

$Q_{12}, A_{12}, \Delta U_{12} - ?$

$Q_{23}, A_{23}, \Delta U_{23} - ?$

$Q_{31}, A_{31}, \Delta U_{31} - ?$

$Q, A, \Delta U - ?$

$P_2, P_3 - ?$

Yechilishi:

Dastlab 1 nuqtadagi hajmni topamiz.

$$P_1 V_1 = \nu R T_1, \ \rightarrow \ V_1 = \frac{\nu R T_1}{P_1} = \frac{1 \cdot 8,31 \cdot 300}{101000} =$$

$$= 2,468^{-2} m^3 = 24,68 L.$$

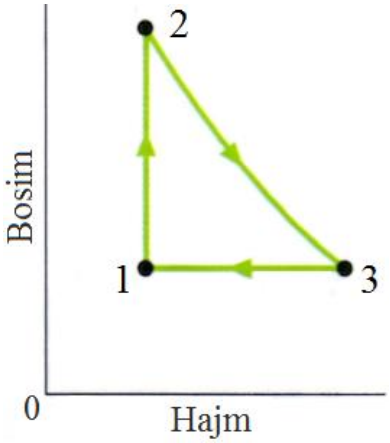
$1 \rightarrow 2$ o'tishda $V_2 = V_1 = 24,68 L$ bo'ladi.

$3 \rightarrow 1$ o'tish izobarik bo'lgani uchun

$$\frac{V_3}{T_3} = \frac{V_2}{T_2}, \ \rightarrow \ V_3 = \frac{T_3}{T_2} V_2 = \frac{455}{300} \cdot 24,68 = 37,43 L \cdot$$

a) $1 \rightarrow 2$ o'tish izoxorik bo'lgani uchun

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}, \ \rightarrow \ P_2 = \frac{T_2}{T_1} P_1 = \frac{600}{300} \cdot 101 = 202 kPa$$



bo'ladi. $3 \rightarrow 1$ o'tish izobarik bo'lgani uchun $P_3 = P_1 = 101kPa$ bo'ladi.

b) $1 \rightarrow 2$ o'tish izoxorik jarayon bo'lgani uchun $A_{12} = 0$ bo'ladi. Bunda issiqlik to'la ichki energiyani oshirishga sarf bo'ladi.

$$Q_{12} = \Delta U_{12} = \frac{3}{2} \nu R (T_2 - T_1) = \frac{3}{2} \cdot 1 \cdot 8,31 \cdot (600 - 300) = 3739,5 J$$

c) $2 \rightarrow 3$ adiabatik jarayon bo'lgani uchun $Q_{23} = 0$ bo'ladi. Bunda ichki energiya (sovish) evaziga kengayish sodir bo'ladi.

$\Delta U_{23}=\frac{3}{2}\nu R\left(T_3-T_2\right)=\frac{3}{2}\cdot 1\cdot 8{,}31\cdot\left(455-600\right)=-1807{,}4\,J$. $A_{23}=-\Delta U_{23}=1807{,}4\ J$.

d) $3\to 1$ o‘tish izobarik jarayon bo‘lib, unda bajarilgan ish $A_{31}=\nu R\left(T_3-T_2\right)=1\cdot 8{,}31\cdot\left(300-455\right)=-1288\ J$ ga, ichki energiya o‘zgarishi $\Delta U_{31}=\frac{3}{2}\nu R\left(T_3-T_2\right)=1{,}5A_{31}=1{,}5\cdot\left(-1288\ J\right)=-1932\ J$ ga, issiqlik miqdori esa $Q_{31}=A_{31}+\Delta U_{31}=-1288-1932=-3220\ J$ ga teng bo‘ladi.

e) $1\to 2\to 3\to 1$ berk siklda ichki energiya o‘zgarishi $\Delta U=0$ bo‘ladi. bajarilgan ish berk kontur yuzasiga teng, ya’ni $A=A_{12}+A_{21}+A_{31}=0+1807{,}4-1288=519{,}4\ J$ ga teng bo‘ladi. umumiy issiqlik esa $Q=Q_{12}+Q_{23}+Q_{31}=3739{,}5+0-3220=519{,}5J$ ga teng bo‘ladi.

Javob: $a)P_2=202kPa;\ P_3=101kPa;\ b)A_{12}=0;\ Q=\Delta U_{12}=3739{,}5\ J;$ $c)Q_{23}=0;\ A_{23}=1807{,}4\,J;\ \Delta U_{23}=-1807{,}4\ J;$ $d)A_{31}=-1288\,J;\ \Delta U_{31}=-1932\ J;$ $Q_{31}=-3220\,J;\ e)\Delta U=0;\ A=519{,}4\,J;\ Q=519{,}4\ J;$

Masala № 11. *m=2 kg* massali kislorod gazi *V_1=1 m³* hajm egallaydi va *P_1=0,2 MPa* bosim ostida turibdi. Bu gazni qizdirilish natijasida, dastlab gaz doimiy bosim ostida *V_2=3 m³* hajmgacha kengaytirildi, so‘ngra doimiy hajmda *P_3=0,5 MPa* bosimgacha oshirildi. Ichki energiyaning o‘zgarishi *ΔU* ni, gazning bajargan ishi *A′*ni, gazga uzatilgan issiqlik miqdori *Q* ni hisoblang.

Berilgan:

$m=2kg, i=5$

$M=32\ \frac{g}{mol}$

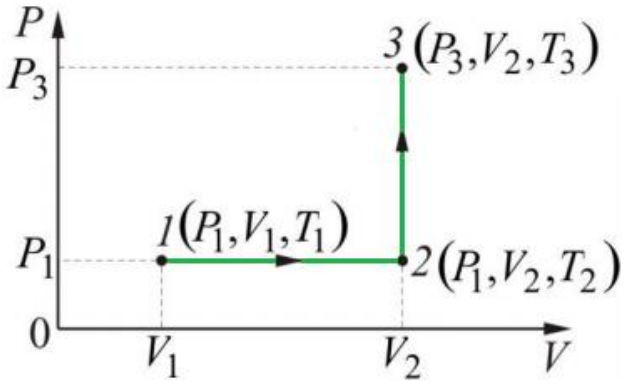
$P_1=0{,}2\,\text{MPa}$

$V_1=1m^3,\ V_2=3m^3$

$P_3=0{,}5\,MPa$

ΔU, A′, Q –?

Yechilishi:



Ichki energiya o‘zgarishi 1 va 2 nuqtalardagi temperaturalar farqiga bog‘liq.

$$\Delta U=\frac{i}{2}\nu R\Delta T=\frac{i}{2}\nu R\left(T_3-T_1\right)=\frac{i}{2}\nu R\left(\frac{P_3V_2}{\nu R}-\frac{P_1V_1}{\nu R}\right)=\frac{i}{2}\left(P_3V_2-P_1V_1\right)=$$

$$=\frac{5}{2}\left(5\cdot 10^5\cdot 3-2\cdot 10^5\cdot 1\right)=3{,}25\cdot 10^6\ J=3{,}25\,MJ$$

Jami bajarilgan ish 1→2 va 2→3 o‘tishlardagi bajarilgan ishlar yig‘indisiga teng.

$$A_{1\to 3}=A_{1\to 2}+A_{2\to 3}=A_P+A_V=P_1\left(V_2-V_1\right)+0=2\cdot 10^5\cdot\left(3-1\right)=4\cdot 10^5\ J=0{,}4\ MJ$$

Sistemaga jami uzatilgan issiqlik miqdori termodinamikaning 1-qonuniga ko‘ra ichki ebergiya o‘zgarishi bilan ishning yig‘indisiga teng bo‘ladi.

$$Q = \Delta U + A' = 3,25\,MJ + 0,4\,MJ = 3,65\,MJ$$

Javob: ΔU=3,25 MJ; A'=0,4 MJ; Q=3,65 MJ

Masala № 12. *m=14 g* massali azot gazi *T=300 K* temperaturada *P_1=100 kPa* bosimdan *P_2=500 kPa* bosimgacha izotermik ravishda siqiladi. Quyidagilarni aniqlang: a) ichki energiya o'zgarishini; b) tashqi kuchlarni gazni siqishda bajargan ishini; c) ajralgan issiqlik miqdorini.

Berilgan:
m=14 g
P_1=100 kPa
P_2=500 kPa
M=28 g/mol
A =?

Yechilishi:

a) Izotermik jarayonda *ΔT=0* bo'lgani uchun *ΔU=0* bo'ladi.

b) Izotermik siqilishda tashqi kuchlar gazning bosim kuchini yengib ish bajaradi.

$$A_T = -A_T' = -\nu RT\ln\frac{P_1}{P_2} = \frac{m}{M}RT\ln\frac{P_2}{P_1} = \frac{14\cdot10^{-3}}{28\cdot10^{-3}}\cdot8,31\cdot300\cdot\ln\frac{5\cdot10^5}{10^5} =$$
$$= 0,5\cdot831\cdot3\cdot\ln5 = 2006\,J$$

Izotermik siqilishda tashqi kuchlar *A_T =2006 J* ga teng musbat ish, gaz esa *A_T'* =-2006 J ga teng manfiy ish bajaradi.

c) Izotermik jarayon uchun termodinamikaning1-qonuniga asosan, *$Q=A_T'$* bo'ladi. Shunga asosan *Q=-2006 J* bo'ladi. Bu esa issiqlik gazdan tashqariga uzatilishini bildiradi.

Javob: *ΔU=0; A_T=2006 J; Q=-2006 J*

Masala № 13. *P_1=1 MPa* bosim ostida turgan *m=0,5 kg* massali azot gazi *$t_1=127^0C$* temperaturada izotermik kengayishi natijasida bosimi *k=3* marta kamayadi. Undan keyin dastlabki bosimgacha adiabatik siqiladi, undan keyin esa boshlang'ich hajmgacha izobarik siqiladi. Jarayonning P=P(V) grafigini chizing. Har bir jarayon uchun gazning bajargan ishini aniqlang. Umumiy ishni aniqlang.

Berilgan:
M=28 g/mol
P_1=1 MPa
$t_1=127^0C$
m=0,5 kg
k=3 , i=5
$A'_{1\to2}$ = ? $A'_{2\to3}$ = ?
$A'_{3\to1}$ = ? A'_{um} = ?

Yechilishi:

Jarayonni rasmdagi kabi tasvirlaymiz.

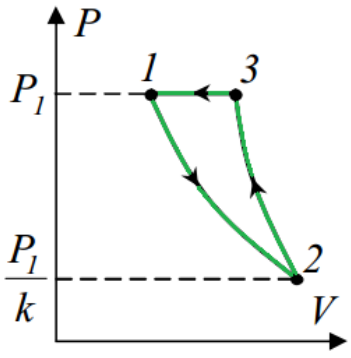
Bunda:

1→2 – T=const

2→3 – Q=0

3→1 – P=const

jarayonlaridir.



Gaz kengayganda musbat, siqilganda esa manfiy ish bajaradi. Shuning uchun

$$A'_{1\to2} > 0;\ A'_{2\to3} < 0;\ A'_{3\to1} < 0$$

bo'ladi. Har bir jarayonda bajarilgan ishlarni alohida-alohida hisoblaymiz.

$$A'_{1\to2} = \nu RT_1\ln\frac{V_2}{V_1} = \frac{m}{M}RT_1\ln\frac{P_1}{P_2} = \frac{0,5}{28\cdot10^{-3}}\cdot8,31\cdot400\cdot\ln3 \approx 65200\ J$$

Adiabatik jarayonda bajarilgan ishni aniqlash uchun 3 nuqtadagi temperaturaini aniqlab olamiz.

$$\frac{P^{\gamma-1}}{T^{\gamma}}=const,\ \rightarrow\ \frac{P_2^{\gamma-1}}{T_2^{\gamma}}=\frac{P_3^{\gamma-1}}{T_3^{\gamma}},\ \rightarrow\ \left(\frac{T_3}{T_2}\right)^{\gamma}=\left(\frac{P_3}{P_2}\right)^{\gamma-1},\ \rightarrow\ \frac{T_3}{T_2}=\left(\frac{P_3}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_2}{T_1}=3^{\frac{7/5-1}{7/5}}=3^{\frac{2}{7}}=1{,}369,\ \rightarrow\ T_2=1{,}369\cdot T_1=1{,}369\cdot 400\approx 548\,K$$

Gazning adiabatik siqilishda bajarilgan ish quyidagicha.

$$A'_{2\to3}=A'_{\gamma}=-\Delta U=-\frac{i}{2}\frac{m}{M}R\left(T_3-T_2\right)=-\frac{5}{2}\frac{0{,}5}{0{,}028}\cdot 8{,}31\cdot\left(548-400\right)\approx -54900\ J$$

Endi 3→1 o‘tishdagi gaz bajargan ishni aniqlash uchun uni izobarik jarayon uchun yecahmiz.

$$A'_{3\to1}=A'_{P}=\frac{m}{M}R\left(T_1-T_3\right)=\frac{0{,}5}{0{,}028}\cdot 8{,}31\cdot\left(400-548\right)\approx -21960\ J$$

Gazning berk sikldagi umumiy ishini aniqlaymiz.

$$A'_{umum}=A'_{1\to2}+A'_{2\to3}+A'_{3\to1}=65200-54900-21960=-11660\ J$$

Javob: $A'_{1\to2}=65200\ J;\ A'_{2\to3}=-54900\ J;\ A'_{3\to1}=-21960\ J;\ A'_{umum}-11660\ J$

9-amaliy mashg‘ulot topshirig‘i

9.1. $10^5\ Pa$ bosim ostida turgan ideal gazning hajmi izobar ravishda $300\ sm^3$ dan $500\ sm^3$ gacha oshdi. Bunda gaz necha joul ish bajargan? **Javob:** $A=20\ J$

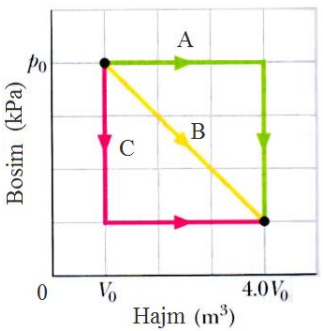
9.2. $300\ K$ temperaturadagi miqdori $5\ mol$ bo‘lgan gaz $50\ L$ hajm egallagan. Uning hajmini dastlab o‘zgarmas bosim sharoitida, keyin esa $\frac{P}{V}=const$ sharoitida ikki marta oshirildi. Bunda bajarilgan ishlar necha marta farq qiladi? **Javob:** $A_1=12465\ J;\ A_2=18698\ J;\ A_2/A_1=1{,}5\ marta$

9.3. Ikki atomli ideal gaz adiabatik ravishda siqilmoqda. Uning boshlang‘ich bosimi $120\ kPa$ va hajmi $0{,}2\ m^3$ ga teng. Gazning oxiridagi bosimi $360\ kPa$ ga teng. Tashqi kuchlar gazni siqishda qancha ish bajargan? **Javob:** $A_{tash}=22757\ J$

9.4. Adiabatik kengayish $PV^{\gamma}=const$ qonunga bo'ysunishini yaxzhi bilamiz. $2\ mol$ miqdordagi ikki atomli ideal gazning temperaturasi $T=300\ K$ bo‘lganda uni bosimi $P=120\ kPa$ bo‘lgani haqida ma’lumotga tayanib, $const$ qiymatni aniqlang.

Javob: $const=1397\ \frac{kg\cdot m^{3{,}2}}{s^2}$

9.5. Ideal gaz hajmi rasmdagi kabi V_0 dan $4V_0$ gacha oshganda bosim P_0 dan $P_0/4$ gacha kamayadi. Agar $V_0=1m^3$ va



$P_0 = 40\,kPa$ ga teng bo‘lsa, u holda A, B, C trayektoriyalar bo‘yicha kengayishda bajarilgan ishlarni aniqlang. **Javob:** $A_A = 90\,kJ;\ A_B = 75\,kJ;\ A_C = 30\,kJ$

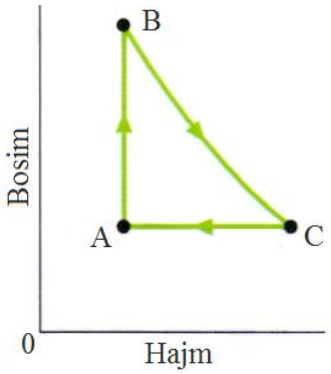
Termodinamikaning 1-qonuni va uning turli jarayonlarga tadbiqlari

9.6. *6 g* massali kislorod doimiy bosim sharoitida *2* marta kengaydi. Gazning boshlang‘ich temperaturasi *303 K*. Gazning kengayishda bajargan ishini, bundagi ichki energiya o‘zgarishini hamda gazga uzatilgan issiqlik miqdorini aniqlang. **Javob:** *A’=472 J; ΔU=1180 J; Q=1652 J*

9.7. *T=280 K* temperaturaga ega bo‘lgan *m=1 g* massali vodorod gazini izotermik ravishda kengaytirishda gazning hajmi 3 marta oshdi. Gazning kengayishidagi ishini va gazga uzatilgan issiqlik miqdorini aniqlang. **Javob:** *A’=Q=1278 J*

9.8. P_1*=200 kPa* bosim ostida V_1*=10 l* hajm egallagan azot gazi izotermik ravishda V_2*=28 l* hajmgacha kengaydi. Gaz kengayishidagi *A’* ishni va gazga uzatilgan issiqlik miqdorini aniqlang. **Javob:** *A’=Q=2060 J*

9.9. Porshen ostidagi ideal gaz bosimi rasmdagi kabi yopiq kontur bo‘yicha o‘zgaradi. A→B o‘tishda sistema tomonidan uzatilgan issiqlik $Q_{AB} = 25\,kJ$ ga B→C o‘tishda esa $Q_{BC} = 0$ va sikl davomida bajarilgan ish $A_{ABC} = 15\,kJ$ bo‘lsa, C→A o‘tishda qancha issiqlik atroga uzatilgan? **Javob:** $Q_{CA} = 15\,kJ$

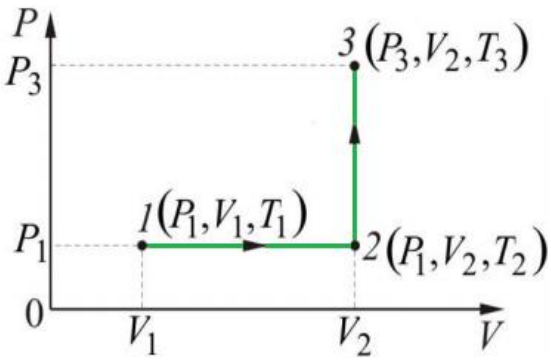


9.10. T_1*=300 K* temperaturaga ega bo‘lgan *m=2 g* massali vodorod gazini adiabatik ravishda hajmini *n=10* marta kamayguncha siqildi. Oxirgi T_2 temperaturani hamda gazni siqishda tashqi kuchlar bajargan A ishni aniqlang. **Javob:** $T_2 = 754\,K;\ A = 674\,J$

9.11. *m=20 g* massali kislorod gazini adiabatik ravishda siqishda gazning ichki energiyasi *ΔU=8 kJ* ga oshdi va temperatura *T_2=900 K* gacha yetdi. Aniqlang: 1) dastlabki T_1 temperaturani; 2) agar dastlabki bosim P_1*=200 kPa* bo‘lgan bo‘lsa, oxirgi P_2 bosimni. **Javob:** *T1=284 K; P_2=11,33 MPa*

9.12. Ikkita slindrik idishda porshen ostida miqdorlari *1 mol*dan bo‘lgan bir atomli va ikki atomli ideal gazlar turibdi. Ularni har birining hajmlari *2* marta kamayguncha siqildi. Idishlardagi gazlarning siqish oxiridagi temperaturalari nisbati T_1/T_2 ni hamda ichki energiyalari nisbati U_1/U_2 ni aniqlang. **Javob:** T_1*/* U_1/U_2T_2*=1,2; =0,72*

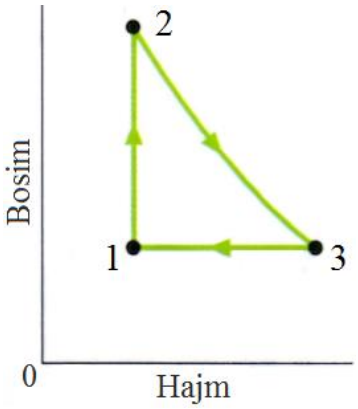
9.13. *m=2 kg* massali kislorod gazi V_1*=1* m^3 hajm egallaydi va P_1*=0,2 MPa* bosim ostida turibdi. Bu gazni qizdirilish natijasida, dastlab gaz doimiy bosim ostida V_2*=3* m^3 hajmgacha kengaytirildi, so‘ngra doimiy hajmda P_3*=0,5 MPa* bosimgacha



oshirildi. Ichki energiyaning o‘zgarishi ΔU ni, gazning bajargan ishi A' ni, gazga uzatilgan issiqlik miqdori Q ni hisoblang. **Javob:** *$\Delta U=3,25$ MJ; $A'=0,4$ MJ; $Q=3,65$ MJ*

9.14. *0^0C* temperatura va *100 kPa* bosimda *10 mol* ideal gaz *10 l* hajm egallaydi. Bu gaz hajmi ikki marta oshguncha adiabatik ravishda kengaydi. Kengayishda gazning bajargan ishini, gazning oxirgi bosimini va va gazning oxirgi ichki energiyasini aniqlang. **Javob:** *$P_2=37,9$ kPa; $A=605$ J; $U_2=1895$ J*

9.15. Rasmda porshen ostidagi 1 mol bir atomli gazning sikli tasvirlangan. Temperaturalar *$T_1=300$ K, $T_2=600$ K, $T_3=455$ K* ga teng. 1 nuqtada bosim $P_1=101kPa$ ga teng. Quyidagilarni aniqlang: *a)* 2 va 3 nuqtalardagi bosimlarni *b)* $1\to2$ o‘tishda $Q_{12},A_{12},\Delta U_{12}$ kattaliklarni; *c)* $2\to3$ o‘tishda $Q_{31},A_{31},\Delta U_{31}$ kattaliklarni; *d)* $3\to1$ o‘tishda $Q_{23},A_{23},\Delta U_{23}$ kattaliklarni; *e)* berk sikl uchun $Q,A,\Delta U$ kattaliklarni aniqlang. **Javob:**

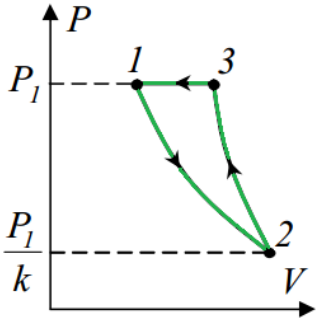


$a)P_2=202kPa;\ P_3=101kPa;\quad b)A_{12}=0;\ Q=\Delta U_{12}=3739,5\ J;$

$c)Q_{23}=0;\ A_{23}=1807,4\ J;\ \Delta U_{23}=-1807,4\ J;\quad d)A_{31}=-1288\ J;\ \Delta U_{31}=-1932\ J;$

$Q_{31}=-3220\ J;\ e)\Delta U=0;\ A=519,4\ J;\ Q=519,4\ J;$

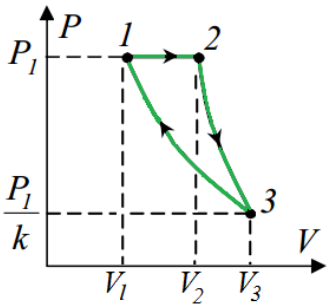
9.16. *$P_1=1$ MPa* bosim ostida turgan *$m=0,5$ kg* massali azot gazi *$t_1=127^0C$* temperaturada izotermik kengayishi natijasida bosimi *$k=3$* marta kamayadi. Undan keyin dastlabki bosimgacha adiabatik siqiladi, undan keyin esa boshlang‘ich hajmgacha izobarik siqiladi. Jarayonning P=P(V) grafigini chizing. Har bir jarayon uchun gazning bajargan ishini aniqlang. Umumiy ishni aniqlang.



