O’zbekiston respublikasi Oliy va O’rta maxsus ta’lim vazirligi

Al Xorazmiy nomli Urganch davlat universiteti

“Umuminjenerlik fanlari” kafedrasi

«Nazariy mexanika»
fanidan xisob-grafika ishlarini bajarish bo’yicha

Uslubiy qo’llanma

Bakalavriat: - **"Avtomobilsozlik va traktorsozlik" va “Yer usti transporti tizimlari va ularning ekspluatatsiyasi” ta’lim yo’nalishi talabalari uchun**

Urganch-2015.

Bekiyev M.A. “Nazariy mexanika” fanidan xisob-grafika ishlarini bajarish bo’yicha uslubiy qo’llanma. Urganch 2015 yil. 5 bet.

Ushbu uslubiy qo’llanmada “Nazariy mexanika” fanidan xisob-grafika ishlari "Avtomobilsozlik va traktorsozlik" va “Yer usti transporti tizimlari va ularning ekspluatatsiyasi” ta’lim yo’nalishlari bo’yicha ta’lim olayotgan talabalar uchun mo’ljallangan bo’lib, unda statika ,kinemetika va dinamika bolimlari bo’yicha xisob-grafika ishlarini bajarish namunasi hamda variantlar va jadvallar keltirilgan. Qo’llanmada xar bir mavzu bo’yicha xisob-grafika ishini bajarish namunasi va har bir talaba uchun variantlar jadval asosida berilgan.

Ushbu uslubiy qo’llanmadan barcha texnika ta’lim yo’nalishlari bo’yicha tahsil olayotgan talabalar ham foydalanishlari mumkin.

Taqrizchi; prof. Qutliyev U.O.

Uslubiy qo’llanma Urganch Davlat universiteti ilmiy-uslubiy kengashi tomonidan nashrga tavsiya qilindi.

“----------“ yil “----------“ № --------- sonli bayonnoma.

S’OZ BOSHI.

Mamlakatimiz oliy ta’limida bir pogonali tizimdan ikki pogonali bakalavr-magistr tizimiga utishi bilan barcha texnika fanlari katori, nazariy mexanika fanining xam axamiyati kattadir. Umuman olganda «Nazariy mexanika» fani moddiy jismlarning bir-biriga ta’siri va mexanik xarakatlarning umumiy konunlari xakidagi fandir.

«Nazariy mexanika» fanining o‘quv dasturi ma’ruza o‘qilishini, amaliy hamda talabalarning mustaqil ta’limi (ishi) bilan bog‘liq bo‘lgan hisob –grafik ishlarini (H.G.I.) o‘z ichiga oladi.

«Nazariy mexanika» fanini 2 semestr davomida o‘rganuvchi mutahassisliklarning talabalari har semestr davomida dastur buyicha hisob –grafik ishlarini bajaradilar. Xar bir hisob –grafik ishlarini bajarishda talabalar gurux jurnalidagi rakami bo’yicha o’z variantlarini olishlari uchun qo’llanmada variantlar keltirilgan. Ushbu uslubiy qo‘llanmada «Nazariy mexanika» fanining «Statika», «Kinematika» xamda «Dinamika» bo’limlariga oid hisob –grafik ishlaridan bitta variant to‘la izohlashlari bilan echib ko‘rsatilgan xamda to‘la izohlab tushuntirilgan.

Bu uslubiy qo‘llanma talabalarga hisob –grafik ishlarini bajarishda amaliy yordam ko‘rsatadi.

“ NAZARIY MEXANIKA ” FANIDAN BAJARILADIGAN HISOB-GRAFIK ISHLARINI BAJARISH VA HIMOYA QILISH TARTIBI.

Hisob-grafik ishlari (XGI) quyidagi bosqichlarga bo‘lingan holda bajariladi va himoya qilinadi.

1. Har bir talaba bu fan bo‘yicha amaliy mashg‘ulot darsini olib boruvchi o‘qituvchidan o‘zi bajarishi lozim bo‘lgan variant raqamini aniqlab oladi.

2. Tegishli variant avvalo daftarda echilib, o‘qituvchiga ko‘rsatiladi va o‘qituvchi vazifaning to‘g‘ri echilganligini qayd qilgach, qog’ozga ko‘chirish haqida ruxsat olinadi.

3. Hisob-grafika ishining jildida hisob-grafika ishining mavzusi, variant nomeri, talaba (bajardi) va hisob-grafika ishini qabul qiluvchi o‘qituvchining (qabul qildi) ismi sharifi yoziladi.

4. Hisob-grafika ishi uni bajargan talaba tomonidan himoya qilinadi va o‘qituvchi hisob-grafika ishiga tegishli mavzular bo‘yicha savol-javoblardan so‘ng talabaning hisob-grafika ishiga xar bir joriy baholashda 3ta baho(ball xisobida) qo’yiladi. Agar talaba hisob-grafika ishini himoya qila olmasa, qaytadan himoya qilish kuni belgilanadi.

5. Hisob-grafika ishi butun guruh talabalari oldida, ya’ni doskada yoki nazariy mexanika kursi bo‘yicha amaliy mashg‘ulot darslarini olib boruvchi o‘qituvchi ishtirokida himoya qilinishi mumkin.

6. Hisob-grafika ishiga qo‘yilgan reyting bali «Nazariy mexanika» fanidan semestr oxirida topshiriladigan yakuniy nazoratda e’tiborga olinadi. Hisob-grafika ishlarini bajarmagan yoki topshirmagan talaba bu fandan bo‘ladigan yakuniy nazoratga kiritilmaydi. SHuning uchun har

bir vazifani belgilangan muddatda bajarish va topshirish har bir talaba uchun zarur va shartdir.

Hisob-grafik ishlarini topshirish muddatini bu fan yuzasidan amaliy mashg‘ulotlarni olib boruvchi o‘qituvchi belgilaydi va kafedra e’lonlar doskasida ko‘rsatilgan bo‘ladi. Uzrli sabablar bilan hisob-grafika ishini o‘z vaqtida bajarmagan va topshirmagan talabalar uchun alohida jadval belgilanadi.

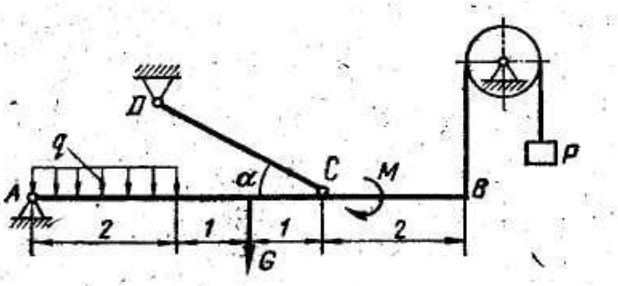
Xisob-grafika ishi №1
Qattiq jism tayanchlarining reaksiyalarini aniqlash. (Statika bo'limi)

Konstruksiya tayanchlarining reaksiyalari aniqlansin. Konstruksiyalar sxemalari 3-5-rasmlarda tasvirlangan (o'lchamlar - metrda), yuklanish 1-jadvalda keltirilgan.

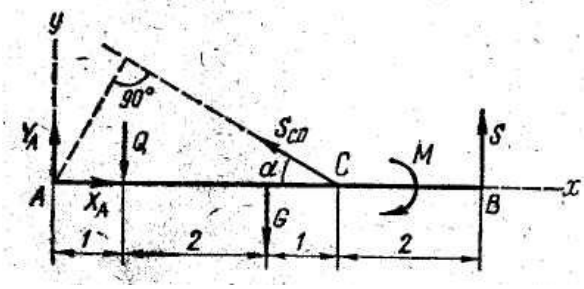
1-jadval

Номер варианта задания (рис. 9 — 11)	G, кН	P, кН	M, кНм	q, кН/м	α, град	Номер варианта задания (рис. 9—11)	G, кН	P, кН	M, кНм	q, кН/м	α, град
1	10	5	20	1	30	16	20	10	—	2	45
2	12	8	10	4	60	17	25	5	—	0,5	45
3	8	4	5	2	60	18	20	10	10	—	30
4	14	—	8	3	30	19	—	4	8	1	45
5	—	6	7	1	45	20	—	10	6	0,5	45
6	—	10	4	2	60	21	—	8	7	0,5	30
7	—	6	5	1	45	22	—	10	8	1	30
8	16	7	6	3	60	23	—	7	10	2	30
9	6	6	4	2	30	24	—	6	7	1,5	30
10	10	8	9	1	30	25	—	14	20	0,5	45
11	—	4	7	0,5	45	26	—	16	14	1	30
12	10	6	8	—	45	27	5	4	8	2,5	45
13	12	10	6	2	30	28	—	10	7	3	30
14	10	6	10	1	45	29	—	6	8	1	15
15	4	4	4	2	60	30	15	10	14	—	30

Masalani bajarishga doir misol. Berilgan: konstruksiya sxemasi (1-rasm); G=10,0 kN; P=5,0 kN; M=8,0 kNm; q=0,5 kN/m; $\alpha = 30°$, o'lchamlar - metrda.