Javob: $A'_{1\to2}=65200\ J;\ A'_{2\to3}=-54900\ J;$

$A'_{3\to1}=-21960\ J;\ A'_{umum}-11660\ J$

9.17. *Rasmdagi sikl izobarik, adiabatik va izotermik jarayonlardan iborat. Bunda eng kichik temperatura izotermik jarayonga mos keladi. 1 nuqtadagi bosim, hajm va temperaturalar P_1, V_1 va T_1 ga teng. 2 va 3 nuqtadagi makroskopik parametr (bosim, hajm va temperatura) larni aniqlang. **Javob:** 2- nuqta uchun $P_2=P_1;\ V_2=k^{\frac{2}{i+2}}V_1;\ T_2=k^{\frac{2}{i+2}}T_1$; 3- nuqta uchun $P_3=P_1/k;\ V_3=kV_1;\ T_3=T_1$*



9.18. *Oldingi masala shartida $k=3$ deb olib, uni quyidagi hollar uchun yeching: a) iseal gaz bir atomli; b) ideal gaz ikki atomli; c) ideal gaz uch atomli. **Javob:** a) 2- nuqta uchun $P_2=P_1;\ V_2=1,55V_1;\ T_2=1,55T_1;$ 3- nuqta uchun $P_3=P_1/3;\ V_3=3V_1;\ T_3=T_1;$ b) 2- nuqta uchun $P_2=P_1;\ V_2=1,369V_1;\ T_2=1,369T_1;$ 3- nuqta uchun $P_3=P_1/3;\ V_3=3V_1;$*

$T_3=T_1$; c) 2- *nuqta uchun* $P_2=P_1$; $V_2=1{,}316V_1$; $T_2=1{,}316T_1$; 3- *nuqta uchun* $P_3=P_1/3$; $V_3=3V_1$; $T_3=T_1$

9.19. **9.17-masala shartida $P1=100$ *kPa*, $V1=1\ell$, $T1=400$ *K* va $k=3$ deb deb hisoblab, siklning 1→2, 2→3 va 3→1 o‘tishlardagi ko‘p atomli ideal gazning bajargan ishlarini hisoblang. Siklda gazning umumiy bajargan ishi nimaga teng bo‘ladi? Har bir o‘tishda ideal gazga qancha isiqlik uzatilgan? **Javob:** $A_{1\to2}=31{,}6\,J$; $A_{2\to3}=94{,}8\,J$; $A_{3\to1}=-109{,}9\,J$; $\oint A=16{,}5\,J$; $Q_{1\to2}=126{,}4\,J$; $Q_{2\to3}=0\,J$; $Q_{3\to1}=-109{,}9\,J$

9.20. *100 kPa* bosimda 2ℓ hajm egallagan ideal gaz 4ℓ hajmgacha izotermik ravishda kengaydi. So‘ngra gazni izoxorik ravishda sovitilib bosimi 2 marta kamaytirildi. Undan keyin esa gaz hajmini izobarik ravishda 8ℓ gacha oshirildi. $P=P(V)$ grafigini chizing va gazning bajargan ishini aniqlang. **Javob:** *240 J*

9.21. Molyar massasi $M=40$ *g/mol* va massasi $m=80$ *g* bo‘lgan slindrda porshen ostidagi bir atomli ideal gazni shunday qizdiriladiki, bunda temperatura dasrlabki $T_1=300$ *K* dan $T_2=400$ *K* gacha bo‘lgan oraliqda bosimning kvadratiga proporsional ($T\sim P^2$) bo‘ladi. Bunda ideal gaz bajargan ishni hamda gazga uzatilgan issiqlikmiqdori nimaga teng bo‘ladi? **Javob:** $A'=800\,J$; $Q=2300\,J$

10-MAVZU: Ideal gazlar uchun issiqlik sig‘imlari. Mayer va Puasson formulalari. Aralashma gazlar uchun issiqlik sig‘imlari va Puasson koeffitsiyenti.

Mavzuga oid muhim formulalar

Ideal gazni izobarik jarayonda qizdirilganda solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$c_P = \frac{i+2}{2}\frac{R}{M}, \qquad c_P^* = \frac{i+2}{2}R$$

Ideal gazni izoxorik jarayonda qizdirilganda solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$c_V = \frac{i}{2}\frac{R}{M}, \qquad c_V^* = \frac{i}{2}R$$

Mayer formulasi

$$c_P - c_V = \frac{R}{M}, \qquad c_P^* - c_V^* = R$$

Puasson formulasi

$$\gamma = \frac{c_P}{c_V} = \frac{i+2}{i}$$

$$\gamma_1 = \frac{5}{3}, \quad \gamma_2 = \frac{7}{5}, \quad \gamma_3 = \frac{4}{3}$$

Gazlar aralashmasini izobarik jarayonda qizdirilganda solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$c_P = \frac{(i_1+2)\nu_1 + (i_2+2)\nu_2 + (i_3+2)\nu_3 + \ldots + (i_n+2)\nu_n}{\nu_1 M_1 + \nu_2 M_2 + \nu_3 M_3 + \ldots + \nu_n M_n} \cdot \frac{R}{2}$$

$$c_P^* = \frac{(i_1+2)\nu_1 + (i_2+2)\nu_2 + (i_3+2)\nu_3 + \ldots + (i_n+2)\nu_n}{\nu_1 + \nu_2 + \nu_3 + \ldots + \nu_n} \cdot \frac{R}{2}$$

Bir atomli, ikki atomli, uch atomli ideal gazlar aralashmasini izobarik qizdirilganda solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$c_P = \frac{5\nu_1 + 7\nu_2 + 8\nu_3}{\nu_1 M_1 + \nu_2 M_2 + \nu_3 M_3} \cdot \frac{R}{2}, \qquad c_P^* = \frac{5\nu_1 + 7\nu_2 + 8\nu_3}{\nu_1 + \nu_2 + \nu_3} \cdot \frac{R}{2}$$

Gazlar aralashmasini izoxorik jarayonda qizdirilganda solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$c_V = \frac{i_1\nu_1 + i_2\nu_2 + i_3\nu_3 + \ldots + i_n\nu_n}{\nu_1 M_1 + \nu_2 M_2 + \nu_3 M_3 + \ldots + \nu_n M_n} \cdot \frac{R}{2}, \qquad c_V^* = \frac{i_1\nu_1 + i_2\nu_2 + i_3\nu_3 + \ldots + i_n\nu_n}{\nu_1 + \nu_2 + \nu_3 + \ldots + \nu_n} \cdot \frac{R}{2}$$

Bir atomli, ikki atomli, uch atomli ideal gazlar aralashmasini izoxorik qizdirilganda solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$c_P = \frac{3\nu_1 + 5\nu_2 + 6\nu_3}{\nu_1 M_1 + \nu_2 M_2 + \nu_3 M_3} \cdot \frac{R}{2}, \qquad c_P^* = \frac{3\nu_1 + 5\nu_2 + 6\nu_3}{\nu_1 + \nu_2 + \nu_3} \cdot \frac{R}{2}$$

Politropik jarayon uchun solishtirma issiqlik sig‘imi va molyar issiqlik sig‘imi

$$\begin{cases} c = c_V + \dfrac{P}{m}\dfrac{dV}{dT} \\ c^* = c_V^* + \dfrac{P}{\nu}\dfrac{dV}{dT} \end{cases}, \qquad \begin{cases} c = c_V \dfrac{n-\gamma}{n-1} \\ c^* = c_V^* \dfrac{n-\gamma}{n-1} \end{cases}$$

Politropa ko'rsatkichi

$$n = \frac{c^* - c_P^*}{c^* - c_V^*}, \quad yoki \quad n = \frac{c - c_P}{c - c_V}$$

Gazlar aralashmasi uchun adiabata ko'rsatkichi

$$\gamma = \frac{c_P}{c_V} = \frac{(i_1+2)\nu_1 + (i_2+2)\nu_2 + (i_3+2)\nu_3 + \ldots}{i_1\nu_1 + i_2\nu_2 + i_3\nu_3 + \ldots}$$

10-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Bir atomli, ikki atomli va uch atomli gazlardan teng miqdorda olib, ularni aralashtirilganda o'zgarmas hajmdagi va o'zgarmas bosimdagi molyar solishtirma issiqlik sig'imilari nimaga teng bo'ladi? Puasson koeffitsiyenti-chi?

Berilgan:

$i_1 = 3, i_2 = 5$

$i_3 = 6$

$\nu_1 = \nu_2 = \nu_3 = \nu$

$c' = ?$

Yechilishi:

Bunda mavzuda hisoblab chiqarilgan formuladan foydalanamiz.

$$c'_V = \frac{3\nu_1 + 5\nu_2 + 6\nu_3}{\nu_1 + \nu_2 + \nu_3} \cdot \frac{R}{2} = \frac{3+5+8}{3} \cdot \frac{R}{2} = \frac{8}{3}R = 22{,}16\ \frac{J}{mol \cdot K}$$

$$c'_P = \frac{5\nu_1 + 7\nu_2 + 8\nu_3}{\nu_1 + \nu_2 + \nu_3} \cdot \frac{R}{2} = \frac{5+7+8}{3} \cdot \frac{R}{2} = \frac{10}{3}R = 27{,}7\frac{J}{mol \cdot K}$$

$$\gamma = \frac{c'_P}{c'_V} = \frac{(10/3)R}{(8/3)R} = \frac{5}{4} = 1{,}25$$

Javob: $c'_V = 22{,}16\ \dfrac{J}{mol \cdot K}$; $c'_P = 27{,}7\ \dfrac{J}{mol \cdot K}$; $\gamma = 1{,}25$

Masala № 2. Biror ideal gazga *22,5 J* issiqlik berilganda uning hajmi *50 sm³* dan *100 sm³* gacha oshdi. Bunda *p=100 kPa* bosim o'zgarmasligicha qolaverdi. Gazning ichki energiyasi qanchaga o'zgargan? Agar gazning modda miqdori $\nu = 2 \cdot 10^{-3} mol$ bo'lsa, u holda c'_P va c'_V solishtirma molyar issiqlik sig'imlarini aniqlang.

Berilgan:

Q=22,5 J

P=100 kPa

$\nu = 2 \cdot 10^{-3} mol$

$\Delta U = ?$

$c'_P, c'_V - ?$

Yechilishi:

Dastlab ishni aniqlaymiz.

$$A' = P(V_2 - V_1) = 100000\left(100 \cdot 10^{-6} - 50 \cdot 10^{-6}\right) = 5\ J\ .$$

Ichki energiya o'zgarishi quyidagicha:

$$Q = A' + \Delta U, \ \rightarrow \ \Delta U = Q - A' = 22{,}5 - 5 = 17{,}5\,J$$

Temperatura o'zgarishini aniqlaymiz.

$$A' = \nu R\Delta T,\ \rightarrow\ \Delta T = \frac{A'}{\nu R} = \frac{5}{2\cdot 10^{-3}\cdot 8{,}31} = 300\,K\,.$$

Gazning erkinlik darajasini topamiz.

$$\Delta U = \frac{i}{2}\nu R\Delta T,\ \rightarrow\ i = \frac{2\Delta U}{\nu R\Delta T} = \frac{2\cdot 17{,}5}{2\cdot 10^{-3}\cdot 8{,}31\cdot 300} = \frac{35}{5} = 7$$

Molyar issiqlik sig‘imlarini aniqlaymiz.

$$c'_P = \frac{i+2}{2}R = \frac{7+2}{2}R = 4{,}5R \approx 37{,}4\ \frac{J}{mol\cdot K}\,,\qquad c'_V = \frac{i}{2}R = \frac{7}{2}R = 3{,}5R \approx 29{,}1\ \frac{J}{mol\cdot K}\,.$$

Javob: $\Delta U = 17{,}5\,J;\ c'_P \approx 37{,}4\ \frac{J}{mol\cdot K};\ c'_V \approx 29{,}1\ \frac{J}{mol\cdot K}\,.$

Masala № 3. *200 mol* miqdordagi neon va *500 mol* miqdordagi vodorod gazlari aralashtirildi. Hosil bo‘lgan aralashma gaz uchun quyidagilarni aniqlang: a) ozgarmas bosim va o‘zgarmas hajm sharoitidagi solishtirma molyar issiqlik sig‘imlarini; b) ozgarmas bosim va o‘zgarmas hajm sharoitidagi solishtirma issiqlik sig‘imlarini; c) Puasson koeffitsiyentini?

Berilgan:

$i_1 = 3, i_2 = 5$

$\nu_1 = 200\,mol$

$\nu_2 = 500\,mol$

$M_1 = 20\,g/mol$

$M_2 = 2\,g/mol$

a) $c_P = ?,\ c_V = ?$

b) $c'_P = ?,\ c'_V = ?$

c) $\gamma = ?$

Yechilishi:

a) Dastlab solishtirma issiqlik sig’imlarini topamiz.

$$c_P = \frac{(i_1+2)\nu_1 + (i_2+2)\nu_2}{\nu_1 M_1 + \nu_2 M_2}\cdot\frac{R}{2} = \frac{5\cdot 200 + 7\cdot 500}{200\cdot 20\cdot 10^{-3} + 500\cdot 2\cdot 10^{-3}}\cdot\frac{8{,}31}{2} =$$

$$= \frac{4500}{5}\cdot\frac{8{,}31}{2} = 3740\ \frac{J}{kg\cdot K}$$

$$c_V = \frac{i_1\nu_1 + i_2\nu_2}{\nu_1 M_1 + \nu_2 M_2}\cdot\frac{R}{2} = \frac{3\cdot 200 + 5\cdot 500}{200\cdot 20\cdot 10^{-3} + 500\cdot 2\cdot 10^{-3}}\cdot\frac{8{,}31}{2} =$$

$$= \frac{3100}{5}\cdot\frac{8{,}31}{2} = 2576\ \frac{J}{kg\cdot K}$$

b) Endi solishtirma molyar issiqlik sig’imlarini topamiz.

$$c'_P = \frac{(i_1+2)\nu_1 + (i_2+2)\nu_2}{\nu_1+\nu_2}\cdot\frac{R}{2} = \frac{5\cdot 200 + 7\cdot 500}{200+500}\cdot\frac{R}{2} = \frac{4500}{700}\cdot\frac{R}{2} = \frac{45}{14}R = 26{,}71\ \frac{J}{mol\cdot K}$$

$$c'_V = \frac{i_1\nu_1 + i_2\nu_2}{\nu_1+\nu_2}\cdot\frac{R}{2} = \frac{3\cdot 200 + 5\cdot 500}{200+500}\cdot\frac{R}{2} = \frac{3100}{700}\cdot\frac{R}{2} = \frac{31}{14}R = 18{,}4\ \frac{J}{mol\cdot K}$$

c) Nihoyat Puasson ko‘tsatkichini topamiz.

$$\gamma = \frac{c'_P}{c'_V} = \frac{3740}{2576} = \frac{45}{31} = 1{,}451$$

Javob: $a)\ c_P = 3740\ \frac{J}{kg\cdot K};\ c_V = 2576\ \frac{J}{kg\cdot K};\ b)\ c'_P = 26{,}71\ \frac{J}{mol\cdot K};\ c'_V = 18{,}4\ \frac{J}{mol\cdot K}$

$c)\ \gamma = \frac{45}{31} = 1{,}451$ s

Masala № 4. Geliy (*He*) gazini siqish $V=\alpha P^{-1/2}$ qonunga ko‘ra ro‘y bermoqda. Bunda α=const. Bu jarayondagi solishtirma issiqlik sig‘imini aniqlang.

Berilgan:	*Yechilishi:*
$i=3$ $M=4\,g/mol$ $V=\alpha P^{-1/2}$	Ushbu masalani 2 xil usulda yechish mumkin. Har bir usulga alohida-alohida to‘xtalib o‘taylik.
c=?	

1-usul:

Bu usul politropik jarayonga asoslangandir. Berilgan tenglamani qayta o‘zgartirib uni $PV^2=const$ ko‘rinishga osongina keltirish mumkin. Bundan politropik ko‘rsatkichi $n=2$ ekani kelib chiqadi. Politropik jarayon uchun solishtirma issiqlik sig‘imi

$$c=c_V\frac{n-\gamma}{n-1}$$

formuladan aniqlanadi. Bunda bir atomli gaz bo‘lgani uchun $c_V=\frac{3}{2}\frac{R}{M}$ va $\gamma=\frac{5}{3}$ formulalardan foydalanamiz.

$$c=c_V\frac{n-\gamma}{n-1}=c_V\cdot\frac{2-\gamma}{2-1}=c_V\left(2-\gamma\right)=2c_V-c_P=c_V-\frac{R}{M}=\frac{3}{2}\frac{R}{M}-\frac{R}{M}=$$

$$=\frac{R}{2M}=\frac{8{,}31}{2\cdot4\cdot10^{-3}}=\frac{8310}{8}=1039\,\frac{J}{kg\cdot K}$$

2-usul:

Bu usul umumiyroq va ma’qulroq usul bo’lib, u ideal gazdagi ixtiyoriy jarayon uchun o’rinlidir. Ixtiyoriy m massali ideal gaz uchun

$$c=c_V+\frac{P}{m}\frac{dV}{dT}\quad(*)$$

o‘rinlidir. Bunda $P=\frac{\alpha^2}{V^2}$ va $P=\frac{mRT}{MV}$ larni tenglashtirish orqali

$$T=\frac{\alpha^2M}{mRV}$$

ni hosil qilamiz. Buni hajm bo‘yicha differensiallab

$$\frac{dT}{dV}=-\frac{\alpha^2M}{mRV^2}$$

ni hosil qilamiz. Bu ifodalarni (*) ifodaga qo‘yish orqali jarayon uchun solishtirma issiqlik sig‘imini anilqlashimiz mumkin.

$$c=c_V+\frac{P}{m}\frac{dV}{dT}=c_V+\frac{P}{m\left(dT/dV\right)}=c_V+\frac{\alpha^2}{mV^2\left(-\frac{\alpha^2M}{mRV^2}\right)}=c_V-\frac{R}{M}=\frac{3}{2}\frac{R}{M}-\frac{R}{M}=\frac{R}{2M}$$

Bu natijani hisoblash orqali esa $c = 1039\ \frac{J}{kg \cdot K}$ javobni olamiz.

Javob: $c = \frac{R}{2M} = 1039\ \frac{J}{kg \cdot K}$

Masala № 5. Bir mol kislorod $P=P_0+kV^2$ qonun bilan berilgan jarayonda ishtirok etmoqda. Bunda P_0 va k musbat doimiylar. Ideal gaz modeli doirasida gazning molyar issiqlik sig'imini hajmning funksiyasi sifatida c'=c'(V) aniqlang.

Berilgan:

$i = 5,\ \nu = 1 mol$

$M = 32\ g / mol$

$P = P_0 + kV^2$

c'=c'(V) –?

Yechilishi:

1 mol ideal gaz uchun ideal gaz holat tenglamasi

$$PV=RT$$

dan foydalanib, T va V kattaliklarni o'zaro bog'liqlik ifodasini aniqlaymiz.

$$T = \frac{PV}{R} = \left(P_0 + kV^2\right)\frac{V}{R} = \frac{1}{R}\left(P_0V + kV^3\right)$$

Bundan V bo'yicha hosila olamiz.

$$\frac{dT}{dV} = \frac{1}{R}\left(P_0 + 3kV^2\right)$$

Endi so'ralgan kattalikni aniqlaymiz.

$$c' = c'_V + P\frac{dV}{dT} = c'_V + \frac{P}{(dT/dV)} = c'_V + \frac{P_0 + kV^2}{\frac{1}{R}\left(P_0 + 3kV^2\right)} = c'_V + R\frac{P_0 + kV^2}{P_0 + 3kV^2} =$$

$$= c'_V + R\left(1 - \frac{2kV^2}{P_0 + 3kV^2}\right)$$

Masala shartiga ko'ra a>0 bo'lgani uchun

$$0 < \frac{2kV^2}{P_0 + 3kV^2} < 1$$

oraliqda joylashadi, shuning uchun molyar issiqlik sig'imi har doim musbat bo'ladi.

Javob: $c' = c'_V + R\left(1 - \frac{2kV^2}{P_0 + 3kV^2}\right)$

Masala № 6. Ideal gaz uchun solishtirma issiqlik sig'imini *T* va *V* kattaliklar orqali ifodalash uchun, ya'ni *c=c(T, V)* bog'lanish uchun $c = c_V + \frac{P}{m}\frac{dV}{dT}$ munosobatdan foydalanish qulaydir. Chunki bunda tenglama tarkibiga *dV/dT* hosila kiradi. *P* va *T* o'zgaruvchili solishtirma issiqlik sig'imi uchun *c=c(P, T)* munosobatni aniqlang.

Berilgan:

$c = c_V + \frac{P}{m}\frac{dV}{dT}^{-1/2}$

c=(P, T) – ?

Yechilishi:

Ideal gaz uchun ideal gaz holat tenglamasi

$$PV = \frac{m}{M}RT$$

dan foydalanib, *V* kattalikni ifodasini aniqlaymiz.

$$V = \frac{mRT}{MP}$$

Bu ifodadan T bo'yicha hosila olamiz.

$$\frac{dV}{dT} = \frac{mR}{M}\left(\frac{T}{V}\right)_V' = \frac{mR}{M}\left(\frac{1}{P} - \frac{T}{P^2}\frac{dP}{dT}\right)$$

Endi yuqoridagi olingan ifodani solishtirma issiqlik sig'imi formulasiga qo'yamiz.

$$c = c_V + \frac{P}{m}\frac{dV}{dT} = c_V + \frac{P}{m}\frac{mR}{M}\left(\frac{1}{P} - \frac{T}{P^2}\frac{dP}{dT}\right) = c_V + \frac{PR}{M}\left(\frac{1}{P} - \frac{T}{P^2}\frac{dP}{dT}\right) =$$

$$= c_V + \frac{R}{M} - \frac{RT}{PM}\frac{dP}{dT} = c_P - \frac{RT}{PM}\frac{dP}{dT}$$

Javob: $c = c_P - \frac{RT}{PM}\frac{dP}{dT}$

10-amaliy mashg'ulot topshirig'i

10.1. Azot gazi uchun o'zgarmas bosimdagi va o'zgarmas hajmdagi solishtirma issilqik sig'imlarini aniqlang. **Javob:** $c_P = 1039\ \frac{J}{kg \cdot K};\ c_V = 742\ \frac{J}{kg \cdot K}$

10.2. Ikki atomli ideal gaz uchun o'zgarmas bosimdagi va o'zgarmas hajmdagi solishtirma issilqik sig'imlarini aniqlang. Bu gazning normal sharoitdagi zichligi *1,43 kg/m*^{3} ga teng. **Javob:** $c_P = 906\ \frac{J}{kg \cdot K};\ c_V = 647\ \frac{J}{kg \cdot K}$

10.3. Agar uch atomli ideal gazning normal sharoitdagi zichligi *1,5 kg/m*^{3} ga teng bo'lsa, u holda bu gaz uchun o'zgarmas bosimdagi va o'zgarmas hajmdagi solishtirma issilqik sig'imlarini hamda Puasson koeffitsiyentini aniqlang. **Javob:** $c_P = 987\ \frac{J}{kg \cdot K};$

$c_V = 740\ \frac{J}{kg \cdot K};\ \gamma = 1{,}33$

10.4. Ideal gazning normal sharoitdagi zichligi *1,25 kg/m*^{3} ga teng. Bu gaz uchun adiabata ko'rsatkichi γ*=1,4* ga teng. Bu gaz uchun o'zgarmas bosimdagi va o'zgarmas hajmdagi solishtirma issilqik sig'imlarini aniqlang. **Javob:**

$c_P = 1039\ \frac{J}{kg \cdot K};\ c_V = 742\ \frac{J}{kg \cdot K}$

10.5. *3g* massali karbonat angidrid va *4 g* massali azot gazlari aralashmasining o‘zgarmas bosimdagi va o‘zgarmas hajmdagi solishtirma issilqik sig‘imlarini hamda adiabata ko‘rsatkichini aniqlang. **Javob:** $c_P = 917\ \frac{J}{kg \cdot K};\ c_V = 666\ \frac{J}{kg \cdot K};\ \gamma = 1{,}377$

10.6. Bundan oldingi masala sharti uchun aralashma gazning molyar massasini aniqlang. Bu aralashma gaz uchun Mayer formulasi $\left(c_P - c_V = \frac{R}{M}\right)$ to‘g‘ri ekanini tekshiring. **Javob:** $M = 33{,}17 \cdot 10^{-3}\ \frac{kg}{mol};\ \frac{R}{M} = 251\frac{J}{kg \cdot K}$ – *to'g'ri*

10.7. Biror miqdordagi azot (N_2) hamda ν_2*=5 mol* ammiak (NH_3) gazlari aralashmasining solishtirma issiqlik sig‘imlari nisbati γ*=1,35* ga teng. Bu aralashmada necha mol azot gazi bor? J: ν_2*=2 mol*

10.8. *4g* massali vodorod va *22 g* massali karbonat angidrid gazlari aralashmasining o‘zgarmas bosimdagi va o‘zgarmas hajmdagi solishtirma issilqik sig‘imlari nisbatini aniqlang. **Javob:** $\gamma = \frac{18}{13} = 1{,}385$

10.9. Bir atomli, ikki atomli va uch atomli ideal gazlardan teng miqdorda aralashtirilgan. Bu aralashma uchun o‘zgarmas bosimdagi va o‘zgarmas hajmdagi solishtirma molyar issiqlik sig‘imlarini hamda adiabata ko‘rsatkichini aniqlang. **Javob:** $c_P = \frac{10}{3}R = 27{,}7\frac{J}{mol \cdot K};\ c_V = \frac{7}{3}R = 19{,}39\ \frac{J}{mol \cdot K};\ \gamma = \frac{10}{7} = 1{,}429$

10.10. Massalari teng bo‘lgan neon (*Ne*), kislorod (O_2) va karbonat angidrid (CO_2) gazlaridan olinib ularni aralashtirilgan. Bu aralashma uchun o‘zgarmas bosimdagi va o‘zgarmas hajmdagi solishtirma issiqlik sig‘imlarini hamda adiabata ko‘rsatkichini aniqlang. **Javob:** $c_P = 901\ \frac{J}{kg \cdot K};\ c_V = 613\ \frac{J}{kg \cdot K};\ \gamma = 1{,}47$

10.11. *m=1 kg* massali ideal gaz *P=150 kPa* bosim ostida turibdi. Gaz isitiganda kengayadi. Agar gaz temperaturasi ΔT*=3 K* ga isitilganda uning hajmi ΔV*=2 l* ga oshgan bo‘lsa, u holda bu jarayon uchun solishtirma issiqlik sig‘imi nimaga teng? Bu gazning o‘zgarmas hajmdagi solishtirma issiqlik sig‘imi $c_V = 700\ \frac{J}{kg \cdot K}$ ga teng. Gazning berilgan issiqlik va hajm o‘zgarishi uchun bosimni sezilarli o‘zgarmaydi deb hisoblang. **Javob:** $c = 925\ \frac{J}{kg \cdot K}$

10.12. Oldingi masala shartida ideal gazni havo deb olib, o‘zgarmas bosimdagi solishtirma issiqlik sig‘imini hamda kechayotgan jarayon uchun politropa ko‘rsatkichini aniqlang. **Javob:** $c_P = c_V + \frac{R}{M} = 986\ \frac{J}{kg \cdot K};\ n = -0{,}328$

10.13. Ideal gaz temperaturasi hajmga $T=\alpha V^2$ qonunga ko‘ra bog‘langan. Bu jarayon uchun solishtirma molyar issiqlik sig‘imini aniqlang. Masalani ideal gaz: *a)* bir atomli; *b)* ikki atomli; *c)* uch atomli bo‘lgan hollar uchun yeching. Bunda α – biror doimiy son. **Javob:** $c'_1 = 2R;\ c'_2 = 3R;\ c'_3 = 3{,}5R$

10.14. Ideal gaz temperaturasi bosimga $T=\beta P^3$ qonunga ko‘ra bog‘langan. Bu jarayon uchun solishtirma molyar issiqlik sig‘imini aniqlang. Masalani ideal gaz: *a)* bir atomli; *b)* ikki atomli; *c)* uch atomli bo‘lgan hollar uchun yeching. Bunda β – biror doimiy son. **Javob:** $c'_1 = \frac{13}{8}R;\ c'_2 = \frac{19}{8}R;\ c'_3 = \frac{11}{4}R$

10.15. Ideal gaz bosimi hajmga $P=\delta V^2$ qonunga ko‘ra bog‘langan. Bu jarayon uchun solishtirma molyar issiqlik sig‘imini aniqlang. Masalani ideal gaz: *a)* bir atomli; *b)* ikki atomli; *c)* uch atomli bo‘lgan hollar uchun yeching. Bunda δ – biror doimiy son. **Javob:** $c'_1 = \frac{11}{4}R;\ c'_2 = \frac{17}{4}R;\ c'_3 = 5R$

10.16. **200 mol* miqdordagi neon va *500 mol* miqdordagi vodorod gazlari aralashtirildi. Hosil bo‘lgan aralashma gaz uchun quyidagilarni aniqlang: a) ozgarmas bosim va o‘zgarmas hajm sharoitidagi solishtirma molyar issiqlik sig‘imlarini; b) ozgarmas bosim va o‘zgarmas hajm sharoitidagi solishtirma issiqlik sig‘imlarini; c) Puasson koeffitsiyentini? **Javob:** $a)\, c_P = 3740\,\frac{J}{kg\cdot K};\ c_V = 2576\,\frac{J}{kg\cdot K};$

$b)\, c'_P = 26{,}71\,\frac{J}{mol\cdot K};\ c'_V = 18{,}4\,\frac{J}{mol\cdot K};\ \ c)\, \gamma = \frac{45}{31} = 1{,}451$

10.17. *Geliy (*He*) gazini siqish $V=\alpha P^{-1/2}$ qonunga ko‘ra ro‘y ber-moqda. Bunda $\alpha=const$. Bu jarayondagi solishtirma issiqlik sig‘imini aniqlang. **Javob:** $c = \frac{R}{2M} = 1039\,\frac{J}{kg\cdot K}$

10.18. *Bir mol kislorod $P=P_0+kV^2$ qonun bilan berilgan jarayonda ishtirok etmoqda. Bunda P_0 va k musbat doimiylar. Ideal gaz modeli doirasida gazning molyar issiqlik sig‘imini hajmning funksiyasi sifatida $c'=c'(V)$ aniqlang. **Javob:** $c' = c'_V + R\left(1 - \frac{2kV^2}{P_0 + 3kV^2}\right)$

10.19. *Ideal gaz uchun solishtirma issiqlik sig‘imini T va V kattaliklar orqali ifodalash uchun, ya’ni $c=c(T,V)$ bog‘lanish uchun $c = c_V + \frac{P}{m}\frac{dV}{dT}$ munosobatdan foydalanish qulaydir. Chunki bunda tenglama tarkibiga dV/dT hosila kiradi. P va T o‘zgaruvchili solishtirma issiqlik sig‘imi uchun $c=c(P,\ T)$ munosobatni aniqlang. **Javob:** $c = c_P - \frac{RT}{PM}\frac{dP}{dT}$

11-MAVZU: Real issiqlik mashinasi va ideal issiqlik mashinasi (Karno sikli) ning FIK. Har xil sikllar (Otto sikli, Stirling sikli va b.) va ularning FIK.

Mavzuga oid muhim formulalar

Real issiqlik mashinasining FIKni aniqlash formulasi $\eta_{real} = \frac{Q_1 - Q_2}{Q_1} = \frac{A'}{Q_1}, \qquad \eta = \frac{\oint \delta A}{Q_1} = \frac{\oint \delta Q}{Q_1}$	
$\eta_K = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1}$	*Ideal issiqlik mashinasining (Karno sikli uchun) FIK ni aniqlash formulasi*

11-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. Issiqlik mashinasi sikl davomida isitkichdan *100 J* issiqlik oldi va sovitkichga *60 J* issiqlik berdi. Mashinaning FIK ni toping.

Berilgan:

$Q_1 = 100\,J$

$Q_2 = 60\,J$

$\eta = ?$

Yechilishi:

Issiqlik mashinasining foydali ish kaeffitsientini topish formulasidan foydalanamiz.

$$\eta = \frac{Q_1 - Q_2}{Q_1} \cdot 100\% = \frac{100-60}{100} \cdot 100\% = 40\%$$

Javob: $\eta = 40\%$

Masala № 2. *600 W* quvvatli Karno dvigateli *100^0C* va *60^0C* temperaturalar oralig‘ida ishlaydi. Bu dvigatelning ishitkichdan oladigan va sovitkichga uzatadigan quvvatlari nimaga teng?

Berilgan:

P=600 W

$T_1 = 373\,K$

$T_2 = 333\,K$

$P_1 = ?,\ P_2 = ?$

Yechilishi:

Dvigatelning FIKini aniqlaymiz.

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{373 - 333}{373} = \frac{40}{373} = 0{,}107 = 10{,}7\%$$

Berilgan P=600 W quvvat –bu foydali quvvatdir. Endi isitkichdan olingan va sovitkichga uzatilgan quvvatlarni aniqlaymiz.

$$\eta = \frac{P_f}{P_1}, \rightarrow P_1 = \frac{P_f}{\eta} = \frac{600}{0{,}107} = 5595W$$

$$P_2 = (1 - \mu) P_1 = (1 - 0{,}107) \cdot 5595 = 4995W$$

Javob: $P_1=5595\ W;\ P_2=4995\ W$

Masala № 3. Ko‘p atomli ideal gaz Karno sikli bo‘yicha ishlaydi. Bunda adiabatik kengayishda gaz hajmi $k=4$ marta oshadi. Sikl uchun Fikning qiymati nimaga teng bo‘ladi?

Berilgan:

$\frac{V_2}{V_3}=k=4$

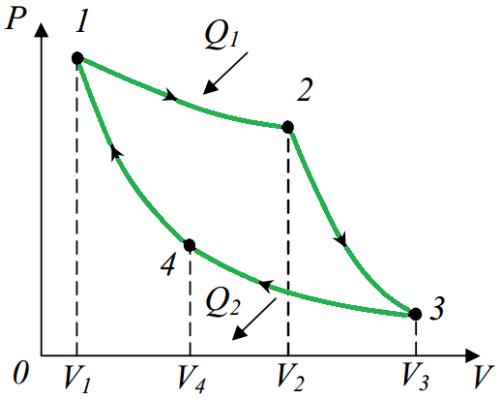
$i=6$

$\eta=?$

Yechilishi:

Ko‘p atomli ideal gaz uchun adiabata ko‘rsatkichi

$$\eta=\frac{c_P}{c_V}=\frac{i+2}{i}=\frac{6+2}{6}=\frac{4}{3}$$



Karno sikli rasmda tasvirlangan bo‘lib, masala shartida aytilgan adiabatik kengayish 2→3 o‘tishga mos keladi. Bun masalani yechish adiabatik jarayon uchun Puasson formulasidan foydalanamiz.

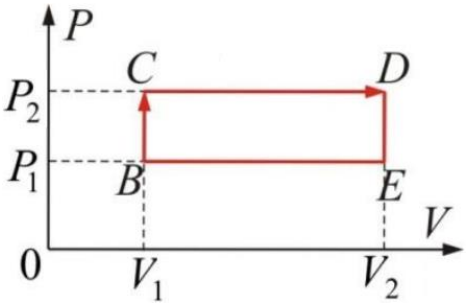
$$TV^{\gamma-1}=const,\ \rightarrow T_2V_2^{\gamma-1}=T_3V_3^{\gamma-1},\ \rightarrow \frac{T_2}{T_3}=\left(\frac{V_3}{V_2}\right)^{\gamma-1}=\frac{1}{k^{\gamma-1}}=\frac{1}{4^{4/3-1}}=4^{-1/3}=0,63$$

Endi sikl uchun FIKning qiymatini aniqlaymiz.

$$\eta=1-\frac{T_2}{T_3}=1-0,63=0,37=37\ \%$$

Javob: $\eta=37\ \%$

Masala № 4. Bir atomli ideal gaz rasmda ko‘rsatilgan siklni o‘tadi. Agar $V_1=1\ \ell$, $V_2=4\ \ell$, $P_1=100\ kPa$ va $P_2=200\ kPa$ bo‘lsa, u holda sikl uchun FIKning formulasini keltirib chiqaring va uning qiymati nimaga teng?



Berilgan:

$i=3$

$V_1=10^{-3}m^3$

$V_2=3\cdot10^{-3}m^3$

$P_1=10^5\,Pa$

$P_2=2\cdot10^5\,Pa$

$\eta=?$

Yechilishi:

Issiqlik mashinasining berk siklda FIK

$$\eta=\frac{\oint\delta A'}{Q_1}$$

bo‘ladi. Bu yerda: $\oint A'$ – berk siklda gazning bajaradigan ishi; Q_1 – gazning isirkichdan oladigan issiqlik miqdori.

Berk sikldagi ish rasmdagi to‘g‘ri to‘rtburchakning yuziga teng.

$$\oint\delta A'=(P_1-P_2)(V_2-V_1)=\left(2\cdot10^5-10^5\right)\left(4\cdot10^{-3}-10^{-3}\right)=400\,J$$

Endi gazning isitkichdan olgan issiqlik miqdorini hisoblaymiz. Bunda $B\to C$ o‘tish izoxorik jarayonda, $C\to D$ o‘tish esa izobarik jarayonda sodir bo‘layotganini e’tibordan qochirmaslik kerak.

$$Q_1 = Q_{B\to C} + Q_{C\to D} = \Delta U_{B\to C} + \Delta U_{C\to D} + A'_{C\to D} = \Delta U_{B\to D} + A'_{C\to D} =$$

$$= \frac{i}{2}\nu R\left(T_D - T_B\right) + P_2(\mathrm{V}_2 - \mathrm{V}_1) = \frac{i}{2}\left(P_2\,\mathrm{V}_2 - P_1\,\mathrm{V}_1\right) + P_2(\mathrm{V}_2 - \mathrm{V}_1) =$$

$$= \frac{3}{2}\left(2\cdot 10^5 \cdot 4\cdot 10^{-3} - 10^5\cdot 10^{-3}\right) + 2\cdot 10^5\left(4\cdot 10^{-3} - 10^{-3}\right) = 1050 + 600 = 1650\,J$$

Chiqarilgan formulalardan rasmda berilgan jarayon uchun FIKni aniqlash formulasini yozishimiz mumkin bo‘ladi.

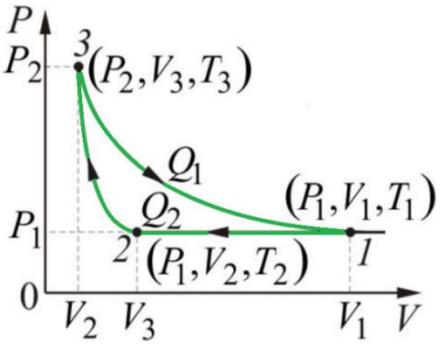
$$\eta = \frac{\oint \delta A'}{Q_1} = \frac{(P_1 - P_2)(V_2 - V_1)}{\frac{i}{2}\left(P_2\,\mathrm{V}_2 - P_1\,\mathrm{V}_1\right) + P_2(\mathrm{V}_2 - \mathrm{V}_1)}$$

Hisolash natijasida FIK ning quyidagi natijasini olamiz.

$$\eta = \frac{400}{1650} = 0,2424 = 24,24\ \%$$

Javob: $\eta = \dfrac{(P_1 - P_2)(V_2 - V_1)}{\frac{i}{2}\left(P_2\,\mathrm{V}_2 - P_1\,\mathrm{V}_1\right) + P_2(\mathrm{V}_2 - \mathrm{V}_1)}$; $\eta = 24,24\ \%$

Masala № 5.: Ideal gaz bilan ishlaydigan issiqlik mashinasi 1→2 izobara, 2→3 adiabata va 3→1 izotermalardan iborat berk sikl (qaytar jarayon) bo‘yicha ishlaydi. Bu siklda ishchi moddaning eng yuqori temperaturasi T_1 va eng past temperatrurasi T_2 larni bilgan holda FIK ni aniqlash formulasini keltirib chiqaring.



Berilgan:

T_1, T_2

$\eta = ?$

Yechilishi:

3→1 o‘tish izotermik jarayon bo‘lgani uchun $T_3=T_1$ bo‘ladi. Bu o‘tishda ishchi jism isitkichdan issiqlik olib kengayadi. Bu issiqlik

$$Q_1 = \frac{m}{M}RT_1 \ln\frac{V_1}{V_3}$$

bo’ladi.

1→2 o‘tish izobarik holda siqilish jarayoni bo‘lib, bunda ishchi jism sovitgichga Q_2 issiqlik uzatadi.

$$Q_2 = c_P m\Delta t = \frac{i+2}{2}\frac{R}{M}m\left(T_2 - T_1\right) = -\frac{i+2}{2}\frac{m}{M}R\left(T_1 - T_2\right)$$

1→2 o‘tishda hajm izobarik ravishda kamaygani uchun temperatura ham kamayadi, ya’ni

$$\frac{V_1}{V_2}=\frac{T_1}{T_2},\ \rightarrow\ V_2=\frac{T_2}{T_1}V_1\quad (*)$$

bo’ladi. 2→3 o‘tish adiabatik jarayon bo‘lgani uchun Q=0 bo’ladi. Bunda hajm va temperatura

$$TV^{\gamma-1}=const,\ \rightarrow\ T_2V_2^{\gamma-1}=T_3V_3^{\gamma-1},\ \rightarrow\ \frac{T_2}{T_3}=\left(\frac{V_3}{V_2}\right)^{\gamma-1},\ \rightarrow\ \frac{T_2}{T_1}=\left(\frac{V_3}{V_2}\right)^{\gamma-1}$$

bo’ladi. Bunga (*) ifodani qo‘yib

$$\frac{T_2}{T_1}=\left(\frac{V_3}{V_2}\right)^{\gamma-1}=\left(\frac{V_3}{\frac{T_2}{T_1}V_1}\right)^{\gamma-1}=\left(\frac{V_3}{V_1}\cdot\frac{T_1}{T_2}\right)^{\gamma-1},\ \rightarrow\ \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}=\frac{V_3}{V_1}\cdot\frac{T_1}{T_2},\ \rightarrow$$

$$\rightarrow\ \frac{V_1}{V_3}=\left(\frac{T_1}{T_2}\right)^{1+\frac{1}{\gamma-1}}=\left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{\gamma-1}}$$

natijani olamiz. Endi sikl uchun FIKni

$$\eta=\frac{|Q_1|-|Q_2|}{|Q_1|}=1-\frac{|Q_2|}{|Q_1|}$$

formuladan hisoblaymiz.

$$\eta=1-\frac{\left|-\frac{i+2}{2}\frac{m}{M}R(T_1-T_2)\right|}{\left|\frac{m}{M}RT_1\ln\frac{V_1}{V_3}\right|}=1-\frac{\frac{i+2}{2}\frac{m}{M}R(T_1-T_2)}{\frac{m}{M}RT_1\ln\frac{V_1}{V_3}}=1-\frac{\frac{i+2}{2}(T_1-T_2)}{T_1\ln\left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{\gamma-1}}}=$$

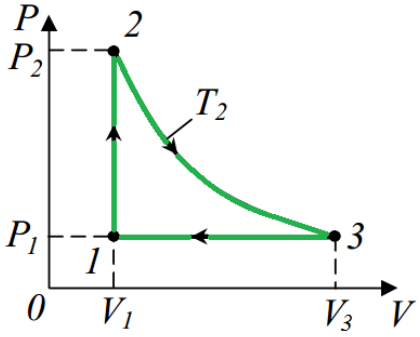
$$=1-\frac{\frac{i+2}{2}(T_1-T_2)}{\frac{\gamma}{\gamma-1}T_1\ln\frac{T_1}{T_2}}=1-\frac{\frac{i+2}{2}(T_1-T_2)}{\frac{(i+2)/i}{(i+2)/i-1}T_1\ln\frac{T_1}{T_2}}=1-\frac{\frac{i+2}{2}(T_1-T_2)}{\frac{i+2}{2}T_1\ln\frac{T_1}{T_2}}=1-\frac{T_1-T_2}{T_1\ln\frac{T_1}{T_2}}$$

Javob: $\eta=1-\dfrac{T_1-T_2}{T_1\ln\frac{T_1}{T_2}}$

Masala № 6. *P_1=1 MPa* bosim ostida turgan, *V_1=5 ℓ* hajm egallagan *ν=3 mol* miqdordagi ikki atomli ideal gazni *T_2=500 K* gacha izoxorik ravishda isitishga qo‘yiladi. Undan keyin bu gazni dastlabki bosimgacha izotermik ravishda kengaytiriladi, va nihoyat gazni daslabki izobarik ravishda siqish orqali

boshlang‘ich holatga keltiriladi. Siklning *P=P(V)* grafigini quring va sikl uchun FIKni aniqlang.

Berilgan:	*Yechilishi:*
$P_1=1\ MPa$	1-nuqtadagi temperaturani aniq-
$i=5,\ V_1=5\ \ell$	laymiz.
$\nu=3\ mol$	$$T_1=\frac{P_1V_1}{\nu R}=\frac{10^6\cdot5\cdot10^{-3}}{3\cdot8,31}=200\ K$$
$T_2=500\ K$	
$\eta=?$	2-nuqtadagi bosimni aniqlaymiz.



$$\frac{P_1}{T_1}=\frac{P_2}{T_2},\ \rightarrow\ P_2=\frac{T_2}{T_1}P_1=\frac{500}{200}\cdot10^6=2,5\cdot10^6=2,5MPa$$

3-nuqtadagi hajmni aniqlaymiz.

$$P_2V_2=P_3V_3,\ \rightarrow\ V_3=\frac{P_2}{P_3}V_2=\frac{P_2}{P_3}V_2=\frac{2,5\cdot10^6}{10^6}\cdot5\cdot10^{-3}=12,5\cdot10^{-3}=12,5\ \ell$$

Ideal gaz isitkichdan olgan issiqlik miqdorini hisoblaymiz.

$$Q_1=Q_{1\to2}+Q_{2\to3}=\Delta U_{1\to2}+A_{2\to3}=\frac{i}{2}\nu R\left(T_2-T_1\right)+\nu RT_2\ln\frac{V_3}{V_2}=$$

$$=\frac{5}{2}\cdot3\cdot8,31\cdot\left(500-200\right)+3\cdot8,31\cdot500\cdot\ln\frac{12,5\cdot10^{-3}}{5\cdot10^{-3}}=$$

$$=18698+11422=30120\ J=30,12\ kJ$$

Ideal gaz sovitkichga uzatgan issiqlik miqdorini hisoblaymiz.

$$Q_2=Q_{3\to1}=\Delta U_{3\to1}+A_{3\to1}=\frac{i}{2}\nu R\left(T_1-T_3\right)+P_1\left(V_1-V_3\right)=$$

$$=\frac{5}{2}\cdot3\cdot8,31\cdot\left(200-500\right)+10^6\left(5\cdot10^{-3}-12,5\cdot10^{-3}\right)=$$

$$=-18698+7500=-11198\ J=-11,198\ kJ$$

Endi sikl uchun FIK ning qiymatini aniqlaymiz.

$$\eta=1-\frac{\left|Q_2\right|}{Q_1}=1-\frac{11\,198}{30\,120}=1-0,3717=0,6282=62,82\ \%$$

Javob: $\eta=62,82\ \%$

Masala № 7. FIK $\eta_k=40\ \%$ bo‘lgan issiqlik mashinasidan sovitish mashinasi sifatida rasmdagi kabi foydalanish boshlandi. Agar har bir siklda tashqi kuchlar $A=200\ J$ ish bajarsa, sovitish koeffitsiyenti η_s ni (sovitish mashinasining

unumdorligini) hamda bir siklda bu mashina sovitkichdan (sovitilayotgan jismdan) olish mumkin bo‘lgan issiqlik miqdorini aniqlang.