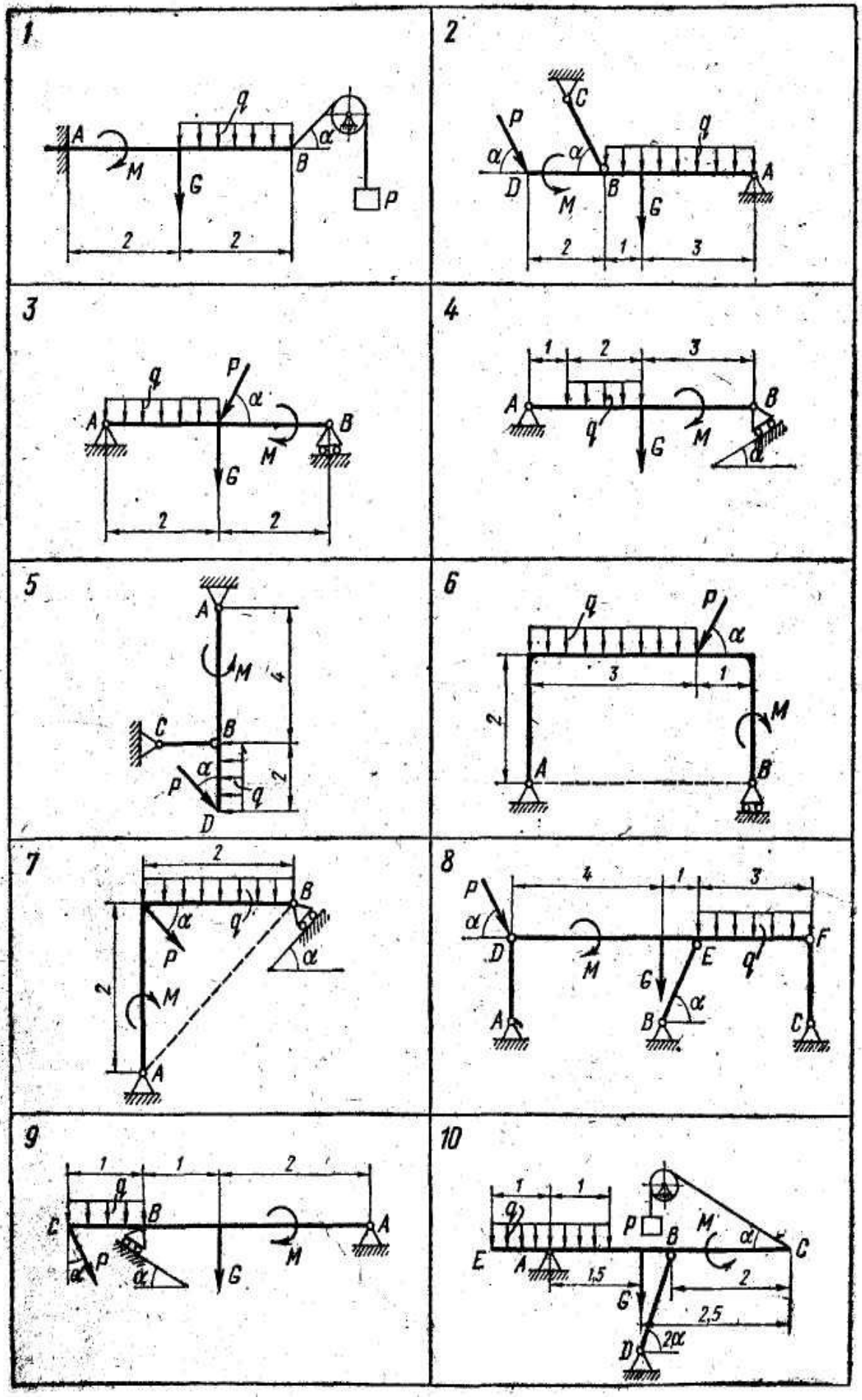


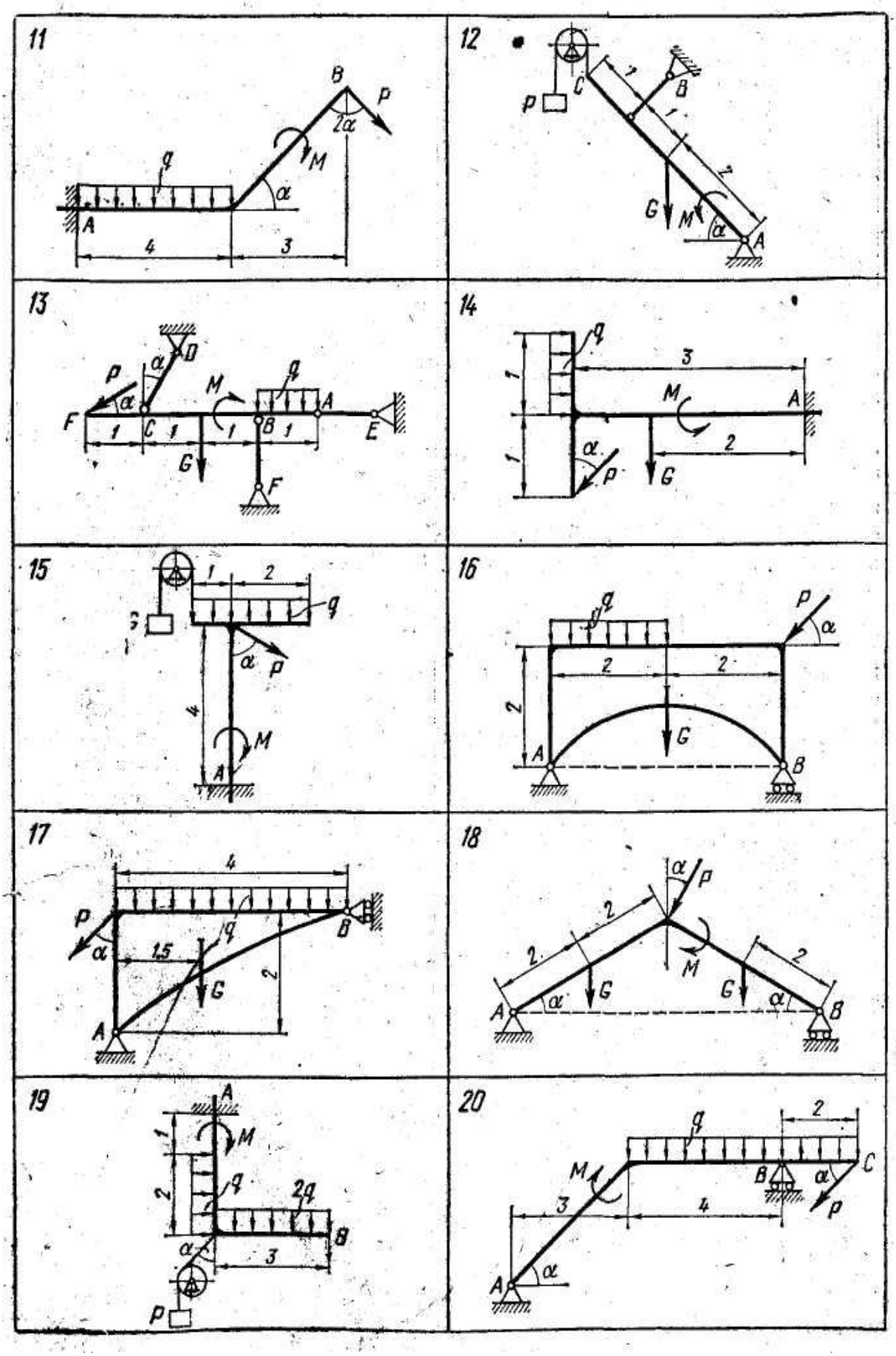
1-rasm.



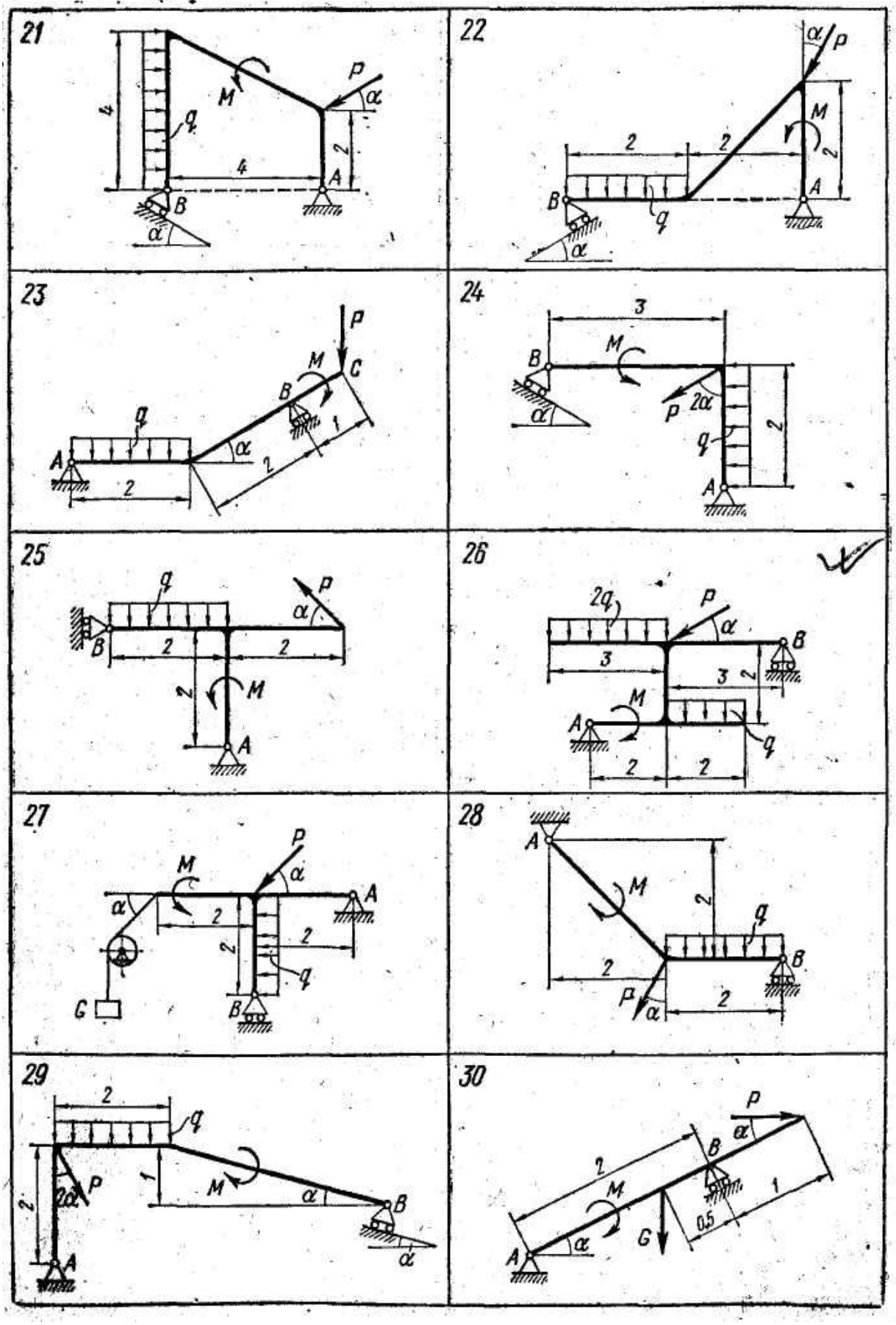
2-rasm.