Berilgan:

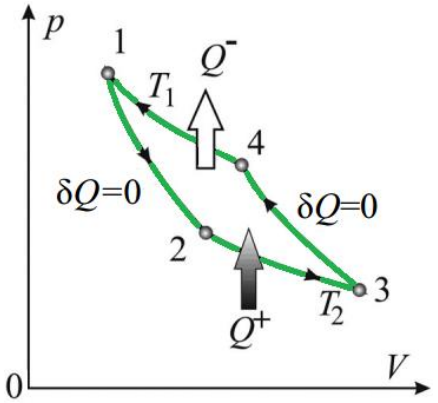
$\eta_K = 40\%$

$\oint \delta A = 200\,\text{J}$

$\eta_s = ?$

$Q^+_{SM} = ?$

Yechilishi:



Sovitkichdan issiqlik olish uchun sikl rasmdagi kabi soat miliga teskari yo‘nalishda bo‘lish kerak. Issiqlik mashinasi issiqlikdan olgan ish hisobiga ish bajarsa, sovitish mashinasida esa tashqi kuchlarning bajargan ishi hisobiga issiqlik sovitkichdan isitkichga (odatda atrof muhitga) uzatiladi va shu orqali sovitkichning temperaturasi pasaytiriladi. Shuning uchun sovitkichdan ishchi jism oladigan Q^+_{SM} issiqlik miqdori maqsadimiz (foydali ish) hisoblanadi. Sovitish mashinasining ish unumdorligi (sovitish koeffitsiyenti) quyidagi formuladan aniqlanadi:

$$\eta_S = \frac{Q^+_{SM}}{\left|\oint \delta A\right|}$$

Bu teskari siklda tashqi kuchlar ish bajarayotgan bo‘lgani uchun $\oint \delta A < 0$ bo‘ladi. Ish unumdorligi esa musbat bo‘lishi kerak. Shuning uchun yuqoridagi formulada kasr maxraji $\left|\oint \delta A\right|$ deb olindi. Yuqoridagi formulani yana ushb ko‘rinishda ham yozish mumkin.

$$\eta_S = \frac{Q^+_{SM}}{\left|\oint \delta A\right|} = \frac{Q^+_{SM}}{\left|Q^+_{SM} + Q^-_{SM}\right|} = \frac{1}{\left|1 + \dfrac{Q^-_{SM}}{Q^+_{SM}}\right|}$$

Bu yerda: Q^-_{SM} – ishchi jism isitkichga (atrof muhitga) uzatgan issiqlik miqdori. Yuqoridagi formulada issiqlik miqdorlari uchun $Q^+_{SM} > 0, Q^-_{SM} < 0$ ishorali bo‘lishini e’tiborga olsa, uni modul orqali quyidagicha yozish mumkin:

$$\eta_S = \frac{1}{\left|1 - \dfrac{\left|Q^-_{SM}\right|}{Q^+_{SM}}\right|}$$

Karno sikli qaytar jarayon bo‘lgani uchun to‘g‘ri va teskari sikllarda sikl yuzasi, ya’ni $\left|\oint \delta A\right|$ bir xil. Boshqacha aytganda, teskari siklda sovitkichdan qancha issiqlik miqdori olinsa, to‘g‘ri siklda issiqlik mashinasi shuncha issiqlik beradi.

Shuning uchun sovitish mashinasining unumdorligi η_S ni issiqlik mashinasining FIK η_K bilan bog‘lash mumkin. Bunda $Q^+_{SM} \to Q^-_{IM}$, $Q^-_{SM} \to Q^+_{IM}$ almashtirishlarni inobatga olamiz.

$$\eta_S = \frac{1}{\left|1-\frac{|Q^-_{SM}|}{Q^+_{SM}}\right|} = \frac{1}{\left|1-\frac{Q^+_{IM}}{|Q^-_{IM}|}\right|} = \frac{1}{\left|1-\frac{1}{1-\eta_K}\right|} = \frac{1}{\left|1+\frac{1}{\eta_K-1}\right|} = \left|\frac{\eta_K-1}{\eta_K}\right| = \left|1-\frac{1}{\eta_K}\right| = \frac{1}{\eta_K}-1$$

Demak, sovitish mashinasining sovitish koeffitsiyenti (unumdorligi) quyidagicha bo‘lar ekan:

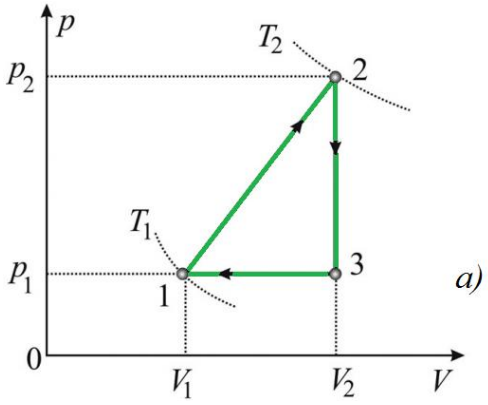
$$\eta_S = \frac{1}{\left|1-\frac{|Q^-_{SM}|}{Q^+_{SM}}\right|} = \frac{1}{\eta_K}-1 = \frac{1}{0,4}-1 = 2,5-1 = 1,5$$

Endi sovitkichdan ishchi jism bir siklda oladigan Q^+_{SM} issiqlik miqdorini aniqlaymiz.

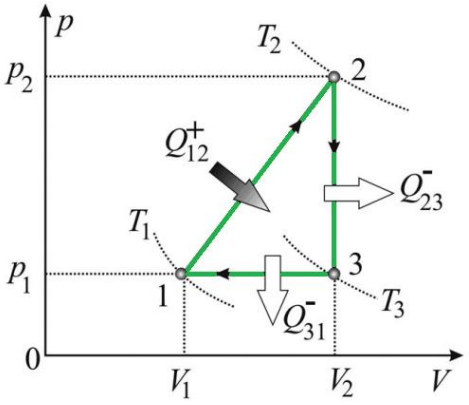
$$\eta_S = \frac{Q^+_{SM}}{\left|\oint \delta A\right|}, \ \to \ Q^+_{SM} = \eta_S \cdot \left|\oint \delta A\right| = 1,5 \cdot 200 = 300\,J$$

Javob: $\eta_S = 1,5,\ Q^+_{SM} = 300\,J$

Masala № 8. Sikli a-rasmda tasvirlangan issiqlik mashinasining FIK ni aniqlang. Issiqlik mashinasining ishchi jismi – erkinlik darajasi $i=5$ bo‘lgan ideal gazdir. Temperaturalar nisbati $T_2/T_1=\alpha=2,5$ ga, hajmlar nisbati esa $V_2/V_1=\beta=2$ ga teng.



a)



b)

Berilgan:

$V_2/V_1=\beta=2$, $i=5$

$T_2/T_1=\alpha=2,5$

$\eta = ?$

Yechilishi:

Siklning FIK ishchi jismning massasiga yoki modda miqdoriga bog‘liq emas.

Rasmdagi P–V sikl uchburchak shaklda bo‘lgani sikl davomidagi bajarilgan ishni hisoblashga imkon beradi.

Shuning uchun FIK ni aniqlashning eng qulay usuli ushbu

$$\eta = \frac{\oint \delta A}{Q^+}$$

formuladanishdir. Sikl davomidagi bajarilgan ish uchburchaning yuzasiga teng.

$$\oint \delta A = \frac{1}{2}(P_2 - P_1)(V_2 - V_1) = \frac{1}{2}\nu R\left(\frac{T_2}{V_2} - \frac{T_1}{V_1}\right)(V_2 - V_1) =$$

$$= \frac{1}{2}\nu R\left(\frac{\alpha T_1}{\beta V_1} - \frac{T_1}{V_1}\right)(\beta V_1 - V_1) = \frac{\nu R T_1}{2}\left(\frac{\alpha}{\beta} - 1\right)(\beta - 1)$$

Uchala nuqtadan izotermalar o‘tkazish orqali qaysi nuqtada temperatura katta yoki kichikligini osongina aniqlash mumkin. 1–2 o‘tishda gaz isiydi, qolgan 2–3 va 3–1 o‘tishlarda gaz soviydi. Shuningdek, 1–2 o‘tishda gazga issiqlik uzatiladi, qolgan 2–3 va 3–1 o‘tishlarda gazdan tashqariga issiqlik uzatiladi. Isitkichdan ishchi jism olgan issiqlikni aniqlash uchun 1–2 o‘tishdagi issiqlikni aniqlash kerak.

$$Q^+ = Q_{12} = \Delta U_{12} + A_{12} = \frac{i}{2}\nu R(T_2 - T_1) + \frac{1}{2}(P_2 + P_1)(V_2 - V_1) = \frac{i}{2}\nu R(\alpha T_1 - T_1) +$$

$$+ \frac{1}{2}\nu R\left(\frac{T_2}{V_2} + \frac{T_1}{V_1}\right)(V_2 - V_1) = \frac{i}{2}\nu R T_1(\alpha - 1) + \frac{1}{2}\nu R\left(\frac{\alpha T_1}{\beta V_1} + \frac{T_1}{V_1}\right)(\beta V_1 - V_1) =$$

$$= \frac{i}{2}\nu R T_1(\alpha - 1) + \frac{1}{2}\nu R T_1\left(\frac{\alpha}{\beta} + 1\right)(\beta - 1)$$

Endi sikl uchun FIK ni aniqlaydigan formulanim keltirib chiqaramiz.

$$\eta = \frac{\oint \delta A}{Q^+} = \frac{\frac{\nu R T_1}{2}\left(\frac{\alpha}{\beta} - 1\right)(\beta - 1)}{\frac{i}{2}\nu R T_1(\alpha - 1) + \frac{1}{2}\nu R T_1\left(\frac{\alpha}{\beta} + 1\right)(\beta - 1)} = \frac{\left(\frac{\alpha}{\beta} - 1\right)(\beta - 1)}{i(\alpha - 1) + \left(\frac{\alpha}{\beta} + 1\right)(\beta - 1)} =$$

$$= \frac{(\alpha - \beta)\left(1 - \frac{1}{\beta}\right)}{i(\alpha - 1) + (\alpha + \beta)\left(1 - \frac{1}{\beta}\right)}$$

Endi esa hisoblashi ishlarini bajaramiz.

$$\eta = \frac{(\alpha - \beta)\left(1 - \frac{1}{\beta}\right)}{i(\alpha - 1) + (\alpha + \beta)\left(1 - \frac{1}{\beta}\right)} = \frac{(2{,}5 - 2)\cdot\left(1 - \frac{1}{0{,}5}\right)}{5\cdot(2{,}5 - 2) + (2{,}5 + 2)\cdot\left(1 - \frac{1}{0{,}5}\right)} = \frac{0{,}25}{2{,}5 + 2{,}25} = \frac{1}{19} = 5{,}26\%$$

Javob: $\eta = 40\%$

11-amaliy mashg‘ulot topshirig‘i

11.1. Bug‘ turbinasiga bug‘ *500°C* harorat bilan kirib, undan *30°C* harorat bilan chiqib ketadi. Bug‘ turbinasini ideal issiqlik mashinasi deb hisoblab, uning *FIK* ni toping (%). **Javob:** *61%*

11.2. FIK ning maksimal qivmati *50%* bo‘lishi uchun isitkichining harorati *527°C* bo‘lgan issiqlik mashinasi sovitkichining harorati qanday (*°C*) bo‘lishi kerak? **Javob:** *127°C*

11.3. Isitkichining temperaturasi *127°C*, sovitkichining temperaturasi *7°C* bo‘lgan ideal issiqlik mashinasi bir siklda isitkichdan *1200 J* issiqlik olsa, necha joul foydali ish bajaradi? **Javob:** *360 J*

11.4. Issiqlik mashina isitkichining temperaturasi *500 K*, sovitkichiniki *250 K* bo‘lsa va u bir siklda isitkichdan *3000 J* issiqlik olsa, bir siklda bajarilgan ish necha joul bo‘laai? **Javob:** *A =1500 J*

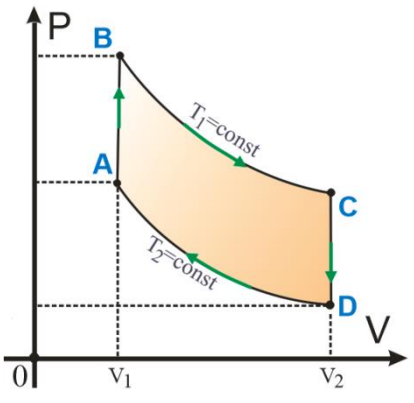
11.5. Karno sikli bo‘yicha ishlaydigan issiqlik mashinasining FIK *40 %* ga teng. Bu siklning izotermik kengayishida ishchi jism A_1*=300 J* ish bajaradi. Izotermik siqilishda tashqi kuchlar qanday A_2 ish bajaradi? **Javob:** *A2=180 J*

11.6. ** Karno sikli bo‘yicha ishlaydigan issiqlik mashinasining ishchi jismi havo bo‘lib, u dastlab normal sharoitda (P_1*=100 kPa,* T_1*=273 K*) turibdi. Bu ishchi jism dastlab V_1*=1 ℓ* hajmga ega bo‘lib, izotermik va adiabatik ravishda kengayishlardan so‘ng V_2*=3 ℓ* va V_3*=5 ℓ* hajmlarni egallashadi. Karno siklining har bir qismidagi hamda umumiy berk sikldagi ishchi jism bajargan ishlarni aniqlang. Siklning FIK nimaga teng?

Javob: $A_1 = 110\ J;\ A_2 = 46,2\ J;\ A_3 = -89,54;\ A_4 = -46,2\ J;\ A_{um} = \sum_{i=1}^{4} A_i = 20,32\ J;$

$$\eta = 1 - \frac{T_2}{T_1} = 0,185$$

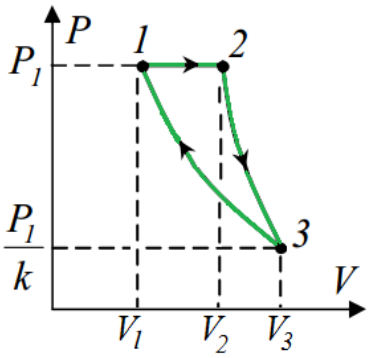
11.7. * Issiqlik mashinasi rasmdagi kabi ikkita izoxora va ikkita izotermadan iborat sikl bo‘yicha ishlaydi (Stiling sikli). Bunda ideal gaz molekulasining erkinlik darajasi *i* ga, siqish darajasi esa $V_2/V_1=k$ ga, sikldagi maksimal temperatura T_1 ga va minimal temperatura T_2 ga teng. Shu sikl uchun FIK ni aniqlaydiga formulani keltirib chiqaring.



Javob: $\eta = \dfrac{(T_1 - T_2)\ln k}{\frac{i}{2}(T_1 - T_2) + T_1 \ln k}$

11.8. Issiqlik mashinasi ikkita izoxora va ikkita izotermadan iborat sikl bo‘yicha ishlaydi (Stiling sikli). Bunda ikki atomli ideal gazning minimal temperatura $T_2=300\ K$. Agar siqish darajasi $V_2/V_1=10$ hamda siklning FIK $\eta=0{,}3$ bo‘lsa, u holda maksimal temperatura T_1 nimaga teng? Dastlab siklni $P=P(V)$ grafikda tasvirlang va keyin hisoblash ishlarini olib boring. **Javob:** $T_1=540\ K$

11.9. *Issiqlik mashinasining ish sikli izobarik, adiabatik va izotermik jarayonlardan iborat (rasmga qarang). Ishchi jismni bir atomli ideal gaz deb oling. Bunda eng kichik temperatura izotermik jarayonga mos keladi. Bir atomli gazni siqish darajasi $P_1/P_3=2$. Grafikda 2 va 1 nuqtalardagi temperaturalar necha marta farq qiladi? Sikl uchun FIK ni aniqlash formulasini keltirib chiqaring va uning son qiymatini aniqlang. **Javob:** $\frac{T_2}{T_1}=\left(\frac{P_1}{P_3}\right)^{\frac{2}{i+2}}=2^{\frac{2}{5}}=1{,}32$



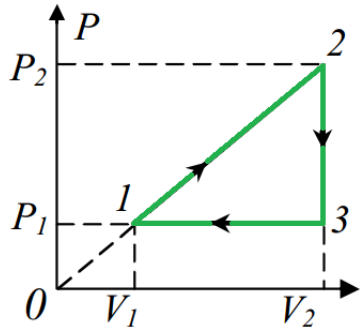
$$\eta=1-\frac{T_1\ln\frac{P_1}{P_3}}{\frac{i+2}{2}(T_2-T_1)}=0{,}134$$

11.10. Oldingi masala shartida $P_1/P_3=4$ deb hamda issiqlik mashinasining ishchi jismini ko‘p atomli ideal gaz deb olib ishlang. **Javob:** $\frac{T_2}{T_1}=\sqrt{2};\ \eta=0{,}155$

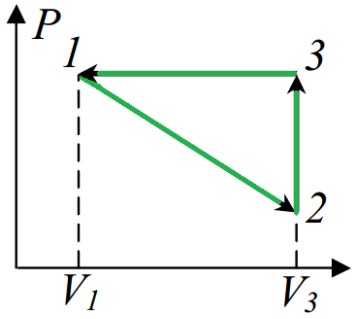
11.11. Ko‘p atomli ideal gaz Karno sikli bo‘yicha ishlaydi. Bu siklning adiabatik kengayishi paytida gaz hajmi 4 marta oshadi. Karno siklining FIK nimaga teng? **Javob:** *37%*

11.12. Quvvati *14,7 kW* bo‘lgan bug‘ mashinasi *1 soatl*ik ishi davomida solishtirma yonish issiqligi *33 MJ/kg* bo‘lgan toshko‘mirdan *8,1 kg* sarflaydi. Isistkichnning temperaturasi 200^0C, sovutkichniki esa 58^0C. Mazkur bug‘ mashinasining FIK ini aniqlang hamda uni Karno sikli bilan solishtiring. **Javob:** $\eta\approx19{,}8\%;\ \eta_K\approx30\%$

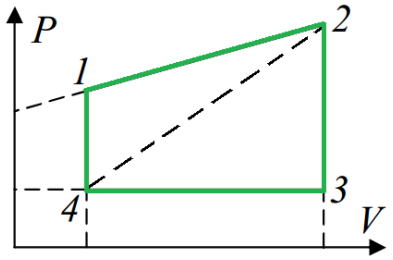
11.13. *Issiqlik mashinasi rasmdagi kabi izobara, izoxora hamda posim hajmga $P=\alpha V$ qonun bo‘yicha bog‘langan politropalardan iborat sikl bo‘yicha ishlaydi. Bu yerda: α – doimiy kattalik. Agar bu issiqlik mashinasida ishchi jism sifatida o‘zgarmas bosimdagi molyar issiqlik sig‘imi $c_V^*=\frac{3}{2}R$ ga teng bo‘lgan ideal gazdan foydalanilsa, issiqlik mashinasining FIK ini toping. J: $\eta=\frac{1-\sqrt{T_1/T_2}}{4\cdot\left(1+\sqrt{T_1/T_2}\right)}=\frac{1}{12}$



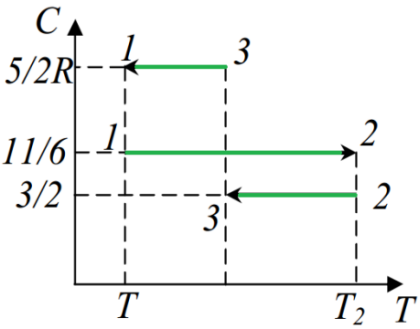
11.14. Bir mol bir atomli ideal gaz rasmdagi kabi bosim hajmga chiziqli bog‘liq bo‘lgan (1→2), izoxora (2→3) va izobara (3→1) chizqlaridan iborat berk sikl yasaydi. Siklning temperatura oshadigan qismida gazga uzatilgan issiqlik miqdorini hamda butun sikldagi bajarilgan ishni aniqlang. 1 va 2 holatlarda gazning temperaturalari teng, ya’ni $T_1=T_2=300\ K$, izobarik jarayonda hajmlar nisbati $V_3/V_1=5/2$. Jarayon yo‘nalishi strelkalar bilan ko‘rsatilgan. J: $Q_{23}=5609\ J;\ A=-1122\ J$



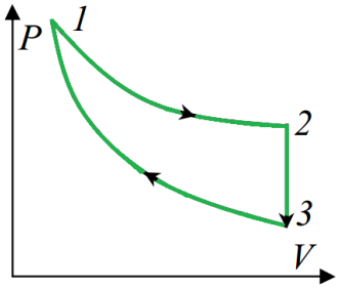
11.15. **Rasmdagi berk sikning 1–2–4–1 qismining FIK η_1 ga, 2–3–4-2 qismining FIK η_2 ga teng. 1–2–3–4–1 siklning FIK ni aniqlang. Siklning 4–1 va 2–3 qismlari izoxora, 3–4 qismi izobara, 1–2 va 2–4 qismlari bosimning hajmga chiziqli bog‘lanishini o‘z ichiga oladi. Barcha sikllar soat mili bo‘yicha sodir bo‘ladi. Ishchi jismni ideal gaz deb oling. J: $\eta=\eta_1+\eta_2-\eta_1\cdot\eta_2$



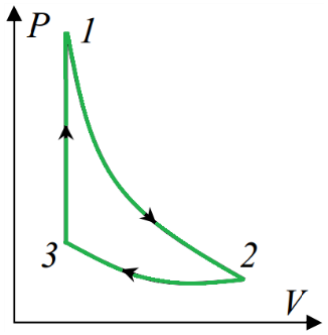
11.16. **Ideal issiqlik mashinasining ketma-ket uchta 1-2, 2-3, 3-1 jarayonlardan tashkil topgan siklidagi bir atomli ideal gaz molyar issiqlik sig‘imi c^* ning temperaturaga bog‘lanish grafigi rasmda tasvirlangan. Agar mashinaning FIK $\eta=1/11$, sikldagi gaz miqdori o‘zgarmas hamda temperaturalar nisbati $T_2/T_1=n=2$ bo‘lsa, u holda bu gazning maksimal T_2 va minimal T_1 temperaturalardagi bosimlari nisbatini aniqlang. J: $\frac{P_2}{P_1}=\frac{6n}{2(2+n)-11\eta(n-1)}$



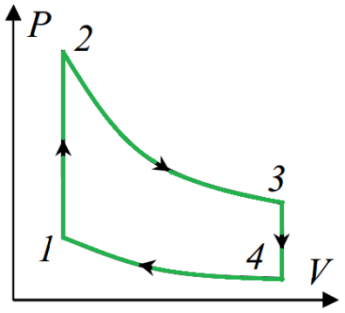
11.17. *Rasmda tasvirlangani kabi 1–2 izoterma, 2–3 izoxora va 3–1 adiabatalardan tashkil topgan sikl bo‘yicha ishlaydigan issiqlik mashinasining FIK η ga teng. Gazning sikldagi maksimal va minimal temperaturalari orasidagi farqi ΔT ga teng. ν miqdordagi bir atomli gazning izotermik jarayondagi bajargan ishini aniqlang. J: $A=\frac{3\nu R\Delta T}{2(1-\eta)}$



11.18. *Rasmda tasvirlangani kabi 1–2 adiabatik kengayish, 2–3 izotermik siqilish va 3–1 izoxorik qizish jarayonlardan tashkil topgan sikldan tashkil topgan hamda ν miqdordagi bir atomli gaz bilan ishlaydigan issiqlik mashinasining FIK nimaga teng? Izotermik jarayonda gaz ustida bajarilgan ish *A* ga teng. Gazning maksimal va minimal temperaturalari farqi ΔT ga teng. J: $A = 1\dfrac{2A}{3\nu R\Delta T}$

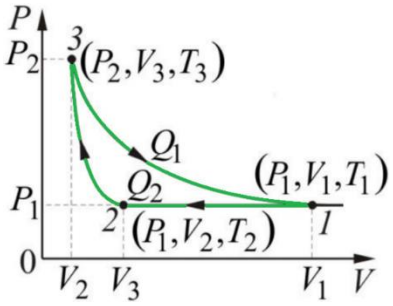


11.19. ** *5 mol* miqdordagi bir atomli ideal gaz rasmdagi kabi ikkita izoxora va ikkita adiabatadan iborat aylanma siklni amalga oshiradi. Berilgan sikl bo‘yicha ishlaydigan issiqlik mashinasining η FIK ini toping. Bu siklga mos keladigan maksimal FIK η_{max} ni aniqlang. Gaz 2 holatda isitkich bilan 4 holatda esa sovutkich bilan muvozonatda turibdi. Bunda $P_1=200\ kPa$, $P_2=1200\ kPa$, $P_3=300\ kPa$, $P_4=100\ kPa$, $V_1=V_2=2m^3$, $V_3=V_4=6\ m^3$. J: $\eta=40\ \%$; $\eta_{max}=75\%$

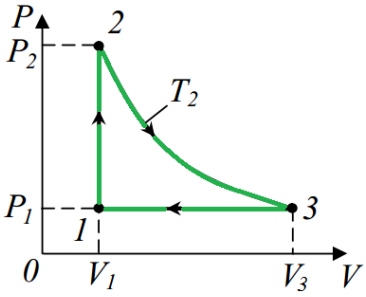


11.20. Ideal gaz bilan ishlaydigan issiqlik mashinasi 1→2 izobara, 2→3 adiabata va 3→1 izotermalardan iborat berk sikl (qaytar jarayon) bo‘yicha ishlaydi. Bu siklda ishchi moddaning eng yuqori temperaturasi T_1 va eng past temperatrurasi T_2 larni bilgan holda FIK ni aniqlash formulasini keltirib chiqaring. **Javob:**

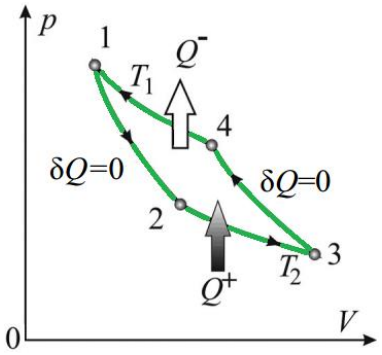
$$\eta = 1 - \frac{T_1 - T_2}{T_1 \ln\left(T_1 / T_2\right)}$$



11.21. $P_1=1\ MPa$ bosim ostida turgan, $V_1=5\ \ell$ hajm egallagan $\nu=3\ mol$ miqdordagi ikki atomli ideal gazni $T_2=500\ K$ gacha izoxorik ravishda isitishga qo‘yiladi. Undan keyin bu gazni dastlabki bosimgacha izotermik ravishda kengaytiriladi, va nihoyat gazni daslabki izobarik ravishda siqish orqali boshlang‘ich holatga keltiriladi. Siklning $P=P(V)$ grafigini quring va sikl uchun FIKni aniqlang. **Javob:** $\eta = 62{,}82\ \%$



11.22. FIK $\eta_k=40\ \%$ bo‘lgan issiqlik mashinasidan sovitish mashinasi sifatida rasmdagi kabi foydalanish boshlandi. Agar har bir siklda tashqi kuchlar $A=200\ J$ ish bajarsa, sovitish koeffitsiyenti η_s ni (sovitish mashinasining unumdorligini) hamda bir siklda bu mashina sovitkichdan (sovitilayotgan jismdan) olish mumkin bo‘lgan issiqlik miqdorini aniqlang. **Javob:** $\eta_S=1{,}5,\ Q^+_{SM}=300\,J$



11.23. Ikkita izotermik va ikkita izobarik jarayonlardan iborat *Erikson* sikli bo‘yicha ishlovchi dvigatelning FIK ni aniqlang. Adiabata ko‘rsatkichi γ bo‘lgan ideal gaz ishchi jism vazifasini bajaradi. Sikldagi maksimal temperatura va bosim – T_1 va P_1 ga, minimal temperatura va bosim – T_2 va P_2 ga teng.

J: $$\eta=\frac{T_1-T_2}{T_1+\frac{\gamma}{\gamma-1}\frac{T_1-T_2}{\ln(P_1/P_2)}}$$

11.24. *Sovitish qurilmasining sovuqlik unumdorligi $\frac{dQ^+_{SM}}{dt}=1000\,\frac{MJ}{soat}$ ga teng. Sovitiliyotgan joyning temperaturasi $+20^0C$ ga, atrof muhit temperaturasi esa -20^0C ga teng. Sovitish qurimasining sovitish koeffitsiyenti η_S nimaga teng? Sovitish qurilmasining quvvatini toping.

J: $$\eta_S=\frac{Q^+_{SM}}{\left|\oint\delta A\right|}=\frac{1}{\eta_K}-1=\frac{T_2}{T_2-T_1}-1=5{,}3;$$

$$N=\frac{d\left|\oint\delta A\right|}{dt}=\frac{1}{\eta_S}\frac{dQ^+_{SM}}{dt}=188{,}7\,\frac{MJ}{soat}=52{,}41\ kW$$

11.25. **Sovitish qurilmasi $t_1=+10^0C$ va $t_2=-5^0C$ oraliqda ishlaydi. Dvigatel quvvati $N=10\ kW$. Agar t_1 temperatura $\Delta t=2^0C$ ga oshirilsa va t_2 temperatura shunchaga kamaytirilsa, u holda sovitish qurilmasining sovitish koeffitsiyenti hamda dvihatel quvvati qanchaga o‘zgaradi?

J: $$\Delta\eta_S=\eta_S^{''}-\eta_S^{'}=\frac{-\Delta T(T_1+T_2)}{(T_1-T_2)^2+2\Delta T(T_1-T_2)}=-3{,}9;$$

$$\Delta N=N^{''}-N^{'}=N^{'}\left(\frac{\eta_S^{'}}{\eta_S^{''}}-1\right)=\frac{N^{'}\Delta T(T_1+T_2)}{(T_1-T_2)(T_2-\Delta T)}=+2{,}8\ kW$$

12-MAVZU: Entropiya tushunchasi. Izojarayonlarda hamda modda agregat holati o'zgarganida entropiya o'zgarishini aniqlash. Entropiyaning o'sishi

Mavzuga oid muhim formulalar

$S=\int\frac{\delta Q}{T},\qquad S=\sum_{i=1}^{n}S_i$	*Entropiya va uning aditivligi*

Ideal gazning entropiyasi o'zgarishini aniqlashning umumiy formulalari

$$\Delta S=S_2-S_1=\int_1^2\frac{\delta Q}{T}=\int_1^2\frac{dU+\delta A'}{T}$$

$$\Delta S=S_2-S_1=\frac{m}{M}c_V^*\int_{T_1}^{T_2}\frac{dT}{T}+\frac{m}{M}R\int_{V_1}^{V_2}\frac{dV}{V}\quad yoki\quad \Delta S=\frac{m}{M}c_V^*\ln\frac{T_2}{T_1}+\frac{m}{M}R\ln\frac{V_2}{V_1}$$

Izoxorik jarayonda entropiya o'zgarishini aniqlash formulalari

$$\Delta S_V=\frac{m}{M}c_V^*\ln\frac{T_2}{T_1}=\frac{m}{M}c_V^*\ln\frac{P_2}{P_1},\qquad \Delta S_V=mc_V\ln\frac{T_2}{T_1}=mc_V\ln\frac{P_2}{P_1}$$

Izotermik jarayonda entropiya o'zgarishini aniqlash formulalari

$$\Delta S_T=\frac{m}{M}R\ln\frac{V_2}{V_1}=\frac{m}{M}R\ln\frac{P_1}{P_2}$$

Izoxorik jarayonda entropiya o'zgarishini aniqlash formulalari

$$\Delta S_P=c_P^*\frac{m}{M}\ln\frac{T_2}{T_1}=c_P^*\frac{m}{M}\ln\frac{V_2}{V_1},\qquad \Delta S_V=mc_P\ln\frac{T_2}{T_1}=mc_P\ln\frac{V_2}{V_1}$$

Politropik jarayonda makroparametrlar orasidagi bog'lanish

$$\frac{P_2}{P_1}=\left(\frac{V_1}{V_2}\right)^n,\qquad \frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{n-1},\qquad \frac{P_2}{P_1}=\left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}$$

Adiabatik jarayonda entropiya o'zgarishi

$$\Delta S_\gamma=0$$

Politropik jarayonda entropiya o'zgarishi

$$\begin{cases}\Delta S_n=c_V^*\dfrac{n-\gamma}{n-1}\dfrac{m}{M}\ln\dfrac{T_2}{T_1}=c_V^*(n-\gamma)\dfrac{m}{M}\ln\dfrac{V_1}{V_2}=c_V^*\dfrac{n-\gamma}{n}\dfrac{m}{M}\ln\dfrac{P_2}{P_1}\\ \Delta S_n=c_V\dfrac{n-\gamma}{n-1}m\ln\dfrac{T_2}{T_1}=c_V(n-\gamma)m\ln\dfrac{V_1}{V_2}=c_V\dfrac{n-\gamma}{n}m\ln\dfrac{P_2}{P_1}\end{cases},\qquad \begin{cases}c^*=c_V^*\dfrac{n-\gamma}{n-1}\\ c=c_V\dfrac{n-\gamma}{n-1}\end{cases}$$

$\Delta S=\pm\frac{\lambda m}{T_{er}}$	*Erish temperaturasidagi kristall jism eriganda yoki qotganda entropiya o'zgarishi*
$\Delta S=\pm\frac{r m}{T_{qay}}$	*Qaynash temperaturasidagi suyuqlik bugga aylanganda yoki bug' kondensatsiyalanganda entropiya o'zgarishi*

$\Delta S = cm\ln\frac{T_2}{T_1}$	*Qattiq yoki suyuq modda temperaturasi o'zgarganda entropiya o'zgarishi*
$S = k_B \ln W,\quad \Delta S = S_2 - S_1 = k_B \ln\frac{W_2}{W_1}$	*Entropiya va statistik vazn orasidagi bog'lanish*
$\Delta S = S_2 - S_1 = \oint \frac{\delta Q}{T} \geq 0$	*Entropiyaning o'sish qonuni*

12-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. Ikki molmiqdordagi uch atomli ideal gazni qizdirish natijasida uning temperaturasi *m=3* marta oshdi. Agar qizdirish: a) izoxorik; b) izobarik jarayon bo'yicha sodir bo'layotgan bo'lsa, u holda entropiya o'zgarishlari nimaga teng bo'ladi?

Berilgan:

$\nu = 3\ mol$

$i = 6,\ m = 3$

$a) V = const$

$b) P = const$

$\Delta S = ?$

Yechilishi:

Ideal gazlar uchun entropiya o'zgarishini aniqlash uchun umumiy bo'lgan ushbu formuladan foydalanamiz:

$$\Delta S = \frac{m}{M} c_V^* \ln\frac{T_2}{T_1} + \frac{m}{M} R \ln\frac{V_2}{V_1} \quad (*)$$

a) Izoxorik jarayonda V=const bo'lgani uchun yuqoridagi formulaning 1-hadi qolib, 2-hadi nolga aylanadi.

$$\Delta S = \frac{m}{M} c_V^* \ln\frac{T_2}{T_1} = \nu \cdot \frac{i}{2} R \cdot \ln m = 3 \cdot \frac{6}{2} \cdot 8{,}31 \cdot \ln 3 = 82{,}16\ \frac{J}{K}$$

b) Izobarik jarayonda (*) formuladagi har ikkala had ham o'zgaruvchan bo'ladi.

$$\Delta S = \frac{m}{M} c_V^* \ln\frac{T_2}{T_1} + \frac{m}{M} R \ln\frac{V_2}{V_1} = \nu \frac{i}{2} R \ln\frac{T_2}{T_1} + \nu R \ln\frac{T_2}{T_1} = \frac{i+2}{2} \nu R \ln m =$$

$$= \frac{6+2}{2} \cdot 3 \cdot 8{,}31 \cdot \ln 3 = 12 \cdot 8{,}31 \cdot \ln 3 = 109{,}55\ \frac{J}{K}$$

Javob: $a)\ \Delta S = 82{,}16\ \frac{J}{K};\ \ b)\ \Delta S = 109{,}55\ \frac{J}{K}$

Masala № 2. *m=0,5 kg* massali kislorodni $t_1 = 27^0 C$ temperaturadan $t_2 = 127^0 C$ temperaturagacha qizdirildi. Agar boshlang'ich va oxirgi temperatura bir xil va atmosfera bosimiga yaqin bo'lsa, u holda entropiya o'zgarishi nimaga teng?

Berilgan:

$m = 0,45\ kg$

$M = 32\ \frac{g}{mol}$

$i = 5$

$T_1 = 300\ K$

$T_2 = 400\ K$

$P = const$

$\Delta S = ?$

Yechilishi:

Eng umumiy hol bo'yicha keltirib chiqaramiz.

$$\Delta S = S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} = \int_1^2 \frac{dU + \delta A'}{T} = \int_1^2 \frac{dU}{T} + \int_1^2 \frac{P\delta V}{T} = \frac{i}{2}\frac{m}{M} R \int_{T_1}^{T_2} \frac{dT}{T} +$$

$$+ \frac{m}{M} R \int_{V_1}^{V_2} \frac{dV}{V} = \frac{i}{2}\frac{m}{M} R \ln\frac{T_2}{T_1} + \frac{m}{M} R \ln\frac{V_2}{V_1} = \frac{i}{2}\frac{m}{M} R \ln\frac{T_2}{T_1} + \frac{m}{M} R \ln\frac{T_2}{T_1} =$$

$$= \frac{i+2}{2}\frac{m}{M} R \ln\frac{T_2}{T_1} = \frac{5+2}{2} \cdot \frac{0,5}{0,032} \cdot 8,31 \cdot \ln\frac{400}{300} = 130,74\ \frac{J}{K}$$

Javob: $\Delta S = 130,74\ \frac{J}{K}$

Masala № 3. Massasi *m=56 g* bo'lgan azot gazining hajmini rasmdagi kabi adiabatik ravishda *k=4* marta kengaytirildi, so'ngra dastlabki hajmigacha izobarik ravishda siqildi. Undan keyin esa izoxorik ravishda boshlang'ich holga to'la qaytarildi. Bunda har bir o'tishlardagi entropiya o'zgarishi nimaga teng? Butun siklda-chi?

Berilgan:

$m = 56\ g$

$M = 28\ \frac{g}{mol}$

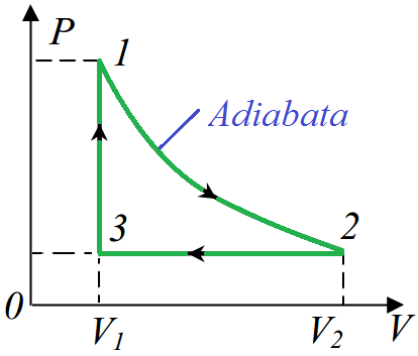
$i = 5$

$\frac{V_2}{V_1} = k = 4$

$\Delta S = ?$

Yechilishi:

Biz bilamizki, entropiya – bu additiv kattalikdir. Shuning uchun avval rasmdagi siklning har bir qismidagi entropiyalarni aniqlab olamiz, keyin esa ularni qo'shib chiqamiz.



Dastlab 1→2 o'tishdagi entropiya o'zgarishini hisoblaymiz. Bu o'tish adiabatik jarayon bo'lgani uchun unda entropiya o'zgarishi sodir bo'lmaydi.

$$S_{1\to 2} = const \qquad yoki \qquad \Delta S_{1\to 2} = 0$$

2→3 o'tishdagi entropiya o'zgarishini hisoblaymiz. Bu izobarik jarayondir.

$$\Delta S_{2\to 3} = \Delta S_P = c_P^* \frac{m}{M} \ln\frac{T_3}{T_2} = \frac{i+2}{2}\frac{m}{M} \ln\frac{V_3}{V_2} = \frac{i+2}{2}\frac{m}{M} \ln\frac{1}{k} = -\frac{5+2}{2} \cdot \frac{0,056}{0,028} \cdot \ln 4 = -9,7\ \frac{J}{K}$$

3→1 o'tishdagi entropiya o'zgarishini hisoblashdan oldin bu nuqtalardagi bosimlar nisbatini aniqlaymiz.

$$P_1 V_1^\gamma = P_2 V_2^\gamma\ ,\ \to\ P_1 V_1^\gamma = P_3 V_2^\gamma\ ,\ \to\ \frac{P_1}{P_3} = \left(\frac{V_2}{V_1}\right)^\gamma = k^\gamma = k^{\frac{i+2}{i}} = 4^{\frac{5+2}{5}} = 4^{1,4} = 6,964$$

3→1 o'tishdagi entropiya o'zgarishini hisoblaymiz. Bu izoxorik jarayondir.

$$\Delta S_{3\to1} = \Delta S_V = \frac{m}{M} c_V^* \ln\frac{T_1}{T_3} = \frac{i}{2}\frac{m}{M} R \ln\frac{P_1}{P_3} = \frac{i}{2}\frac{m}{M} R \ln k^{\frac{i+2}{i}} = \frac{i+2}{2}\frac{m}{M} R \ln k =$$

$$= \frac{5+2}{2} \cdot \frac{0,056}{0,028} \cdot 8,31 \cdot \ln 4 = 9,7 \frac{J}{K}$$

Endi berk sikldagi to'la entropiya o'zgarishini aniqlaymiz.

$$\Delta S = \Delta S_{1\to2} + \Delta S_{2\to3} + \Delta S_{3\to1} = 0 - 9,7 + 9,7 = 0 \frac{J}{K}$$

Javob: $\Delta S_{1\to2} = 0;\ \Delta S_{2\to3} = -9,7 \frac{J}{K};\ \Delta S_{3\to1} = +9,7 \frac{J}{K};\ \Delta S = 0$

Masala № 4. Massasi *m=3 kg* bo'lgan erish temperaturasida turgan muzni to'la eritganda entropiya o'zgarishi qanday bo'ladi? Muzning solishtirma erish issiqligi λ=330 kJ/kg ga teng.

Berilgan:
T=273 K
m=3 kg
λ=330 kJ/kg
ΔS =?

Yechilishi:

Bu masala sharti – modda agregat holatining o'zgarishidagi entropiya o'zgarishini aniqlash masalasidir.

$$\Delta S = S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} = \int_1^2 \frac{\lambda\, dm}{T} = \frac{\lambda m}{T_{er}} = \frac{330000 \cdot 3}{273} = 3626,4 \frac{J}{K}$$

Javob: $\Delta S = 3626,4 \frac{J}{K}$

Masala № 5. Dastlab t_1=-50^{0}C temperaturada turgan *m=40 g* massali muzni t_2==t_{qay}=100^{0}C li bug'ga aylantirilganda umumiy entropya o'zgarishi nimaga teng bo'ladi?

Berilgan:
t_1=-50^{0}C
t_2=100^{0}C
m=40 g
M=18 g/mol
c_m=2100 J/(kg·K)
c_s=4200 J/(kg·K)
λ=330 kJ/kg
r=2,30 MJ/kg
ΔS =?

Yechilishi:

Umumiy entropiya o'zgarishini topish uchun bir necha qismlarga bo'lib, shu qismlardagi entropya o'zgarishlarini hisoblaymiz va eng so'nggida entropiyaning additivlik xossasini qo'llaymiz.

Eng avvalo t_1=-50^{0}C da turgan muzni t_{er} erish temperaturasigacha qizdirishdagi entropiya o'zgarishi ΔS_1 ni topamiz. Bunda muzning qattiq holati saqlanadi.

$$\Delta S_1 = \int_1^2 \frac{\delta Q}{T} = \int_1^2 \frac{c_m\, m\, dT}{T} = c_m m \int_{T_1}^{T_{er}} \frac{dT}{T} = c_m m \ln\frac{T_{er}}{T_1} =$$

$$= 2100 \cdot 0,04 \cdot \ln\frac{273}{223} = 84 \cdot \ln 1,224 \approx 17 \frac{J}{K}$$

Endi erish temperaturasidagi muzni shu temperaturali suvga aylantirishdagi entropiya o'zgarishi ΔS_2 ni topamiz. Bunda moddaning agregat holati qattiq

fazadan suyuq fazaga o‘tadi.

$$\Delta S_2 = \int_1^2 \frac{\delta Q}{T} = \int_1^2 \frac{\lambda\, dm}{T} = \frac{\lambda\, m}{T_{er}} = \frac{330000 \cdot 0,04}{273} = 48,35\ \frac{J}{K}$$

Endi erish temperaturasidagi suvni toki qaynash temperaturasiga yetguncha qizdirishdagi entropiya o‘zgarishi ΔS_3 ni topamiz. Bunda suvning suyuq holati saqlanadi.

$$\Delta S_3 = \int_1^2 \frac{\delta Q}{T} = \int_1^2 \frac{c_s\, m\, dT}{T} = c_m m \int_{T_{er}}^{T_{qay}} \frac{dT}{T} = c_m m \ln \frac{T_{qay}}{T_{er}} = 4200 \cdot 0,04 \cdot \ln \frac{373}{273} = 168 \cdot \ln 1,366 \approx 52,43\ \frac{J}{K}$$

Va nihoyat qaynash temperaturasida (qaynab) turgan suyuqlikni bug‘ga aylantirishdagi entropiya o‘zgarishi ΔS_4 ni topamiz. Bunda moddaning agregat holati suyuq fazadan gazsimon fazaga o‘tadi.

$$\Delta S_4 = \int_1^2 \frac{\delta Q}{T} = \int_1^2 \frac{r\, dm}{T} = \frac{r\, m}{T_{qay}} = \frac{2,3 \cdot 10^6 \cdot 0,04}{373} \approx 246,65\ \frac{J}{K}$$

Shunday qilib entropiyaning additivlik xususiyatidan foydalanib, masala shartidagi umumiy entropiya o‘zgarishini topamiz.

$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3 + \Delta S_4 = 17 + 48,35 + 52,43 + 246,65 = 364,45\ \frac{J}{K}$$

Javob: $\Delta S = 364,45\ \frac{J}{K}$

Masala № 6. $t_1=20^0C$ temperaturali $V_1=5\ \ell$ hajmli sovuq suvga $t_2=80^0C$ temperaturali $V_2=3\ \ell$ hajmli issiq suv aralashtirildi. Bunda muvozonat qaror topganda entropiya qanchaga oshgan bo‘ladi?

Berilgan:

$t_1=20^0C$

$t_2=80^0C$

$V_1=5\ \ell$

$V_2=3\ \ell$

c=4200 J/(kg·K)

$\Delta S = ?$

Yechilishi:

Bunda eng avvalo qaror topgan t' temperaturani aniqlaymiz.

$$t' = \frac{t_1 V_1 + t_2 V_2}{V_1 + V_2} = \frac{20 \cdot 5 + 80 \cdot 3}{5 + 3} = 42,5\ ^0C$$

Endi temperaturalarni Kelvin shkalasiga o‘tkazamiz.

$$T_1 = t_1 + 273 = 293K;\ T_2 = t_2 + 273 = 353K;\ T' = t' + 273 = 315,5\ ^0C$$

Endi aralashtirilgan suvlarning massalarini aniqlaymiz.

$$m_1 = \rho V_1 = 10^3 \cdot 5 \cdot 10^{-3} = 5kg;\quad m_2 = \rho V_2 = 10^3 \cdot 3 \cdot 10^{-3} = 3kg$$

Aralashtirilgan suvlarning umumiy entropiya o‘zgarishi har bir suyuqlikni t’ temperaturagacha kelguncha o‘zgargan entropiyalari yig‘indisiga teng.

$$\Delta S = \Delta S_1 + \Delta S_2 = cm_1 \ln \frac{T'}{T_1} + cm_2 \ln \frac{T'}{T_2} = 4200 \cdot 5 \cdot \ln \frac{315,5}{293} + 4200 \cdot 3 \cdot \ln \frac{315,5}{353} =$$

$$= 21000 \cdot \ln(1,07679) + 12600 \cdot \ln(0,89376) = 1553,7 - 1415,1 = 138,6\ \frac{J}{K}$$

Javob: $\Delta S = 138,6\ \frac{J}{K}$

Masala № 7 **:** Erkinlik darajasi $i=6$ bo‘gan $\nu=2$ mol ideal gazning entropyasi oshishini aniqlang. Bunda biror jarayon natijasida dastlab gaz hajmi $\alpha=2$ marta oshdi, keyin gaz bosimi $\beta=3$ kamaydi (rasmga qarang).