Yechim. *AB* balkaga qo'yilgan muvozanatlashuvchi kuchlar sistemasini ko'rib chiqamiz. Bog'lanishlardan bo'shatamiz: *A* sharnirli-qo'zg'almas tayanchni, *CD* sterjenni va ipni. Bog'lanishlarning balkaga ta'sirini ularning reaksiyalari bilan almashtiramiz (2-rasm). *A* sharnirli-qo'zg'almas tayanchning reaksiyalari


1
A
M
q
G
B
α
P
2
2
2
C
P
α
D
M
q
B
G
A
2
1
3
3
q
P
α
A
B
M
G
2
2
4
1
2
3
A
B
q
G
M
α
5
A
M
4
C
B
α
P
q
2
D
6
q
P
α
3
1
M
2
A
B
7
2
B
α
q
P
α
2
M
A
8
4
1
3
P
α
D
M
E
q
F
G
α
A
B
C
9
1
1
2
q
C
B
A
α
P
α
G
M
10
1
1
q
P
B
M
α
C
E
A
1,5
2
G
2,5
D
2α


11
B
P
2α
M
q
α
A
4
3
12
C
B
P
1
1
2
G
M
α
A
13
D
α
P
α
M
q
A
F
1
C
1
1
B
1
E
G
F
14
q
3
1
M
A
1
α
2
P
G
15
1
2
q
α
P
4
M
A
16
q
P
α
2
2
2
G
A
B
17
4
P
α
B
1,5
q
G
2
A
18
α
P
2
2
M
2
G
G
α
α
A
B
19
A
M
1
2
q
2q
B
α
3
P
20
q
2
M
B
C
α
P
3
4
A
α

4-rasm.



5-rasm.

yo'nalishi noma'lum bo'lgani uchun, uning $\vec{X}_A$ va $\vec{Y}_A$ tashkil qiluvchilarini aniqlaymiz. Shuningdek CD sterjenning reaksiyasi $\vec{S}_{CD}$ va modul jihatdan P ga teng bo'lgan ipning reaksiyasi $\vec{S}$ ni tasvirlaymiz. q jadallikka ega tekis-taqsimlangan yuklanishni markazlashgan kuch Q bilan almashtiramiz, bu holda $Q = 2 \cdot q = 2 \cdot 0{,}5 = 1 kN$ ga teng bo'ladi va bu kuch ushbu yuklanish epyurasining og'irlik markaziga qo'yilgan bo'ladi.

Balkaga qo'yilgan tekis kuchlar sistemasi uchun uchta muvozanat tenglamalarini tuzamiz:

$$\sum M_{iA} = 0; \qquad -Q \cdot 1 - G \cdot 3 + S_{CD} \cdot 4 \cdot \sin 30° - M + S \cdot 6 = 0; \quad (1)$$

$$\sum X_i = 0; \qquad X_A - S_{CD} \cdot \cos 30^0 = 0; \quad (2)$$

$$\sum Y_i = 0; \qquad Y_A - Q - G + S_{CD} \cdot \cos 60^0 + S = 0; \quad (3)$$

(1) tenglamadan

$$S_{CD} = \frac{Q_1 \cdot 1 + G \cdot 3 + M - S \cdot 6}{4 \cdot \sin 30°} = \frac{1 \cdot 1 + 10 \cdot 3 + 8 - 5 \cdot 6}{4 \cdot 0{,}5} = 4{,}5 kN.$$

(2) tenglamadan

$$X_A = S_{CD} \cdot \cos 30^0 = 4{,}5 \cdot 0{,}866 = 3{,}90 kN.$$

(3) tenglamadan

$$Y_A = Q + G - S_{CD} \cdot \cos 60^0 - S = 1 + 10 - 4{,}5 \cdot 0{,}5 - 5 = 3{,}75 kN.$$

X_A, Y_A va S_{CD} larning qiymatlari musbat bo'ldi. Bu hol shuni ko'rsatadiki, ushbu kuchlarning qabul qilingan yonalishlari ularning haqiqiy yonalishlari bilan mos tushadi.

Xisob-grafika ishi №2

Tekis ferma sterjenlaridagi zo'riqishlarni Ritter usulida aniqlash. (Statika bo'limi)

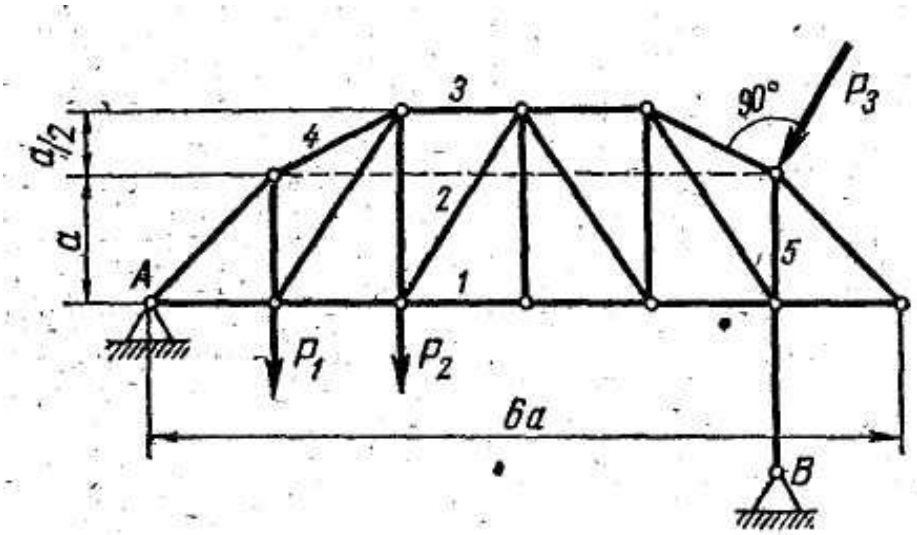
Fermaning 1, 2, 3, 4, 5 sterjenlaridagi zo'riqishlar Ritter usulida aniqlansin. Fermalar sxemalari 4-6 rasmlarda tasvirlangan, hisoblar uchun kerakli ma'lumotlar esa 2-jadvalda keltirilgan.