Berilgan:

$i = 6$

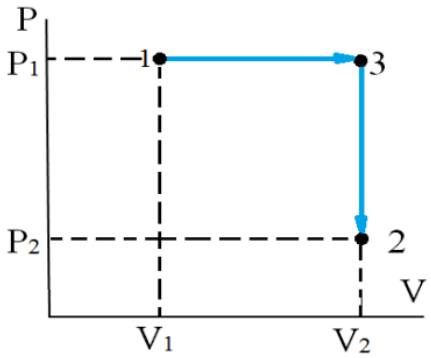
$V_2 = 2V_1$

$P_2 = P_1 / 3$

$\Delta S = ?$

Yechilishi:

O‘tish jarayonlari rasmda ko‘rsatilgan. Entropiya o‘zgarishi trayektoriya shakliga bog‘liq bo‘lmagani uchun izobarik va izoxorik jarayonlar shaklida olindi. Dastlab 1→3 o‘tishdagi entropiya



o‘zgarishini aniqlaymiz.

$$\Delta S_{1\to 3} = \Delta S_P = c_P^* \frac{m}{M} \ln \frac{V_2}{V_1} = \frac{i+2}{2} R\nu \ln \frac{V_2}{V_1} = \frac{i+2}{2} R\nu \ln \alpha = \frac{6+2}{2} \cdot 8,31 \cdot 2 \cdot \ln 2 = 46\ \frac{J}{K}$$

Keyingi 3→2 o‘tishdagi entropiya o‘zgarishini aniqlaymiz.

$$\Delta S_{3\to 2} = \Delta S_V = \frac{m}{M} c_V^* \ln \frac{P_2}{P_1} = \frac{i}{2} R\nu \ln \beta = \frac{6}{2} \cdot 8,31 \cdot 2 \cdot \ln \frac{1}{3} = -49,86 \cdot \ln 3 = -54,77\ \frac{J}{K}$$

Endi umumiy entropiya o‘zgarishini aniqlaymiz.

$$\Delta S_{1\to 2} = \Delta S_{1\to 3} + \Delta S_{3\to 2} = 46 + (-54,77) = -8,77\ \frac{J}{K}$$

Javob: $\Delta S_{1\to 2} = -8,77\ \frac{J}{K}$

Masala № 8 **:** ν miqdordagi ideal gaz shunday jarayonni o‘taydiki, bunda gazning S entropiyasi T temperatura bo‘yicha $S = \alpha\nu T^2$ qonunga muvofiq o‘zgaradi. Gaz molyar issiqlik sig‘imini T temperaturaning funksiyasi sifatida aniqlang. Absalyut temperaturani T_1 dan T_2 gacha oshirishda gaz qancha issiqlik oladi?

Berilgan:

$S = \alpha\nu T^2$

$\nu=1$ *mol*

T_1 , T_2

$c^* = ?$

$Q = ?$

Yechilishi:

Entropiyani termodinamik aniqlashning $dS = \delta Q / T$ formulasidan foydalanib, gaz temperaturasining dT o‘zgarishida gaz olgan issiqlikni aniqlaymiz.

$$\delta Q = T\,dS = T\,d\left(\alpha\nu T^2\right) = 2\alpha\nu T^2 dT$$

Issiqlikni aniqlashning

$$\delta Q = c^* \nu\, dT$$

formulasidan foydalansak,

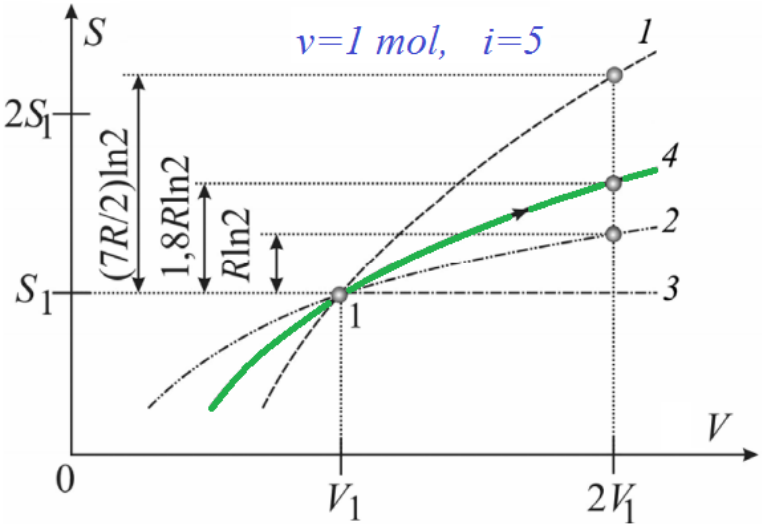
$$c^* = 2\alpha T^2$$

formula hosil bo‘ladi. Endi issiqlik miqdorini aniqlaymiz.

$$Q = \int_T \delta Q = \int_{T_1}^{T_2} c^* \nu\, dT = \int_{T_1}^{T_2} 2\alpha T^2 \nu\, dT = 2\alpha\nu \int_{T_1}^{T_2} T^2 dT = \frac{2\alpha\nu}{3}\left(T_2^3 - T_1^3\right)$$

Javob: $c^* = 2\alpha T^2;\ Q = \frac{2\alpha\nu}{3}\left(T_2^3 - T_1^3\right)$

Masala № 9 **:** 1 mol miqdordagi ideal gazning hajmi $V_1=V$ dan $V_2=2V$ gacha $V = aT^3\,(a = const)$ qonun bo‘yicha kengayishidagi entropiya o‘zgarishini aniqlang. Gaz molekulalari $i=5$ erkinlik darajasiga ega. Mazkur jarayondagi entropiya o‘zgarishini izobarik, izotermik va qaytar adiabatik jarayonlardagi entropiya o‘zgarishlari bilan taqqoslang.



Berilgan:	*Yechilishi:*
$V = aT^3$ $\nu=1\ mol$ $V_1=V$ $V_2=2V$ $i=5$	$V = aT^3$ jarayon tenglamasi gazning boshlang‘ich va oxirgi temperaturasini aniqlash mumkin.
ΔS =?	$$T_1 = V_1^{1/3}/a, \quad T_2 = V_2^{1/3}/a$$ T_1 va V_1 ikkita parametrni hamda $T = V^{1/3}/a$ jarayonni bilgan holda entropiya o‘zgarishini aniqlash mumkin. Entropiya o‘zgarishini $$\Delta S = \frac{m}{M} c_V^* \ln\frac{T_2}{T_1} + \frac{m}{M} R \ln\frac{V_2}{V_1}$$

foydalansak, u holda

$$S(V,T) - S(V_1,T_1) = \nu c_V^* \ln\frac{T}{T_1} + \nu R \ln\frac{V}{V_1} = \nu R\left(\frac{i}{2}\ln\frac{T}{T_1} + \ln\frac{V}{V_1}\right)$$

ko‘rinishga o‘tadi. Masala shartida berilgan oraliqdagi hajm o‘zgarishini qo‘yib, shu oraliq uchun entropiya o‘zgarishini hisoblaymiz.

$$\Delta S_{12} = \nu R\left(\frac{5}{2}\ln\sqrt[3]{2} + \ln 2\right) = R\left(\frac{5}{6}\ln 2 + \ln 2\right) = \frac{11}{6}\cdot\ln 2\cdot 8{,}31 = 10{,}56\ \frac{J}{K}$$

1 mol miqdordagi ideal gazning hajmi V_1 dan $V_2=2V_1$ gacha o‘zgarganda turli jarayonlar uchun entropiya o‘zgarish grafiklari yuqorida rasmda ko‘rsatilgan. Bunbda: 1 – izobarik; 2 – izotermik; 3 – qaytar adiabatik; 4 – $V=aT^3$ qonun bo‘yicha kechadigan jarayonlarga mos keladi.

Endi shu jarayonlar uchun entropiya o‘zgarishlarini hisoblaymiz.

$$\Delta S_P = c_P^* \frac{m}{M}\ln\frac{V_2}{V_1} = \frac{i+2}{2}R\nu\ln\frac{V_2}{V_1} = \frac{7}{2}R\ln 2 = 3{,}5\cdot 8{,}31\cdot\ln 2 = 20{,}16\ \frac{J}{K}$$

$$\Delta S_T = \frac{m}{M}R\ln\frac{V_2}{V_1} = \nu R\ln 2 = 1\cdot 8{,}31\cdot\ln 2 = 5{,}76\ \frac{J}{K}$$

$$\Delta S_\gamma = 0$$

Javob: $\Delta S_{12} = 10{,}56\ \frac{J}{K};\ \Delta S_P = 20{,}16\ \frac{J}{K};\ \Delta S_T = 5{,}76\ \frac{J}{K};\ \Delta S_\gamma = 0$

12-amaliy mashg‘ulot topshirig‘i

12.1. *400 g* massali muzni -10^0C dan $+10^0C$ gacha qizdirishda entropiya oshishini hisoblang. Muz va suvning solishtirma issiqlik sig‘imlari mos holda $c_m=2100\ J/(kg\cdot K)$, va $c_m=4200\ J/(kg\cdot K)$ ga teng, muzning solishtirma erish issiqligi esa $\lambda=330\ kJ/kg$ ga teng. J: $\Delta S = 575{,}31\ \frac{J}{K}$

12.2. $t_1=7^0C$ temperaturali $m_1=8\ kg$ massali sovuq suvga $t_2=77^0C$ temperaturali $m_2=4\ kg$ massali issiq suv aralashtirildi. Bunda muvozonat qaror topganda entropiya qanchaga oshgan bo‘ladi? J: $\Delta S = 283{,}73\ \frac{J}{K}$

12.3. $m_1=3\ kg$ massali $t_1=0^0C$ temperaturada turgan muzni $t_2=100^0C$ temperaturali bug‘ yordamida 0^0C temperaturali suvga aylantirildi. Bunda sarflangan bug‘ning m_2 massasi nimaga teng? Bug‘ – suv sistemasining entropiyasi qanchaga o‘zgaradi? Muzning solishtirma erish issiqligi $\lambda=330\ kJ/kg$ ga, suvning solishtirma issiqlik sig‘imi $c=4200\ J/(kg\cdot K)$ ga, solishtirma bug‘lanish issiqligi esa $r=2{,}3\ MJ/kg$ ga teng. J: $m_2 = 363\,g;\ \Delta S = 906{,}6\ \frac{J}{K}$

12.4. *Hajmi $V=2\ \ell$ bo‘lgan $t_1=20^0C$ temperaturadagi suvga $m_2=400\ g$ massali $t_2=350^0C$ temperaturadagi temir bo‘lagi tashlandi. Bunda qanday temperatura qaror topadi? Temirning va suvning entropiya o‘zgarishini hamda umumiy entropiya o‘zgarishini aniqlang. Suv va temirning solishtirma issiqlik sig‘imlari mos ravishda

$c_1 = 4200\ \frac{J}{kg \cdot K}$ va $c_2 = 460\ \frac{J}{kg \cdot K}$ ga teng. J: $t' = 27^0 C;\ \Delta S_1 = 198,32\ \frac{J}{K};$

$\Delta S_2 = -134,46\ \frac{J}{K};\ \Delta S_{um} = 63,86\ \frac{J}{K}$

12.5. **Issiqlik sig‘imi *C=600 J/K* bo‘lgan idishda $t_1=0^0C$ temperaturadagi *0,5 kg* massali suv va *300 g* massali muz turibdi. Agar suvga $t_2=100^0C$ temperaturali *100 g* massali bug‘ yuborilsa, u holda qanday temperatura qaror topishini aniqlang. Bug‘ning solishtirma kondensatsiyalanish issiqligi *r=2,26 MJ/kg*, suvning solishtirma issiqlik sig‘imi $c_s=4190\ J/(kg \cdot K)$, muzning solishtirma erish issiqligi $\lambda=335\ kJ/kg$, suvning zichligi $\rho=1000\ kg/m^3$ ga teng. Bunda idish-muz–suv–bug‘ sistemasining entropiyasi qanchaga oshadi? J: $t' = 39,5^0 C;\ \Delta S_{um} = 206,82\ \frac{J}{K}$

12.6. *$t_1=-40^0C$ temperaturada olingan *m=70 g* massali muzni uzoq qizdirilish natijasida bug‘ga aylantirildi. Bunda uning entropiyasi qanchaga oshgan? Muz va suvning solishtirma issiqlik sig‘imlari mos holda $c_m=2100\ J/(kg \cdot K)$ va $c_s=4200\ J/(kg \cdot K)$ ga, muzning solishtirma erish issiqligi $\lambda=330\ kJ/kg$ ga, qaynash temperaturasidagi suvning solishtirma bug‘lanish issiqligi esa *2,3 MJ/kg* ga teng. J: $\Delta S = 631,3\ \frac{J}{K}$

12.7. Massasi *2 kg* bo‘lgan *300 K* temperaturadagi suvni bug‘ga aylanguncha qizdirilganda uning entropiyasi qanchaga ortad? J: $\Delta S = 14162\ \frac{J}{K}$

12.8. *m=160 g* massali kislorod 20^0C temperaturadan 120^0C temperaturagacha qizdirilganda uning entropiyasi qanchaga oshgan? Masalani qizdirish jarayoni: *a)* izoxorik; *b)* izobarik jarayonlar uchun yeching. J: $\Delta S_V = \frac{i}{2}\frac{m}{M} \mathrm{R} \ln\frac{T_2}{T_1} = 30,5\ \frac{J}{K}$

$\Delta S_P = \frac{i+2}{2}\frac{m}{M} \ln\frac{T_2}{T_1} = 42,7\ \frac{J}{K}$

12.9. *m=200 g* massali vodorod gazi izobarik ravishda shunday qizdirildiki, bunda uning hajmi *k=4* marta oshdi. So‘ngra bu gazni izoxorik ravishda shunday sobitildiki, bunda uning hajmi *k=4* marta kamaydi. Aytilgan jarayonlarning har biridagi hamda umumiy entropiya o‘zgarishlarini aniqlang. J:

12.10. *v=2 mol* miqdordagi ideal gazni dastlab izobarik ravishda shunday qizdirildiki, bunda uning hajmi *k=3* marta oshdi, so‘nra esa gazni izoxorik ravishda shunday sobitildiki, bunda uning hajmi *k=3* marta kamaydi. Ko‘rsatilgan har bir jarayondagi hamda umumiy entropiya o‘zgarishini aniqlang. J:

12.11. Massasi $m=56\ g$ ga massali azot gazi adiabatik ravishda $k=3$ marta kengaydi, so‘ngra esa izobarik ravishda dastlabki hajmgacha siqildi. Ko‘rsatilgan jarayonlar natijasidagi umumiy entropiya o‘zgarishini aniqlang. J:

12.12. Bir xil massaga va bir xil V hajmga ega bo‘lgan kislorod va vodorod gazlarini izotermik sharoitda $3V$ hajmgacha kengaydi. Entropiya o‘sishi qaysi gazda ko‘p va necha marta ko‘p? J: *Vodorod gazida 16 marta ko‘p*

12.13.*Massalari teng bo‘lgan metan (CH_4) va kislorod (O_2) gazlari bir xil V hajmda turibdi. Gazlarni izotermik kengaytirish natijasida ulardagi entropiya o‘sishlari bir xil bo‘lishi uchun metan gazi $3V$ hajmgacha kengaytirilganda kislorod gazi qanday hajmgacha kengaytirilish kerak? J: $9V$

12.14.*Yuqoridagi masala shartini gazlar izobarik ravishda kengaytirilgan hol uchun bajaring. J: $3^{\frac{16}{7}}V \approx 12,32V$

12.15.*Metan (CH_4) gazini izotermik sharoitda V hajmdan $4V$ hajmgacha kengaytirildi. Bunda entropiya o‘sishi ΔS_T ga teng. Agar shu gazni izobarik sharoitda kengaytirilganda ham entropiya o‘sishi uchun $\Delta S_P = \Delta S_T$ shart bajarilgan bo‘lsa, u holda gaz qanday hajmgacha izobarik kengaytirilgan? J:

12.16.* Karbonat angidrid (CH_4) gazining bosimi izoxorik ravishda P bosimdan $2P$ bosimgacha oshirildi. Bunda entropiya o‘sishi ΔS_V ga teng. Agar shu gazni izotermik sharoitda siqilganda ham entropiya o‘sishi uchun $\Delta S_T = -\Delta S_V$ shart bajarilgan bo‘lsa, u holda gaz qanday bosimgacha izotermik siqilgan? J: $8P$

12.17.* Yuqoridagi masala shartini kislorod va neon gazlari uchun yeching. J: $4\sqrt{2}V \approx 5,66V;\ 2\sqrt{2}V \approx 2,83V$

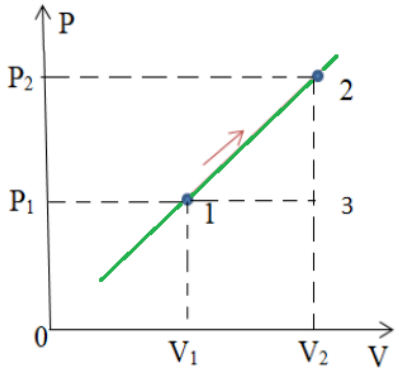
12.18. $T=290\ K$ temperaturada turgan makroskopik sistemaning statistik vaznini (termodinamik ehtimolligini) $1\ \%$ ga, $10\ \%$ ga, $100\ \%$ ga oshirildi. Bunda sistemaga qancha issiqlik miqdori uzatilgan? J: $4\cdot10^{-23}\ J;\ 3,81\cdot10^{-22}\ J;\ 2,77\cdot10^{-21}\ J$

12.19. $T=300\ K$ temperaturada turgan makroskopik sistemaga energiyasi $Q=1\ eV$ ga teng issiqlik miqdori uzatilganda, sistemadagi mikroslopik holatlar soni (statistik vazni) necha marta ortadi? J: $\frac{W_2}{W_1} = e^{\frac{Q}{k_B T}} \approx 6,1\cdot10^{16}\ marta$

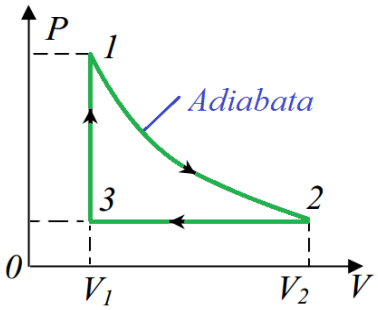
12.20. *$14\ g$ azot gazini adiabatik sharoitda bosimi 5 marta kamayguncha kengaytirildi. So‘ngra gazni izotermik sharoitda dastlabki bosimgacha siqildi. Azotning dastlabki temperaturasi $T_1=420\ K$. Jarayonlarni P–V diagrammadan tasvirlang. Har bir jarayondagi hamda umumiy entropiya o‘zgarishini aniqlang. J: $\Delta S_{1\to2} = 0\ \frac{J}{K};\ \Delta S_{2\to3} = 6,687\ \frac{J}{K};\ \Delta S_{um} = 6,687\ \frac{J}{K}$

12.21. Hajmi $V_1=1,6\ \ell$ bo‘lgan bir idishda $14\ g$ azot gazi bor. $V_2=3,4\ \ell$ hajmli boshqa idishda esa $16\ g$ kislorod gazi bor. Gazlarning temperaturasi bir xil. Idishlar tutashtiriladi va gazlar aralashib ketadi. Entropiya oshishini hisoblang. J: $\Delta S=\left(\frac{m_1}{M_1}+\frac{m_2}{M_2}\right)R\ln\frac{V_1+V_2}{V_1}=9,47\ \frac{J}{K}$

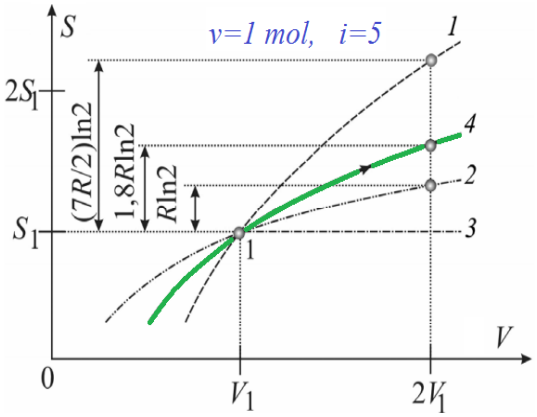
12.22. $\nu=2\ mol$ argon gazi shunday qizdiriladiki, bunda gazning bosimi hajmiga to‘g‘ri proporsional holda ortadi (rasmga qarang). Gaz hajmi 2 marta oshganda entropiya qanchaga o‘zgarishini hisoblang. J: $\Delta S=\nu c_P^*\ln\frac{V_2}{V_1}+\nu c_V^*\ln\frac{P_2}{P_1}=46\ \frac{J}{K}$



12.23. *Massasi $m=56\ g$ bo‘lgan azot gazining hajmini rasmdagi kabi adiabatik ravishda $k=4$ marta kengaytirildi, so‘ngra dastlabki hajmigacha izobarik ravishda siqildi. Undan keyin esa izoxorik ravishda boshlang‘ich holga to‘la qaytarildi. Bunda har bir o‘tishlardagi entropiya o‘zgarishi nimaga teng? Butun siklda-chi? J: $\Delta S_{1\to2}=0;\ \Delta S_{2\to3}=-9,7\ \frac{J}{K};\ \Delta S_{3\to1}=+9,7\ \frac{J}{K};\ \Delta S=0$



12.24. ** $\nu=1\ mol$ miqdordagi ideal gazning hajmi $V_1=V$ dan $V_2=2V$ gacha $V=aT^3\ (a=const)$ qonun bo‘yicha kengayishidagi entropiya o‘zgarishini aniqlang. Gaz molekulalari $i=5$ erkinlik darajasiga ega. Mazkur jarayondagi entropiya o‘zgarishini izobarik, izotermik va qaytar adiabatik jarayonlardagi entropiya o‘zgarishlari bilan taqqoslang. J: $\Delta S_{12}=10,56\ \frac{J}{K};\ \Delta S_P=20,16\ \frac{J}{K};\ \Delta S_T=5,76\ \frac{J}{K};\ \Delta S_\gamma=0$



13-MAVZU: Real gazlar. Van-der-Vaals tenglamasi. Van-der-Vaals parametrlarini aniqlash. Fazaviy o‘tishlar. Kritik kattaliklar.

Mavzuga oid muhim formulalar

$\left(P+\frac{a}{V_m^2}\right)(V_m-b)=RT$	*Bir mol gaz uchun Van-der-Vaals tenglamasi (V_m – molyar hajm)*
$\left(P+\frac{\nu^2 a}{V^2}\right)(V_m-\nu b)=\nu RT$	*Ixtiyoriy miqdordagi gaz uchun Van-der-Vaals tenglamasi (V – hajm, a va b – Van-der-Vaals doimiylari)*
$P'=\frac{a}{V_m^2}\quad yoki\quad P'=\frac{\nu^2 a}{V^2}$	*Molekulalar o‘zaro ta’sr kuchlari tufayli vujudga keladigan ichki bosim*
$V_{m.kr}=3b,\quad P_{kr}=\frac{a}{27b^2},\quad T_{kr}=\frac{8a}{27Rb}$	*Kritik hajm, kritik bosim va kritik temperaturaning Van-der-Vaals doimiylari a va b larga bog‘liqligi*
$U=\nu\left(c_V^* T-\frac{a}{V_m}\right)$	*Real gazning ichki energiyasi (c_V^* – o‘zgarmas hajmdagi molyar issiqlik sig‘imi)*

13-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. *m=1kg* massali suvning eng katta hajmi V ni aniqlang.

Berilgan:
m=1kg
M=18 g/mol

V=?

Yechilishi:

Van-der-Vaals izotermalarida aytiganidek suv egallagan eng katta hajm – bu uning kritik holatdagi hajmidir. Kritik holatda egallagan hajmi esa quyidagicha bo‘ladi:

$$V=\nu V_{m.kr}=\frac{m}{M}V_{m.kr}$$

Kritik holatdagi molyar hajm qiymatini esa jadvaldan olamiz va hisoblaymiz.

$$V=\nu V_{m.k}=\frac{m}{M}V_{m.kr}=\frac{1kg}{0,018\frac{kg}{mol}}\cdot 56\cdot 10^{-6}\frac{m^3}{mol}=3,11\cdot 10^{-3}m^3=3,11\ell$$

Javob: *V=3,11 ℓ*

Masala № 2. Suv bug‘ining kritik holat yaqinidagi Van-derVaals doimiylari hamda individual gaz doimiysi mos holda $a=0,2\frac{Pa\cdot m^6}{mol^2}$, $b=1,83\cdot 10^{-5}\frac{m^3}{mol}$ hamda $R=5\frac{J}{mol\cdot K}$ ga teng bo‘lsa, kritik holatdagi makroparametrlarni aniqlang.

Berilgan:	*Yechilishi:*
$a = 0,2\frac{Pa \cdot m^6}{mol^2}$ $b = 1,83 \cdot 10^{-5}\frac{m^3}{mol}$ $R = 5\frac{J}{mol \cdot K}$	Ushbu $V_{m.kr} = 3b,\quad P_{kr} = \frac{a}{27b^2},\quad T_{kr} = \frac{8a}{27Rb}$ formulalardan foydalanib ishlaymiz. $V_{m.kr} = 3b = 3 \cdot 1,83 \cdot 10^{-5}\frac{m^3}{mol} = 5,49 \cdot 10^{-5}\frac{m^3}{mol}$
$V_{kr}, P_{kr}, T_{kr} - ?$	$P_{kr} = \frac{a}{27b^2} = \frac{0,2\frac{Pa \cdot m^6}{mol^2}}{27 \cdot \left(1,83 \cdot 10^{-5}\frac{m^3}{mol}\right)^2} = 22\ MPa$ $T_{kr} = \frac{8a}{27Rb} = \frac{8 \cdot 0,2\frac{Pa \cdot m^6}{mol^2}}{27 \cdot 5\frac{J}{mol \cdot K} \cdot 1,83 \cdot 10^{-5}\frac{m^3}{mol}} = 643K$

Javob: $V_{m.kr} = 5,49 \cdot 10^{-5}\frac{m^3}{mol};\ P_{kr} = 22\ MPa;\ T_{kr} = 643K$

Masala № 3. Slindrda porshen ostida *m=20 g* massali xlor gazi bor. Bu gazning hajmini izotermik sharoitda V_1*=200 sm³* dan V_2*=500 sm³* gacha oshirishda ichki energiya o‘zgarishi ΔU ni aniqlang.

Berilgan:	*Yechilishi:*
m=20 g V_1*=200 sm³* V_2*=500 sm³* *M=71 g/mol*	Van-der-Vaals gazining ichki energiyasi ushbu formuladan aniqlanadi: $U = \nu\left(c_V^* T - \frac{a}{V_m}\right)$
ΔU =?	Bu formulada molyar hajm V_m hamda modda miqdori ν o‘rniga formulalarini qo‘yib quyidagi formulani hosil qilamiz: $U = \nu\left(c_V^* T - \frac{a}{V_m}\right) = \frac{m}{M}\left(c_V^* T - \frac{ma}{MV}\right)$

Izotermik kengayishdagi ΔU ichki energiya o‘zgarishini real gazning V_1 va V_2 hajmlariga mos ichki energiyalari farqi sifatida aniqlash mumkin.

$$\Delta U = U_2 - U_1 = \frac{m}{M}\left(c_V^* T - \frac{ma}{MV_2}\right) - \frac{m}{M}\left(c_V^* T - \frac{ma}{MV_1}\right) = a\left(\frac{m}{M}\right)^2 \cdot \left(\frac{1}{V_1} - \frac{1}{V_2}\right) =$$

$$= 0,65\frac{N \cdot m^4}{mol^2} \cdot \left(\frac{0,02kg}{0,071kg/mol}\right)^2 \cdot \left(\frac{1}{2 \cdot 10^{-4}m^3} - \frac{1}{5 \cdot 10^{-4}m^3}\right) = 154\ J$$

Javob: *3 marta kam bo'ladi*

13-amaliy mashg‘ulot topshirig‘i

13.18. Agar azot gazi uchun kritik temperatura $T_k=126\ K$ va kritik bosim $P_k=3{,}39\ MPa$ bo‘lsa, u holda Van-der-Vaals tenglamasi uchun a va b koeffitsiyentlarni aniqlang. **Javob:**

13.19. Argon gazi uchun kritik temperatura $T_k=151\ K$ va kritik bosim $P_k=4{,}86\ MPa$ ga teng. Bu ma’lumotlardan foydalanib argon gazining kritik molyar hajmi $V_{k.m}$ ni aniqlang. **Javob:**

13.20. *2 mol* miqdordagi suv egallagan eng katta hajmni aniqlang. **Javob:**

13.21. $m=8\ g$ massali kislorod gazi $T=400\ K$ temperaturada $V=40\ sm^3$ hajm egallaydi. Gazning ichki energiyasini aniqlang. **Javob:**

13.22. $\nu=3\ mol$ miqdordagi neonning hajmi $V_1=1\ \ell$ dan $V_2=2\ \ell$ gacha kengayishida ichki energiya o‘zgarishi ΔU ni aniqlang. **Javob:**

13.23. Slindrda porshen ostida $m=28\ g$ massali azot gazi bor. Bu gazning hajmini izotermik sharoitda $V_1=200\ sm^3$ dan $V_2=500\ sm^3$ gacha oshirishda ichki energiya o‘zgarishi ΔU ni aniqlang. **Javob:**

13.24. $V=10\ \ell$ hajmli ballonda $m=250\ g$ massali azot gazi bor. Quyidagilarni aniqlang: *a)* ichki bosim P' ni; b) molekulalarning xususiy hajmi V' ni. **Javob:** *106,2 kPa*; *86,2* sm^3

13.25. $V=3\ \ell$ hajmli ballonda $\nu=1\ mol$ miqdordagi $T=300\ K$ temperaturali karbonat angidrid gazi bor. Gazning P bosimini aniqlang: a) Mendeleyev-Klapeyron tenglamasi orqali; b) Van-der-Vaals tenglamasi orqali. **Javob:** *8,31 MPa; 5,67 MPa*

13.26. Qalin devorli po‘lat ballon hajmining yarmigacha suv bilan to‘ldirildi. So‘ngra uning og‘zi berkitildi va $T=650\ K$ temperaturagacha qizdirildi. Bu temperaturada ballondagi suvbug‘ining P bosimi nimaga teng bo‘ladi? **Javob:** *544 MPa*

13.27. T=380 K temperatura va V hajmda olingan suv bug‘ining bosimi P ni aniqlang. Bunda hisoblashni V hajm: a) 1000 ℓ; b) 10 ℓ; c) 2 ℓ bo‘lgan hollar uchun bajaring. **Javob:** *174 kPa; 3,94 MPa; 101 MPa*

13.28.

14-MAVZU: Suyuqliklarni xossalari. Sirt taranglik va kapillyar hodisalar. Laplas bosimi. Osmotik bosim. To‘yingan bug‘. Nisbiy va absalyut namlik.

Mavzuga oid muhim formulalar

$F_{tar} = \sigma \ell$	*Sirt taranglik kuchi*
$m = \frac{2\pi\sigma R}{g}$	*Jo‘mrakdan tomadigan tomchining massasi*
$h = \frac{2\sigma}{\rho r g}$	*Kapillyar naychada suyuqlik sathining ko‘tarilishi*
$\Delta P = \frac{F_{tar}}{S}$ *yoki* $\Delta P = \frac{2\sigma}{r}$	*Laplas bosimi*
$W = \sigma S$	*Erkin sirt potensial energiyasi*
$A = W_2 - W_1 = 8\pi\sigma\left(R_2^2 - R_1^2\right)$	*Sovun pufagini kattalashtirishda tashqi kuch bajargan ish*
$W = \sqrt[3]{n^2}\cdot W$	*n ta tomchining qoshilishidan hosil bo‘lgan katta tomchining erkin sirt energiyasi*
$\varphi = \frac{P_0}{P_T}\cdot 100\%$	*Nisbiy namlik*

14-amaliy mashg‘ulot uchun dars ishlanmasi

Masala № 1. *Havo pufagi suv sirtidan qanday chuqurlikda bo‘lganda undagi havoning zichligi 2 kg/m³ ga teng bo‘ladi? Pufakning diametri 0,015 mm, temperaturasi 20⁰C va atmosfera bosimi 760 mm.sm.ust.ga teng.*

Berilgan:

$d = 1{,}5\cdot 10^{-4}\ m$

$\rho_h = 2\ kg/m^3$

$\rho_s = 1000\ kg/m^3$

$T = 293\ K$

$P_0 = 10^5\ Pa$

$M_h = 29\ g/mol$

$\sigma = 73\ mN/m$

h=?

Yechilishi:

Suv sirtidan h *chuqurlikda turgan havo pufagi 3ta bosim ta’siri ostida, ya’ni atmosfera bosimi* (P_0) *, gidrostatik bosim* (P_{gid}) *va suyuqlik sirtining egrilanishidan vujudga keladigan Laplas* (ΔP) *bosimlari ta’siri ostida bo‘ladi.*

$$P = P_0 + P_{gid} + \Delta P \quad (1)$$

Girostatik bosim $P_{gid} = \rho g h$, *Laplas bosimi* $\Delta P = \frac{4\sigma}{d}$ *ga tengligini e’tiborga olsak,*

$$P = P_0 + \rho g h + \frac{4\sigma}{d} \quad (2)$$

bo'ladi. Ideal-gaz holat tenglamasiga ko'ra pufak ichidagi havoning bosimi

$$PV = \frac{m}{M}RT, \ \rightarrow \ P = \frac{\rho_h RT}{M_h} \qquad (3)$$

ga teng bo'ladi. (2) va (3) ifodalarni tenglashtirsak,

$$\rho_h RT = P_0 + \rho gh + \frac{4\sigma}{d}$$

bo'ladi. Bundan chuqurlik

$$h = \frac{1}{\rho_s g}\left(\frac{\rho_h RT}{M_h} - P_0 - \frac{4\sigma}{d}\right)$$

formulasi kelib chiqadi. Endi faqat hisoblash ihi qoldi.

$$h = \frac{1}{1000 \cdot 9{,}8}\left(\frac{2 \cdot 8{,}31 \cdot 293}{0{,}029} - 10^5 - \frac{4 \cdot 0{,}073}{1{,}5 \cdot 10^{-4}}\right) = 4{,}94\, m.$$

Javob: $h = 4{,}94\ m$.

Masala № 2. *Radiusi 5 sm bo'lgan sim halqa sovun eritmasiga gorizontal botirildi. Halqaning massasi 7,5 g, sovun eritmasining sirt taranglik koeffitsienti 40 mN/m bo'lsa, necha nyuton kuch yordamida halqani eritmadan ajratib olish mumkin?*

A) 0,025 B) 0,075 C) 0,1 D) 0,05 E) 0,086

Berilgan:

$R = 5 \cdot 10^{-2}\ m$

$m = 7{,}5 \cdot 10^{-3}\ kg$

$\sigma = 4 \cdot 10^{-2}\ \frac{N}{m}$

$F - ?$

Yechish:

Xalqani tortib olish uchun $F = F_{st} + mg$ *teng kuch kerak,* $F = 2\sigma l + mg = 2\sigma \cdot 2\pi R + mg = 4\pi\sigma R + mg$

$F = 4 \cdot 3{,}14 \cdot 4 \cdot 10^{-2} \cdot 5 \cdot 10^{-2} + 7{,}5 \cdot 10^{-3} \cdot 10 = 0{,}1\ N$

Javob: $0{,}1\ N$ *S*

Masala № 3. *Agar 1 m³ havoda 15 g suv bug'i bo'lsa, uzunligi 70 m, eni 7 m va balandligi 4 m bo'lgan maktab koridorida necha kg suv bug'i bor?*

Berilgan:

$V = 1m^3$

$m = 15\ gr$

$l = 70\ m$

$a = 7\ m$

$b = 4\ m$

$m_h - ?$

Yechish:

Xonaning hajmini quyidagi formuladan topamiz, bunda xona parallelpiped shaklda deb hisoblab formulasini yozamiz: $V = a \cdot b \cdot l = 70 \cdot 7 \cdot 4 = 1960\ m^3$ *, agar* $1m^3$ *hajmda 15 g massali suv bug'i bo'lsa, u holda* V *hajmda* m_h *suv bug'i massasini aniqlaymiz:*

$1m^3 - 15\ gr$

$V - m_h$ *proporsiyadan* m_h *ni topamiz* $m_h = \frac{15\ gr \cdot V}{1m^3}$

endi hisoblaymiz:

$$m_h = \frac{15\ gr \cdot 1960\ m^3}{1m^3} = 29400\ gr = 29{,}4\ kg$$

Javob: *29,4 kg*

Masala № 4. *Suv bug'ining 19°C haroratdagi parsial bosimi 1,1 kPa bo'lsa, havoning nisbiy namligi qanday (%)? 19°C da to'yingan bug' bosimi 2,2 kPa.*

Berilgan:	*Yechish:*
$P = 1{,}1\ kPa$	$\varphi = \frac{P}{P_0} \cdot 100\%$ *formuladan topamiz*
$P_0 = 2{,}2\ kPa$	$\varphi = \frac{1{,}1}{2{,}2} \cdot 100\% = 50\%$
$\varphi - ?$	***Javob:*** 50%

14-amaliy mashg‘ulot topshirig‘i

14.23. 20^0C temperaturada hajmi *100* m^3 bo‘lgan xonada havoning nisbiy namligi 30 % ga teng. Bu xonada aynan shu temperaturada namlikni orttirish uchun qancha suv bug‘lantirish kerak? **Javob:** *0,52 kg*

14.24. Kunduzgi havoning temperaturasi 25^0C, nisbiy namligi *68%* ga teng edi. Kechasi temperatura 11^0C gacha tushdi. Bunda shudring tushadimi? Agar tushgan bo‘lsa, u holda havoning har bir metr kubida qancha suv ajraladi? **Javob:** *5,6* g/m^3

14.25. Massasi *9 g* bo‘lgan suv bug‘ini 30^0C temperaturada izotermik ravishda siqildi. Bu qanday hajmda kodensatsiyalana boshlaydi? **Javob:** *0,3* m^3

14.26. Ichida namlikni yutuvchi moddabo‘lgan naycha orqali *10 ℓ* havo o‘tkazilganda, havoning absolut namligi *30* g/m^3 ekanligi aniqlangan. Bunda naychaning massasi qanchaga ortgan? **Javob:** *0,3 g*

14.27. Ichida namlikni yutuvchi modda bo‘lgan naycha orqali *20 ℓ* havo o‘tkazilgan. Bunda naychaning massasi *400 mg* ortdi. Havoning absolut namligi qanday ? **Javob:** *20* g/m^3

14.28. Havoning nisbiy namligi *50%*, temperaturasi *16°C* bo‘lsa, absolut namlik qanday bo‘ladi? *16°C* temperaturada to‘yingan bug‘ zichligi p_t=13,6·$10^{-3}kg/m^3$. **Javob:** 6,8 g/m^3

14.29. Hajmi *10* cm^3 bo‘lgan idishda parsial bosimi *100 kPa* bo‘lgan suv bug‘i bor. Agar to‘yingan suv bug‘ining *100°C* haroratdagi bosimi 10^5 *Pa* bo‘lsa, idishdagi havo uchun shudring nuqtasi qanday bo‘ladi (*K*)? **Javob:** *373 K*

14.30. Agar shudring nuqtasi *9°C* bo‘lsa, harorati 20°C bo‘lgan havoning nisbiy namligi necha % bo‘ladi? To‘yingan bug‘ bosimi *20°C* da *2,33 kPa* ga, *9°C* da esa *1,15 kPa* ga teng. **Javob:** *50 %*

14.31. Suv shishadan ysalgan kapillyar naychada *40 sm* balandlikka ko‘tarildi. Bu naychaning ichki diametrini aniqlang. **Javob:** $7{,}4\cdot10^{-5}$ *m*

14.32. Radiusi *2 mm* bo‘lgan simob tomchisini teng ikkiga bo‘lish uchun qanday ish bajarish kerak? Simobning sirt taranlik koeffitsiyenti $\sigma = 0{,}46\ N/m$. **Javob:** $6\cdot10^{-6}$ *J*

14.33. Suv diametri *0,1 mm* bo‘lgan kapillyarda qanday balandlikka ko‘tariladi? **Javob:** *0,3 m*

14.34. Diametri *10 sm* bo‘lgan sovun pufagidagi qo‘shimcha bosimni aniqlang. Sirt taranlik koeffitsiyenti $\sigma = 0{,}04\,N/m$. **Javob:** *3,2 Pa*

14.35. Radiusi $1\mu m$ bo‘lgan suv tomchisida sirt taranglik kuchi hisobiga qanday qo‘shimcha bosim hosil qilish mumkin? **Javob:** *150 kPa*

14.36. Ichki diametrlari *0,4* va *1 mm* bo‘lgan kapillar naychalar zichligi *800* kg/m^3 va sirt taranglik koeffitsienti 22 mN/m bo‘lgan suyuqlikka tushirildi. Naychalardagi suyuqlik sathlari farqini toping (mm). **Javob:** *16,5 mm*

14.37. Diametri *0,3 mm* bo‘lgan kapillyarda kerosin *20 mm* ko‘tarildi. Kerosinning sirt taranglik koeffitsientini aniqlang(mN/m). $\rho = 0{,}8\ g/sm^3$. **Javob:** *12 mN/m*

14.38. Sovun pardasi bilan qoplangan ramkada pastki tomonda bo‘lgan kashagining uzunligi *15 sm* ga teng. Pardani *4 sm* ga cho‘zish uchun sirt taranglik kuchlariga qarshi qancha ish bajarish kerak? Suyuqlikning sirt taranglik koeffitsiyenti $\sigma = 45\cdot10^{-3}\ N/m$. **Javob:** *0,54 mJ*

14.39. Sovun pufakchasini puflab, uning diametrini *1 sm* dan *9 sm* gacha orttirish uchun sirt taranglik kuchlariga qarshi qancha ish bajarish kerak? **Javob:** *2,3 mJ*

14.40. Pilik suvni *8 sm* ga ko‘taradi. Shu pilik bo‘ylab kerosin qancha balandlikka ko‘tariladi? Suv uchun $\rho = 1000\ kg/m^3$, $\sigma = 73\cdot10^{-3}\ N/m$ va kerosin uchun $\rho = 800\ kg/m^3$, $\sigma = 30\cdot10^{-3}\ N/m$. **Javob:** *4,1 sm*

14.41. Suv sirtidan *20 sm* chuqurlikda bo‘lgan *0,01 mm* diametrli havo pufakchasidagi havoning bosimi aniqlansin. Tashqi bosim *765 mm.sm.ust*.ga teng. **Javob:** *999 mm.sm.ust*

14.42. Vertikal mahkamlangan *1 mm* diametrli qo‘rg‘oshin simning pastki uchidan eritilganda 20 ta qo‘rg‘oshin tomchisi tomgan. Bunda sim necha santimetrga qisqargan? Suyuq qo‘rg‘oshinnning sirt taranglik koeffitsiyenti *0,47 N/m* ga teng. Tomchining uziladigan joyining diametrini simning diametriga teng deb oling. **Javob:** *34 sm*

14.43. Barometrik naychaning ichki diametri *7,5 mm*. Atmosfera bosimini simob ustunining balandligi orqali aniqlanganda qanday tuzatma kiritish kerak? Simobni mutlaq ho‘llamaydigan suyuqlik deb oling. **Javob:** $\Delta P = 2\,mm.sm.ust$.

14.44.

15-MAVZU: Qattiq jismlarni xossalari, kristallar va amorf jismlar. Jismlarning issiqlikdan kengayishi. Chiziqli va hajmiy kengayish koeffitsiyentlari.

Mavzuga oid muhim formulalar

$\Delta\ell = \alpha \ell_0 t$	*Sterjenning issiqlikdan qo'shimcha uzayishi*
$\ell = \ell_0(1+\alpha t)$	*Sterjenning ixtiyoriy temperaturadagi uzunligi*
$S = S_0\left[1+(\alpha_1+\alpha_2)t\right]$ $V = V_0\left[1+(\alpha_1+\alpha_2+\alpha_3)t\right]$	*Anizatropik jismning issiqlikdan sirtiy va havmiy kengayishi*
$\beta = \alpha_1+\alpha_2+\alpha_3, \quad \gamma = \alpha_1+\alpha_2$	*Anizatropik jismning issiqlikdan havmiy va sirtiy kengayish koeffitsiyentlari*
$S = S_0\left[1+2\alpha t\right] = S_0\left[1+\gamma t\right]$ $V = V_0\left[1+3\alpha t\right] = V_0\left[1+\beta t\right]$	*Izatropik jismning issiqlikdan sirtiy va havmiy kengayishi*
$\beta = 3\alpha, \quad \gamma = 2\alpha$	*Izatropik jismning issiqlikdan sirtiy va havmiy kengayish koeffitsiyentlari*

15-amaliy mashg'ulot uchun dars ishlanmasi

Masala № 1. *Ko'ndalang kesimi 2 cm^2 bo'lgan po'lat tayoqchaga og'irligi $3\cdot10^4$ N bo'lgan yuk osilgan. Tayoqchaning mexanik kuchlanishi topilsin.*

Berilgan:

$F = 3\cdot10^4\ N$

$S = 2\ sm^2$

$\sigma - ?$

Yechish:

$\sigma = \frac{F}{S}$ *formuladan topamiz*

$\sigma = \frac{F}{S} = \frac{3\cdot10^4}{2} = 1{,}5\cdot10^4\ \frac{N}{sm^2}$

Javob: $1{,}5\cdot10^4\ \frac{N}{sm^2}$

Masala № 2. *150^0C temperaturali mis sim ikkita qo'zg'almas devor orasiga tarang qilib tortilgan. Soviganda sim qanday temperaturada uziladi? Guk qonuni simning uzilishiga qadar o'rinli deb hisoblang.*

Berilgan:

$t_1 = 150^0C$

$\alpha = 1{,}6\cdot10^{-5}\ K^{-1}$

$[\sigma] = 2{,}45\cdot10^8\ Pa$

$E = 11{,}8\cdot10^{10}\ Pa$

t_2 *=?*

Yechilishi:

Mis simning dastlabki uzunligini ℓ_1 bilan, sovigandagi uzunligini ℓ_2 bilan belgilasak, u holda sovish natijasida simning nisbiy uzayishi

$$\frac{\ell_2-\ell_1}{\ell_2} = -\frac{\Delta\ell}{\ell_2} = \alpha(t_2-t_1) \quad (1)$$

bo'ladi. Bu yerda: α – misning issiqlikdan chiziqli kengayish koeffitsiyenti.

Temperatura pasaya borishi bilan sim ham qisqarib taranglasha boradi. Deformatsiyalanish tufayli yuzaga kelgan kuchlanish ortib boradi. Guk qonuniga ko'ra deformatsiyalanishdagi nisbiy uzayish

$$\frac{\Delta\ell}{\ell_2}=\frac{[\sigma]}{E} \qquad (2)$$

bo'ladi. (1) va (2) dan so'talgan kattalikni topamiz.

$$-\alpha(t_2-t_1)=\frac{[\sigma]}{E},\ \rightarrow\ t_2=t_1-\frac{[\sigma]}{\alpha E}$$

Endi hisoblaymiz.

$$t_2=150-\frac{2{,}4\cdot10^8}{1{,}6\cdot10^{-5}\cdot11{,}8\cdot10^{10}}=20^0C\,.$$

Javob: $t_2=20^0C$.