2-jadval

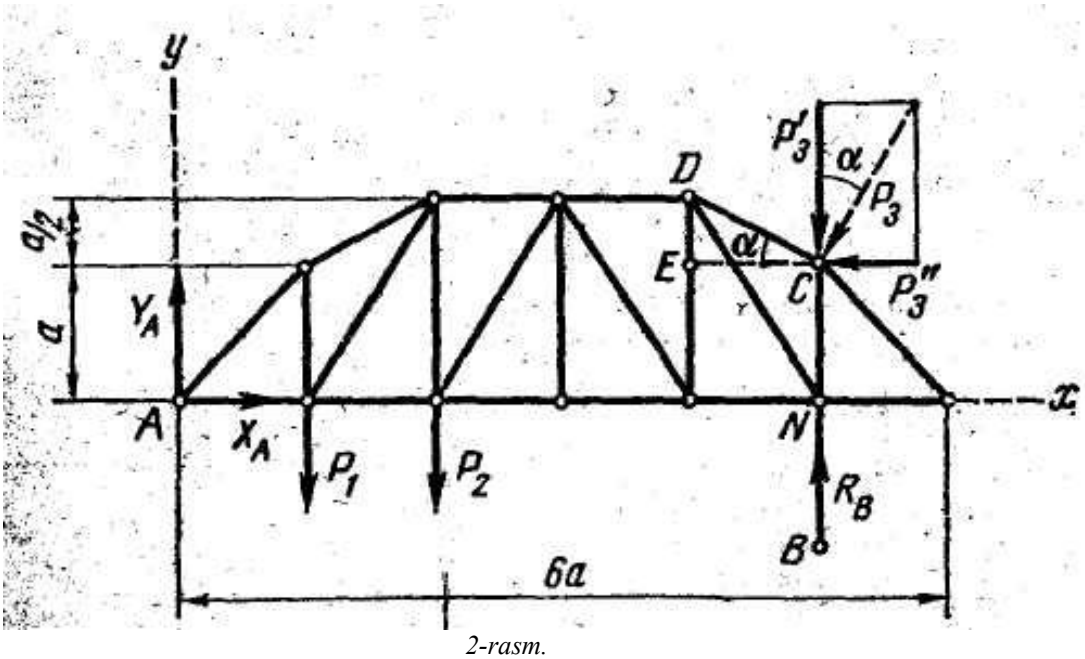
Номер варианта (рис. 14 — 16)	P_1	P_2	P_3	P_4	P_5	a, м	h, м	α, град
	кН							
1	5	5	5	20	30	—	—	—
2	5	10	20	30	—	—	—	30
3	10	5	20	20	—	2	6,0	—
4	10	30	50	—	—	—	—	—
5	5	5	20	20	—	—	—	30
6	10	20	10	10	20	—	—	30
7	5	10	20	—	—	—	—	30
8	10	20	30	—	—	2	5,0	—
9	10	20	30	—	—	—	—	—
10	20	10	10	20	—	—	—	45
11	10	20	40	—	—	—	—	45
12	10	20	30	30	—	2	6,0	—
13	10	10	10	20	20	—	—	45
14	10	10	10	10	20	—	—	—
15	10	20	10	—	—	2	1,5	—
16	10	20	20	30	—	—	—	—
17	10	20	20	—	—	3	5,0	—
18	10	40	20	20	—	3	3,5	—
19	10	10	40	20	—	3	3,5	—
20	10	40	20	—	—	—	—	—
21	10	20	10	40	—	3	4,0	—
22	10	10	20	30	—	—	—	—
23	5	10	10	40	20	—	—	—
24	10	20	20	20	—	2	2,4	—
25	10	20	20	—	—	2	2,4	—
26	10	20	20	—	—	2	2,3	—
27	10	20	10	—	—	2	3,0	—
28	20	20	10	—	—	—	—	—
29	10	20	20	40	—	2	2,2	—
30	10	10	20	30	30	—	—	—

Masalani bajarishga doir misol. Berilgan: ferma sxemasi (1-rasm); $P_1 = 58kN$; $P_2 = 50kN$; $P_3 = 85kN$. S_1, S_2, S_3, S_4, S_5 zo'riqishlar aniqlansin.

Yechim. 1. *Tayanch reaksiyalarini analitik aniqlash.*
Fermaga qo'yilgan muvozanatlashuvchi kuchlar sistemasini ko'rib chiqamiz. Ularning fermaga ta'sirini reaksiyalar bilan almashtirgan holda bog'lanishlardan bo'shatamiz (tayanchlar A, B). A tayanchning reaksiyasini koordinata o'qlari bo'ylab yo'nalgan $\overset{\cup}{X}_A$ va $\overset{\cup}{Y}_A$ tashkil qiluvchilarga ajratamiz.
B sharnirning reaksiyasini BN tayanch sterjen o'qi bo'ylab yuqoriga yo'naltiramiz. $\overset{\cup}{P}_3$ kuchni ikkita $\overset{\cup}{P}_3'$ va $\overset{\cup}{P}_3''$ tashkil qiluvchilarga ajratamiz, ularning moduli $P_3' = P_3 \cdot \cos\alpha$ va $P_3'' = P_3 \cdot \sin\alpha$ (2-rasm).



-rasm.



2-rasm.

$\sin\alpha$ va $\cos\alpha$ ni hisoblaymiz:

$$\sin\alpha = \frac{DE}{CD} = \frac{a}{2\sqrt{a^2 + (a/2)^2}} = 0{,}447;$$

$$\cos\alpha = \frac{CE}{CD} = \frac{a}{\sqrt{a^2 + (a/2)^2}} = 0{,}894\,.$$

$\overset{\cup}{P}_3'$ va $\overset{\cup}{P}_3''$ kuchlar modulini aniqlaymiz:

$$P_3' = 85 \cdot 0{,}894 = 76{,}0\,kN;$$

$$P_3'' = 85 \cdot 0{,}447 = 38{,}0\,kN\,.$$

Fermaga qo'yilgan tekis kuchlar sistemasi uchun uchta muvozanat tenglamalarini tuzamiz:

$$\sum M_{iA} = 0; \qquad -P_1 \cdot a - P_2 \cdot 2a - P_3' \cdot 5a + P_3'' \cdot a + R_B \cdot 5a = 0; \quad (1)$$

$$\sum X_i = 0; \qquad -P_3'' + X_A = 0; \quad (2)$$

$$\sum Y_i = 0; \qquad Y_A - P_1 - P_2 - P_3' + R_B = 0; \quad (3)$$

(1) tenglamadan

$$R_B = \frac{P_1 + P_2 \cdot 2 + P_3' \cdot 5 - P_3''}{5} = \frac{58 + 50 \cdot 2 + 76 \cdot 5 - 38}{5} = 100\,kN\,.$$

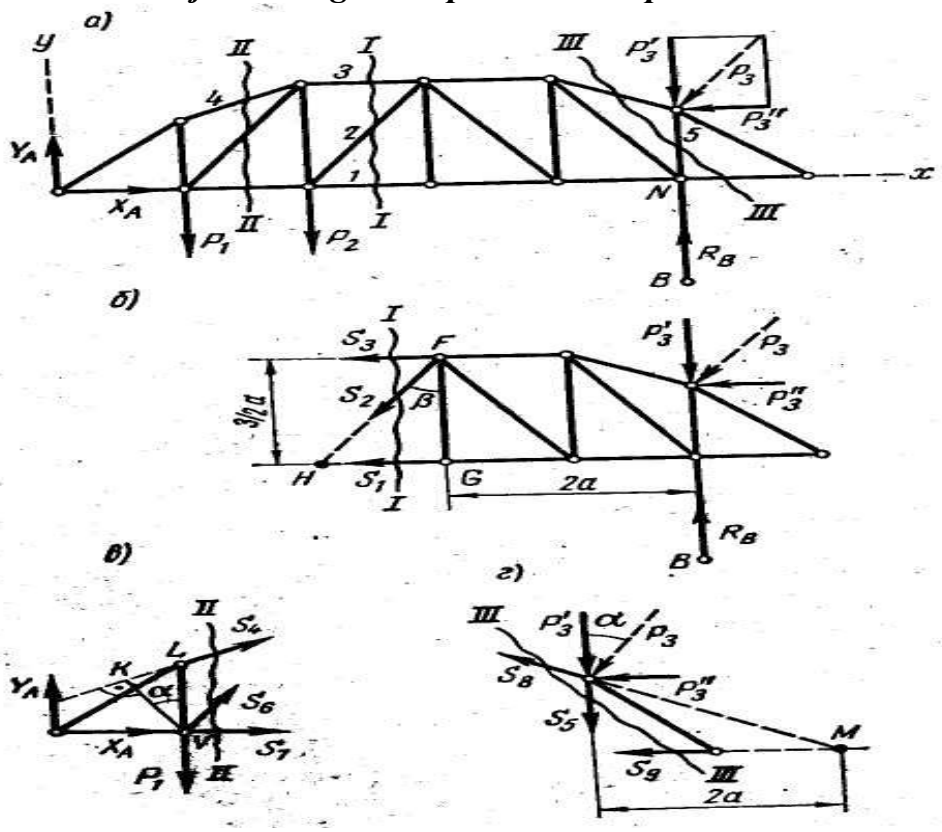
(2) tenglamadan

$$X_A = P_3'' = 38\,kN.$$

(3) tenglamadan

$$Y_A = P_1 + P_2 + P_3' - R_B = 58 + 50 + 76 - 100 = 84\,kN.$$

2. ***Ferma sterjenlaridagi zo'riqishlarni aniqlash.***



3-rasm.

Ritter usulida fermaning beshta sterjenidagi zo'riqishlarni aniqlaymiz. 1, 2, 3 sterjenlardagi zo'riqishlarni aniqlash uchun (3-rasm, a) I-I qirqim o'tkazamiz va fermaning bir qismiga qo'yilgan kuchlar muvozanatini ko'rib chiqamiz (3-rasm, b).

Bu o'rinda hisoblash ishining hajmi kamroq bo'ladigan ferma qismining muvozanatini ko'rib chiqish maqsadga muvofiq bo'ladi. Shunday muvozanat tenglamalarini tuzish kerakki, ularning har birida izlanayotgan zo'riqish yagona noma'lum bo'lib qatnashsin. Bu boshqa sterjenlardagi zo'riqishlarga bog'liq bo'lmagan holda har bir sterjendagi zo'riqishni aniqlash imkonini beradi.

Shartli ravishda barcha sterjenlar cho'ziladi deb taxmin qilamiz. Yechimdagi minus ishorasi sterjen cho'zilishga emas, balki siqilishga ishlaganini ko'rsatadi.

S_1 ni aniqlash uchun $\overset{\cup}{S}_2$ va $\overset{\cup}{S}_3$ ta'sir chiziqlari kesishish nuqtasiga nisbatan momentlar tenglamasini tuzamiz:

$$\sum M_{iF} = 0; \qquad -S_1 \cdot 1{,}5a - P_3^{'} \cdot 2a - P_3^{''} \cdot 0{,}5a + R_B \cdot 2a = 0,$$

bundan

$$S_1 = \frac{R_B \cdot 2 - P_3^{'} \cdot 2 - P_3^{''} \cdot 0{,}5}{1{,}5} = \frac{100 \cdot 2 - 76 \cdot 2 - 38 \cdot 0{,}5}{1{,}5} = 19{,}3\,kN.$$

S_2 ni aniqlash uchun kuchlarni Ay o'qqa proyeksiyalaymiz:

$$\sum Y_i = 0; \qquad -S_2 \cdot \cos\beta - P_3^{'} + R_B = 0,$$

bu yerda

$$\cos\beta = \frac{FG}{FH} = \frac{1{,}5a}{\sqrt{a^2 + (1{,}5a^2)}} = 0{,}832,$$

bundan

$$S_2 = \frac{R_B - P_3^{'}}{\cos\beta} = \frac{100 - 76}{0{,}832} = 28{,}8\,kN.$$

S_3 ni aniqlash uchun $\overset{\cup}{S}_1$ va $\overset{\cup}{S}_2$ larning ta'sir chiziqlari kesishish nuqtasiga nisbatan momentlar tenglamasini tuzamiz:

$$\sum M_{iH} = 0; \qquad S_3 \cdot 1{,}5a - P_3^{'} \cdot 3a + P_3^{''} \cdot a + R_B \cdot 3a = 0,$$

bundan

$$S_3 = \frac{P_3^{'} \cdot 3 - P_3^{''} - R_B \cdot 3}{1{,}5} = \frac{76 \cdot 3 - 38 - 100 \cdot 3}{1{,}5} = -73{,}3\,kN.$$

4 sterjendagi zo'riqishni aniqlash uchun II-II qirqim o'tkazamiz va fermaning chap qismiga qo'yilgan kuchlar muvozanatini ko'rib chiqamiz (3-rasm, c). Tenglama tuzamiz:

$$\sum M_{iV} = 0; \qquad -Y_A \cdot a - S_4 \cdot VK = 0,$$

bu yerda

$$VK = VL \cdot \cos\alpha = a \cdot 0{,}894.$$

Bundan

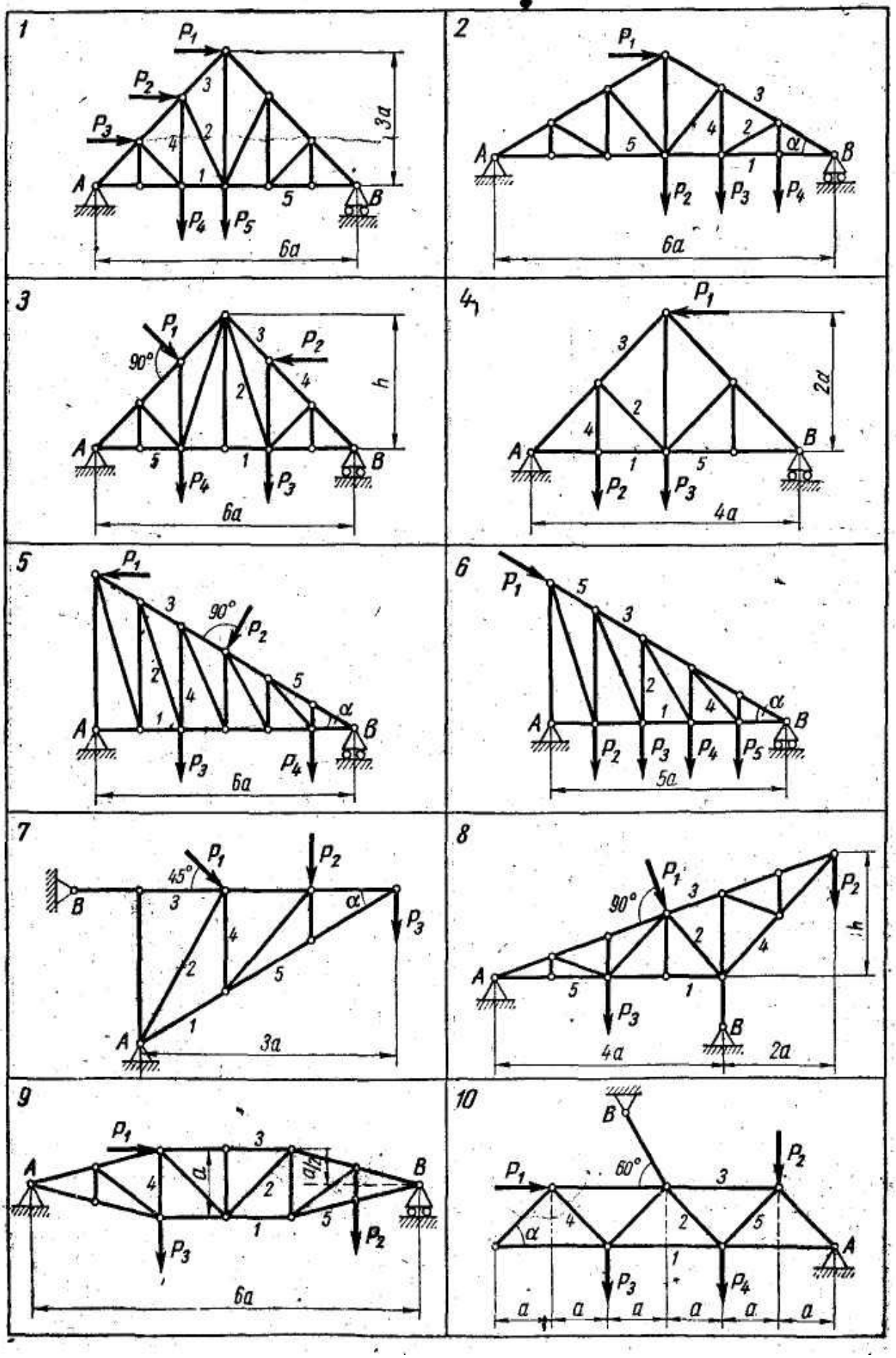
$$S_4 = -Y_A \cdot a / 0{,}894a = -84 / 0{,}894 = -94\,kN.$$

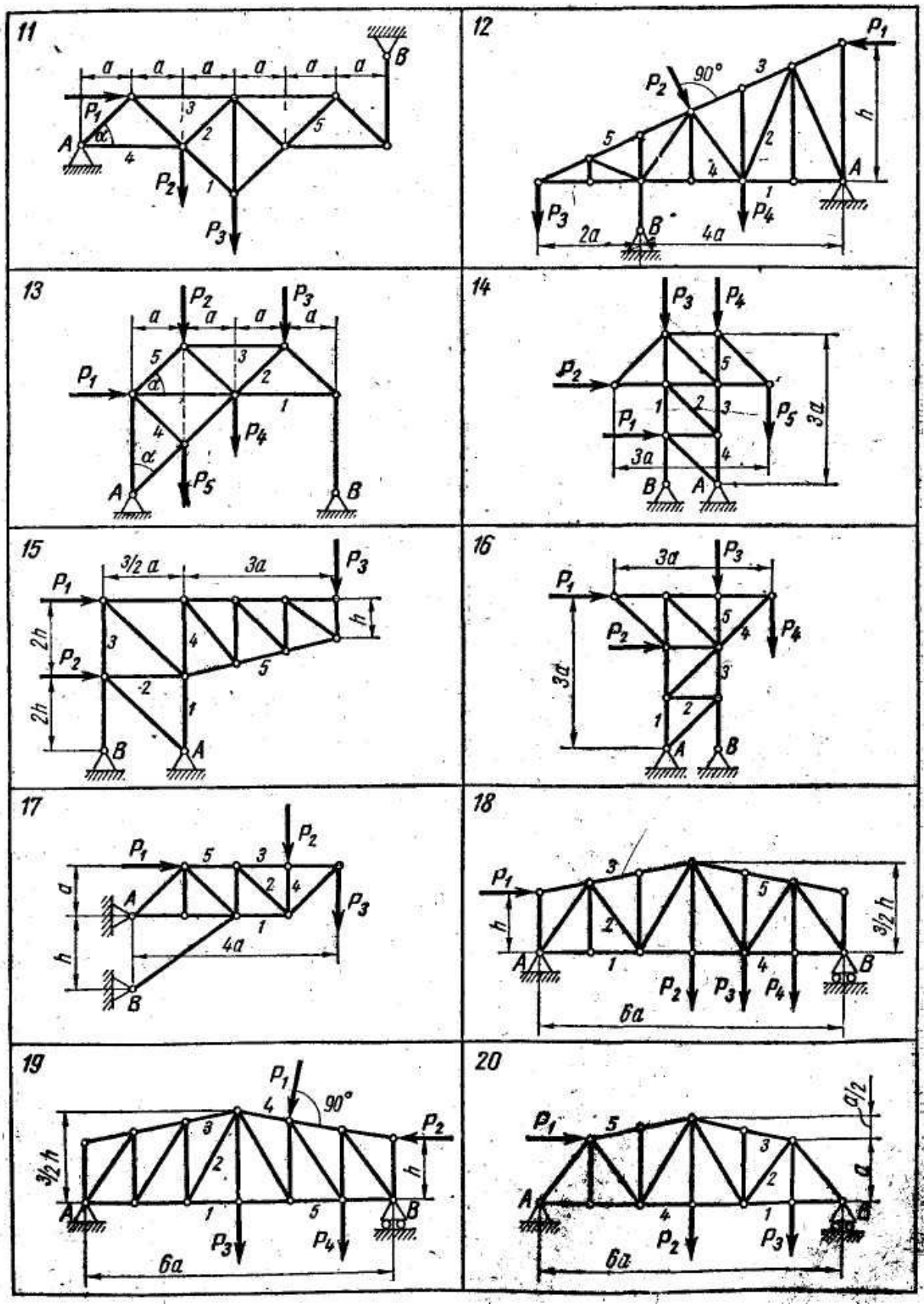
S_5 zo'riqishni aniqlash uchun III-III qirqim o'tkazamiz va fermaning o'ng qismiga qo'yilgan kuchlar muvozanatini ko'rib chiqamiz (3-rasm, d). Tenglama tuzamiz:

$$\sum M_{iM} = 0; \qquad P_3^{'} \cdot 2a + S_5 \cdot 2a + P_3^{''} \cdot a = 0 .$$