15-amaliy mashg‘ulot topshirig‘i

15.24. Diametri *2 cm* bo‘ljgan simga *10 kg* yuk osilgan bo‘lsa, mexanik kuchlanish qanha bo‘ladi? **Javob:** *320 kPa*

15.25. Yuk osilganda sim *9 mm* cho‘zildi. Xuddi shunday, lekin 2 marta uzun sim shu yuk osilganda necha mm cho‘ziladi? **Javob:** *9 mm*

15.26. *30 kN* yuklanish berilganda, $6\cdot10^7$ *N/m²* mexanik kuchlanisn hosil bolishi uchun po‘lat sterjenning ko‘ndalang kesim yuzi qancha bo‘lishi kerak? **Javob:** *5 sm²*

15.27. Birining uzunligi ikkinchisinikidan 2 marta katta bo‘lgan, bir xil materialdan tayyorlangan ikkita sim teng mexanik kuchlanish ta’sirida cho‘zilsa, nisbiy uzayish ularning qaysi birida katta va necha marta katta bo‘ladi? **Javob:** *Ikkkalasida bir xil*

15.28. Kuchni o‘zgartirmasdan deformatsiyalanuvchi simni o‘sha moddadan yasalgan o’shanday uzunlikdagi, lekin diametri 2 marta katta bo‘lgan sim bilan almashtirilsa, uning mutlaq uzayishi qanday o‘zgaradi? **Javob:** *4 marta kamayadi*

15.29. Havoda qo‘zg‘almas bo‘lgan aerostatdan temir sim tushirildi. Simning uchi Yer sirtidan *10 m* balandlikda bo‘lganda sim og‘irlik kuchi ya’siri ostida uzilib ketdi. Aerostat qanday balandlikda bo‘lgan& Temirning mustahkamlik chegarasi $2\cdot10^8\ \frac{N}{m^2}$, zichligi $7800\frac{kg}{m^3}$. **Javob:** *2626 m*

15.30. Ko‘ndalang kesim yuzi o‘zgarmas bo‘lgan g‘shtdan qurilayaotgan devorni qancha balandlikkacha ko‘tarish mumkin? G‘ishtning zichligi $1800\frac{kg}{m^3}$, mustahkamlik chegarasi $5\cdot10^6\ \frac{N}{m^2}$. **Javob:** *280 m*

15.31. Uzunligi *2 m*, ko‘ndalang kesim yuzi *2* mm^2 bo‘lgan temir simga balandligi *20 sm* va ko‘ndalang kesim yuzi *4* sm^2 bo‘lgan temir slindr osildi. Simning deformatsiyasi elastik bo‘ladimi? Agar elastik bo‘lsa, u holda absalyut uzayish qanday? **Javob:** *Elastik,* $\Delta\ell=3\ mm$

15.32. Ko‘ndalang kesiminig yuzasi *10* sm^2 bo‘lgan sterjaenni 0^0C dan 30^0C gacha isitilganda cho‘zilmasligi uchun uning uchlariga qanday kuch qo‘yish kerak? **Javob:** *71 kN*

15.33. Biror metallni 0^0C dan 500^0C gacha isitilganda uning zichligi *1,027* marta kamaygan bo‘lsa, bu metallning issiqlikdan chiziqli uzayish koeffitsiyenti nimaga teng? **Javob:** $1{,}8\cdot10^{-5}\ K^{-1}$

15.34.

ILOVALAR

1 – javal

ASOSIY FIZIK KATTALIKLAR

Kattalikning nomi	**Belgisi**	**Son qimyati**
Erkin tushish tezlanishi	g	9,81 m/s^2
Tortishish doimiysi	γ	$6{,}67 \cdot 10^{-11}$ kg/s^2
Avagadro soni	N_A	$6{,}02 \cdot 10^{23}$ mol^{-1}
Gazning unversal doimiysi	R	8,31 J(mol^{-1})
Boltsman doimiysi	k	$1{,}38 \cdot 10^{-23}$ J/k
Elektronning zaryadi	l	$1{,}6 \cdot 10^{-19}$ kl
Elektronning massasi	m_e	$9{,}1 \cdot 10^{-31}$ kg
Faradey soni	F	$9{,}85 \cdot 10^{4}$ kl/mol
Elektr doimiysi	ε_0	$8{,}5 \cdot 10^{-12}$ f/m
Magnit doimiysi	μ_0	$4 \cdot 10^{-7}$ Gn/m
Yorug'likning vakumdagi tarqalish tezligi	c	$3 \cdot 10^{8}$ m/s
Stefan – Bolsman doimiysi	G	$5{,}67 \cdot 10^{-8}$Wt/m^{2}k^4/
Plank doimisi	h	$6{,}625 \cdot 10^{-24}$ J$\cdot$s
Vodorod atomi uchun Ridberg doimiysi	R	$1{,}097 \cdot 10^{7}$m^{-1}
Birinchi Bor orbitasining doimiysi	r_1	$0{,}629 \cdot 10^{-10}$m
Bor magentioni	μ_b	$0{,}927 \cdot 10^{-24}$J/Tn
Vodorod atomining ionizatsiya energiyasi	E_1	13,6 eV
Massaning atom birligi	$m.a.b$	$1{,}666 \cdot 10^{-23}$kg
Neytronning massasi	m_n	$1{,}666 \cdot 10^{-24k}$g
α – zarraning massasi	m_α	$6{,}64 \cdot 10^{-27}$kg
Massa va energiy orasidagi bog'lanishning proportsionallik foeffitsenti	c^2	$9 \cdot 10^{12}$ j/kg yoki 931 MEV/m.a.b

2 - jadval

SIRPANISH ISHQALANISH KOEFFITSIYENTI

Yog`och bilan yog`och (dub)……. 0,50
Yog`och bilan quruq yer…….0,71
Po`lat bilan po`lat…….0,13
Po`lat bilan muz……0,2
Ko`mir bilan mis……..0,25

3- jadval

YONILG`INING YONISH SOLISHTIRMA ISSIQLIGI, MJ/kg

Benzin…… …..46
Yog`och……..10
Dizel yonilg`i… ..42
Tosh ko`mir…….29
Kerosin…… ..46
Neft……..46
Porox……3
Spirt……29
Shartli yonilg`si….29

4 - jadval

BA'ZI QATTIQ JISMLARNING ISSIQLIK XOSSALARI

Modda	Zichlik, $\cdot 10^3$, kg/m^3	Solishtirma issiqlik sig'imi, J /kg·K	Solishtirma erish issiqligi, kJ /kg	Issiqlik o'tkazuvchalik koeffitsiyenti, W/(m · K)	Chiziqli kengayish koeffitsiyenti, $\cdot 10^{-5}$ K^{-1}	Erish temperaturasi, ^{0}C
Alyuminiy	2,7	880	321	210,0	2,3	659
Kumush	10,7	234	88	420,0	1,9	960
Qo'rg'oshin	11,4	126	22.4	35,0	2,9	327
Qalay	7,3	230	58,5	60,0	2,7	232
Muz	0,9	200	335	2,2	-	0
Mis	8,9	380	176	390,0	1,6	1100
Platina	21,4	117	114	70,0	0,89	1770
Po'lat	7,8	460	205	50,0	1,06	1300
Temir	7,8	449	272	92	1,2	1530
Latun	8,5	386	-	97–110	1,9	900

5 - jadval

BA'ZI SUYUQLIKLARNING XOSSALARI

Modda	Zichlik, $\cdot 10^3$ kg/m^3	20^{0}C dagi solishtirma issiqlik sig'imi J/(kg·K)	20^{0}C dagi sirt tarangligi koeffitsiyenti, N/m	Qovushqoqlik (20^{0}da) 10^4, N · c/m
Benzol	0,9	1720	0,028	6,30
Glitserin	1,20	2430	0,059	14990,0
Kerosin	0,8	2140	0,024	1800,0
Suv	0,95	4187	0,072	10,0
Simob	13,6	125	0,470	1554
Spirt	0,79	2430	0,022	11,9

6 - jadval

BA’ZI ASTRANOMIK KATTALIKLAR

Nomlanishi	Son qiymati
Yerning radiusi	$6{,}37 \cdot 10^4$ m
Yerning massai	$6{,}98 \cdot 10^{24}$ kg
Quyoshning radiusi	$6{,}95 \cdot 10^8$ m
Quyoshning massasi	$1{,}98 \cdot 10^{30}$ kg
Oyning radiusi	$1{,}74 \cdot 10^6$ m
Oyning massasi	$7{,}33 \cdot 10^{22}$ kg
Yerning markazidan Quyoshning markazigacha bo’lgan masofa	$1{,}49 \cdot 10^{11}$ m
Yerning markazidan Oyning markazigacha bo’lgan masofa	$3{,}84 \cdot 10^8$ m

7-jadval

GAZ MOLEKULALARINING EFFEKTIV DIAMETRI

Gaz	**Diametri d, *nm***	**Dinamik qovushqoqlik η, *μPa·s (300K da)***	**Issiqlik o’tkazuvchanlik koeffitsiyenti χ , *mW/(m · K) (300 K da)***
Azot	0,38	16,6	24,3
Argon	0,35	22,9	16,2
Vodorod	0,28	8,66	16,8
Geliy	0,22	20	-
Kripton	0,32	23,3	8,54
Karbonad angidrid	0,45	14	14,7
Kislorod	0,36	19,8	24,4
Neon	0,35	31,1	49,3
Simob	0,30	1526	8300
Xlor	0,45	13	-
Suv bug‘i	-	8,32	15,8
Havo	-	18,6	24,1

8 - jadval

MODDALARNING FIZIK XOSSALARI

Kattalik / Modda	Zichlik $10^3 \frac{kg}{m^3}$	Solishtirma issiqlik sig`imi kJ/kg x K	Solishtirma erish issiqligi kJ/kg	Erish harorati, ^0C	Normal bosimda bug` hosil bo`lish solishtirma issiqligi, MJ/kg
Qattiq jismlar					
Alyuminiy	2,7	0,88	380	660	-
Muz	0,9	2,1	330	0	-
Mis	8,9	0,38	180	1883	-
Qalay	7,3	0,23	59	232	-
Qo`rg`oshin	11,3	0,13	25	327	-
Kumush	10,5	0,21	87	960	-
Po`lat	7,8	0,46	82	1400	-
Latun	8,5	0,38	-	1000	-
Nikel	8,8	-	-	-	-
Suyuqliklar					
Kerosin	0,80	2,1	-	-	-
Suv	1,0	4,2	-	-	2,3
Neft	0,80	2,1	-	-	-
Simob	13,8	0,13	-	-	0,29
Spirt	0,79	2,4	-	-	0,85
Benzin	0,71	2,1	-	-	0,3
Gazlar					
Azot	1,25	1,0	-	-	-
Vodorod	0,09	14,0	-	-	-
Havo	1,29	1,0	-	-	-
Kislorod	1,43	0,92	-	-	-
Geliy	0,18	5,21	-	-	-

9-jadval.

BA’ZI QATTIQ JISMLARNING ELASTIKLIK XOSSALARI

Modda	Mustaxkamlik chegarasi 10^8 /m	Yung moduli 10^{10} N/m^3
Alyuminiy	1,10	6,90
Temir	2,94	19,60
Kumush	2,90	7,40
Qo’rg’oshin	0,2	1,57
Mis	2,45	11,80
Po’lat	7,85	21,60

10-jadval

BA'ZI GAZLARNING NORMAL SHAROIDA ZICHLIGI VA QOVUSHQOQLIGI

Gaz	Zichligi, kg/m^3	Qovushqoqligi, μPa/s	Gaz	Zichligi, kg/m^3	Qovushqoqligi, μPa/s
Azot	1,25	17,0	Geliy	0,18	18,80
Ammiak	0,75	9,35	Karbonad angidrid	1,97	14,30
Argon	1,78	21,20	Kislorod	1,43	19,80
Vodorod	0,09	8,52	Xavo	1,29	17,10

11 –jadval

VAN-DER-VALS DOIMIYLIGI VA T_K, P_K , V_K PARAMETRLAR

Modda	$a,\ \frac{at \cdot m^6}{kmol^2}$	$b,\ \frac{m^3}{kmol}$	T_{kr} , K	$P_{k\,r,}$ at	$V_{kr.m}$, $m^3/kmol$	$R/(kN_A)$
Azot	1,39	0,039	126,0	34,8	0,09	0,782
Argon	1,36	0,032	151,0	48,7	0,0242	
Vodorod	0,194	0,022	33,2	13,2	0,065	0,813
Geliy	0,035	0,024	5,2	2,34	0,058	0,821
Karbonad angidrid	3,72	0,043	304,1	75	0,096	0,745
Kislorod	1,4	0,032	154,3	51,4	0,075	0,768
Xlor	6,5	0,056	417	79,91	0,0187	
Suv bug'i	5,65	0,031	647,3	225	0,056	0,602
Vodorod xlorid	0,922	0,020	324,6	86	0,060	0,469

12 –jadval

BA'ZI ZARRALARNING MASSA VA ENERGIYALARI

Zarra	Massa		Energiya	
	10^{-27}kg	m.a.b	10^{-10}J	MeV
Proton	1,672	1,00728	1,50	988,0
Neytron	1,675	1,00867	1,51	939,0
Deytron	3,350	2,01355	3,00	1876,0
Neytral π – mezon	2,410	0,14526	2,16	135,0
α - zarra	6,640	4,00148	5,96	3733,0
Elektron	0,00091	0,00055	0,00082	0,511

Ba’zi moddalarning molyar massasi [*kg/mol*]

Kislorod atomi(O)	$16\cdot10^{-3}$	Propan (C_3H_8)	$44\cdot10^{-3}$
Kislorod molekulasi(O_2)	$32\cdot10^{-3}$	Geliy(He)	$4\cdot10^{-3}$
Vodorod atomi(H)	$1\cdot10^{-3}$	Temir(Fe)	$56\cdot10^{-3}$
Vodorod molekulasi(H_2)	$2\cdot10^{-3}$	Alyuminiy(Al)	$27\cdot10^{-3}$
Azot atomi(N)	$14\cdot10^{-3}$	Rux(Zn)	$65.4\cdot10^{-3}$
Azot molekulasi(N_2)	$28\cdot10^{-3}$	Qalay(Sn)	$119\cdot10^{-3}$
Xlor atomi (Cl)	$35,5\cdot10^{-3}$	Qo‘rg‘oshin(Pb)	$207.2\cdot10^{-3}$
Xlor molekulasi (Cl_2)	$70\cdot10^{-3}$	Simob(Hg)	$201\cdot10^{-3}$
Karbonat angidrid(CO_2)	$44\cdot10^{-3}$	Mis(Cu)	$63.6\cdot10^{-3}$
Argon(Ar)	$40\cdot10^{-3}$	Litiy(Li)	$7\cdot10^{-3}$
Is gazi(CO)	$28\cdot10^{-3}$	Oltin(Au)	$200\cdot10^{-3}$
Suv(H_2O)	$18\cdot10^{-3}$	Kumush(Ag)	$108\cdot10^{-3}$
Metan(CH_4)	$16\cdot10^{-3}$	Uran(U)	$238\cdot10^{-3}$
Etan(C_2H_6)	$30\cdot10^{-3}$	Havo	$29\cdot10^{-3}$

Psixrometrik jadval

Quruq termometrning ko‘rsatishi	Quruq va nam termometrlar ko‘rsatishlarining farqi										
	0	1	2	3	4	5	6	7	8	9	10
	Nisbiy namlik										
0	100	81	63	45	28	11	—	—	—	—	—
2	100	84	68	51	35	20	—	—	—	—	—
4	100	85	70	56	42	28	14	—	—	—	—
6	100	86	73	60	47	35	23	10	—	—	—
8	100	87	75	63	51	40	28	18	7	—	—
10	100	88	76	65	54	44	34	24	14	5	—
12	100	89	78	68	57	48	38	29	20	11	—
14	100	89	79	70	60	51	42	34	25	17	9
16	100	90	81	71	62	54	45	37	30	22	15
18	100	91	82	73	65	56	49	41	34	27	20
20	100	91	83	74	66	59	51	44	37	30	24
22	100	92	83	76	68	61	54	47	40	34	28
24	100	92	84	77	69	62	56	49	43	37	31
26	100	92	85	78	71	64	58	51	46	40	34
28	100	93	85	78	72	65	59	53	48	42	37
30	100	93	86	79	73	67	61	55	50	44	39

D.I.Mendeleevning elementlar davriy sistemasi

		I	II	III	IV	V	VI	VII	VIII
1	1	1 H 1,01 ВОДОРОД						(H)	2 4,00 He ГЕЛИЙ
2	2	3 Li 6,94 ЛИТИЙ	4 Be 9,01 БЕРРИЛЛИЙ	5 10,81 B БОР	6 12,01 C УГЛЕРОД	7 14,01 N АЗОТ	8 16,00 O КИСЛОРОД	9 19,00 F ФТОР	10 20,18 Ne НЕОН
3	3	11 Na 22,99 НАТРИЙ	12 Mg 24,31 МАГНИЙ	13 26,98 Al АЛЮМИНИЙ	14 28,09 Si КРЕМНИЙ	15 30,97 P ФОСФОР	16 32,06 S СЕРА	17 35,45 Cl ХЛОР	18 39,95 Ar АРГОН
4	4	19 K 39,10 КАЛИЙ	20 Ca 40,08 КАЛЬЦИЙ	21 44,96 Sc СКАНДИЙ	22 47,90 Ti ТИТАН	23 50,94 V ВАНАДИЙ	24 52,00 Cr ХРОМ	25 54,94 Mn МАРГАНЕЦ	26 55,85 Fe ЖЕЛЕЗО	27 58,93 Co КОБАЛЬТ	28 58,70 Ni НИКЕЛЬ
	5	29 63,55 Cu МЕДЬ	30 65,38 Zn ЦИНК	31 69,72 Ga ГАЛЛИЙ	32 72,59 Ge ГЕРМАНИЙ	33 74,92 As МЫШЬЯК	34 78,96 Se СЕЛЕН	35 79,90 Br БРОМ	36 83,80 Kr КРИПТОН		
5	6	37 85,47 Rb РУБИДИЙ	38 87,62 Sr СТРОНЦИЙ	39 88,91 Y ИТТРИЙ	40 91,22 Zr ЦИРКОНИЙ	41 92,91 Nb НИОБИЙ	42 95,94 Mo МОЛИБДЕН	43 98,91 Tc ТЕХНЕЦИЙ	44 101,07 Ru РУТЕНИЙ	45 102,91 Rh РОДИЙ	46 106,42 Pd ПАЛЛАДИЙ
	7	47 107,87 Ag СЕРЕБРО	48 112,41 Cd КАДМИЙ	49 114,82 In ИНДИЙ	50 118,69 Sn ОЛОВО	51 121,75 Sb СУРЬМА	52 127,60 Te ТЕЛЛУР	53 126,90 I ИОД	54 131,30 Xe КСЕНОН		
6	8	55 132,91 Cs ЦЕЗИЙ	56 137,33 Ba БАРИЙ	*57 138,91 La ЛАНТАН	72 178,49 Hf ГАФНИЙ	73 180,95 Ta ТАНТАЛ	74 183,85 W ВОЛЬФРАМ	75 186,21 Re РЕНИЙ	76 190,20 Os ОСМИЙ	77 192,22 Ir ИРИДИЙ	78 195,09 Pt ПЛАТИНА
	9	79 196,97 Au ЗОЛОТО	80 200,59 Hg РТУТЬ	81 204,37 Tl ТАЛЛИЙ	82 207,20 Pb СВИНЕЦ	83 208,98 Bi ВИСМУТ	84 [209] Po ПОЛОНИЙ	85 [210] At АСТАТ	86 [222] Rn РАДОН		
7	10	87 [223] Fr ФРАНЦИЙ	88 226,03 Ra РАДИЙ	**89 [227] Ac АКТИНИЙ	104 [261] Ku КУРЧАТОВИЙ	105 [261] Ns НИЛЬСБОРИЙ	106 [263] Sg СИБОРГИЙ	107 [262] Bh БОРИЙ	108 [265] Hs ХАССИЙ	109 [266] Hs МЕЙТНЕРИЙ	

Nisbiy atom massasi — Elementning belgilanishi

12,01 6 C УГЛЕРОД

Atom nomeri

- s - элемент
- p - элемент
- d - элемент
- f - элемент

* Lantanaoidlar

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce 140,12 ЦЕРИЙ	Pr 140,91 ПРАЗЕОДИМ	Nd 144,24 НЕОДИМ	Pm [145] ПРОМЕТИЙ	Sm 150,40 САМАРИЙ	Eu 151,96 ЕВРОПИЙ	Gd 157,25 ГАДОЛИНИЙ	Tb 158,93 ТЕРБИЙ	D y 162,50 ДИСПРОЗИЙ	Ho 164,93 ГОЛЬМИЙ	Er 167,26 ЭРБИЙ	Tm 168,93 ТУЛИЙ	Yb 173,04 ИТТЕРБИЙ	Lu 174,97 ЛЮТЕЦИЙ

** Aktinaoidlar

90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th 232,04 ТОРИЙ	Pa 231,04 ПРОТАКТИНИЙ	U 238,03 УРАН	Np 237,05 НЕПТУНИЙ	Pu [244] ПЛУТОНИЙ	Am [243] АМЕРИЦИЙ	Cm [247] КЮРИЙ	Bk [247] БЕРКЛИЙ	Cf [251] КАЛИФОРНИЙ	Es [254] ЭЙНШТЕЙНИЙ	Fm [257] ФЕРМИЙ	Md [258] МЕНДЕЛЕВИЙ	(No) [255] НОБЕЛИЙ	(Lr) [256] ЛОУРЕНСИЙ

Foydalanilgan adabiyotlar ro‘yxati

Asosiy adabiyotlar

1. K.A.Tursunmetov, A.A.Uzoqov, I.Bo‘riboyev, A.M.Xudoyberganov. Fizikadan masalalar to‘plami. “O‘qituvchi” nashriyoti. Toshkent.: 2001, 256 b.
2. O‘.Q.Nazarov, X.Z.Ikromova, K.A.Tursunmetov. Umumiy fizika kursi (Mexanika va molekulyar fizika). “O‘zbekiston” nashriyoti. Toshkent.: 1992, 280b.
3. Q.P.Egamov, O‘.Egamov. Fizika, darslik. “Aloqachi” nashriyoti. Toshkent.: 2013, 507b.

Qo‘shimcha adabiyotlar

1. Hojiyev B.I. Fizika. 2008. “Fan” nashriyoti.
2. Suyarov Q. T. va boshqalar. Mexanika va molekulyar fizika - T.: "O'qituvchi", 2002.
3. Suyarov Q. T va boshqalar. Fizika. I kitob. Mexanika. - T.: "Yangi nashr", 2009.
4. Suyarov Q. T., Usmonov Sh., Usarov. J. Fizika. II kitob. Molekulyar fizika. – T. "Yangi nashr", 2010.
5. Физика часть I . «Механика. Молекулярная физика, термодинамика» Т. М. Оплачко, К. А. Турмунметов.
6. A. A. Koptev, A. A. Pasko, A. A. Baranov. Maple v injenernыx raschetax. Tambovskiy gosudarstvennыy texnicheskiy universitet. – Tambov.: 2003
7. D.Djankoli. Fizika, 1-chast. Izdatelstvo “Mir”. Moskva.: 1989, 656 s.
8. D.Djankoli. Fizika, 2-chast. Izdatelstvo “Mir”. Moskva.: 1989, 673s.
9. A.N.Remizov, A.YA.Potapenko. Kurs fiziki. OOO «Drofa». Moskva.: 2002, 720 s.
10. Ronald J. Hershberger, James J. Reynolds. Calculus with Applications, the 2nd edition. Lexington, Massachusetts.: Copyright © 1993 by D.C. Heath and Company.
11. Halliday & Resnick. Principles of physics. Cleveland state university. Cover image from © M.Darlush/Shutterstock, 9th edition. 2011. 1248 pages.

MUNDARIJA