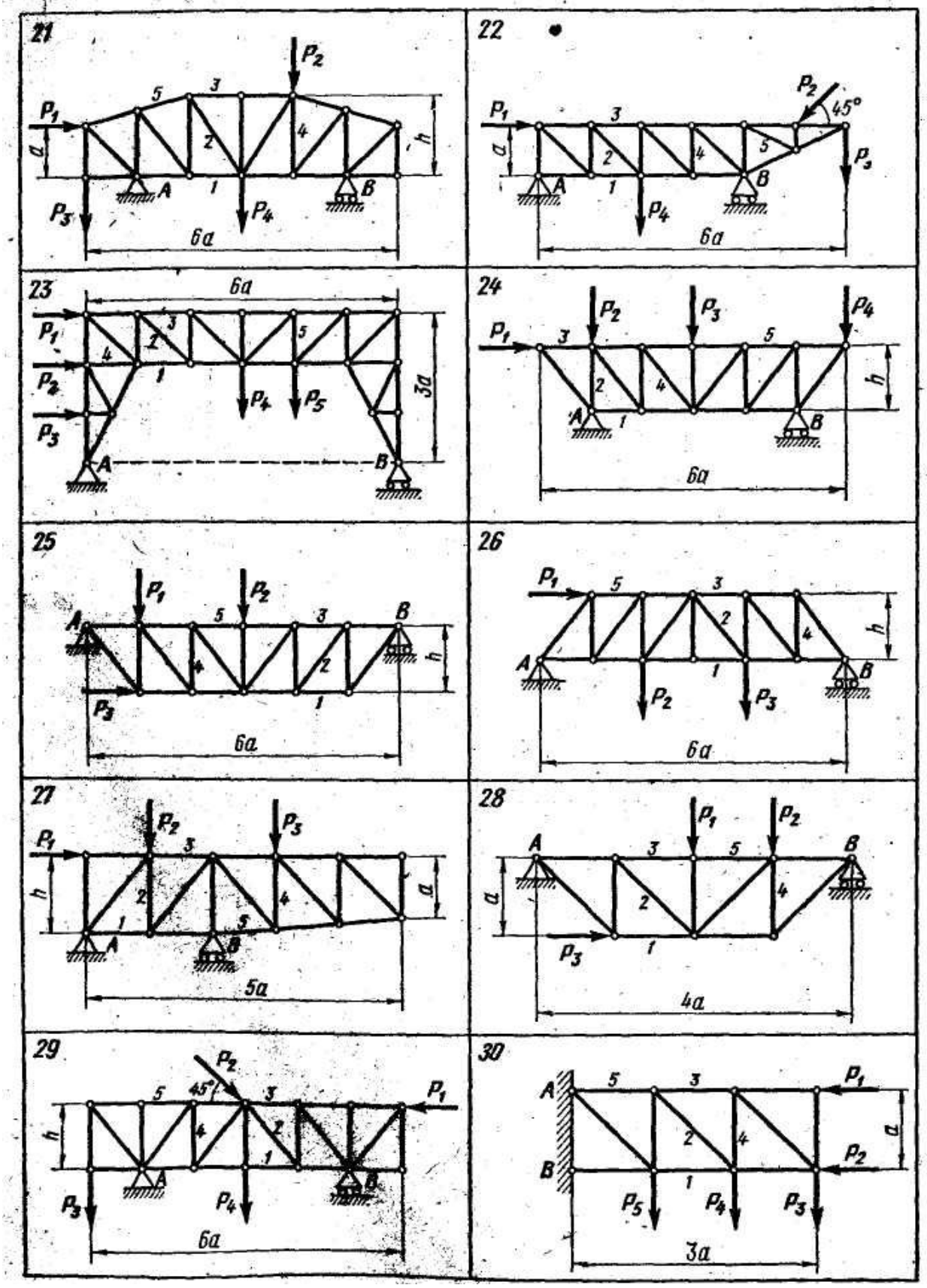
Bundan

$$S_5 = -\frac{P_3^{'} \cdot 2 + P_3^{''}}{2} = -\frac{76 \cdot 2 + 38}{2} = -95\,kN .$$


1
P1
P2
P3
P4
P5
A
B
3a
6a
2
P1
P2
P3
P4
A
B
α
6a
3
P1
P2
90°
P4
P3
A
B
h
6a
4
P1
P2
P3
A
B
2a
4a
5
P1
90°
P2
P3
P4
A
B
α
6a
6
P1
P2
P3
P4
P5
A
B
α
5a
7
45°
P1
P2
P3
B
A
α
3a
8
P1
90°
P2
h
P3
A
B
4a
2a
9
P1
P3
P2
A
B
a
6a
10
B
60°
P1
P2
P3
P4
α
A
a
a
a
a
a
a



5-rasm.



6-rasm.

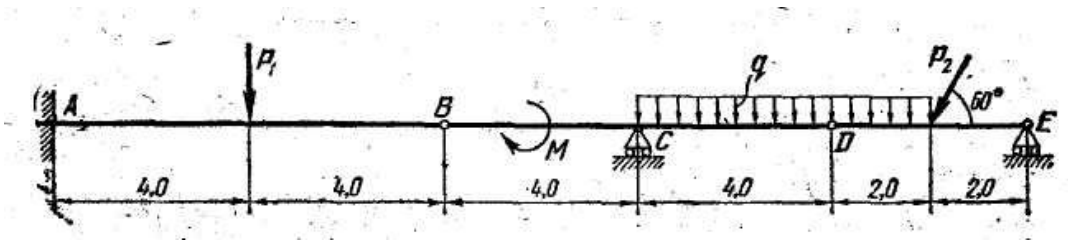
Xisob-grafika ishi №3.
Yig'ma balka tayanch reaksiyalarini aniqlash.
(Statika bo'limi)

Yig'ma balkaning oraliq sharnirlaridagi bosim va tayanchlar reaksiyalari topilsin. Balkalar sxemalari 5-7 rasmlarda tasvirlangan (o'lchamlar - metrda), yuklanish 3-jadvalda keltirilgan.

3-jadval.

Номер варианта (рис. 20—22)	P_1	P_2	P_3	M_1	M_2	q, кН/м
	кН			кНм		
1	6,0	10,0	—	25,0	—	0,8
2	7,0	4,0	—	20,0	—	1,0
3	12,0	18,0	—	36,0	—	1,4
4	8,0	10,0	5,0	30,0	25,0	—
5	9,0	15,0	—	32,0	—	1,8
6	10,0	7,0	—	18,0	—	0,9
7	4,0	6,0	9,0	20,0	28,0	—
8	5,0	4,0	—	16,0	—	1,5
9	10,0	7,0	14,0	24,0	—	1,2
10	8,0	14,0	—	26,0	—	1,0
11	10,0	5,0	13,0	12,0	20,0	—
12	7,0	12,0	—	15,0	—	1,5
13	8,0	12,0	6,0	24,0	—	1,6
14	10,0	7,0	—	30,0	—	1,2
15	14,0	9,0	5,0	26,0	18,0	—
16	11,0	15,0	—	40,0	—	1,0
17	8,0	12,0	—	20,0	28,0	—
18	10,0	15,0	8,0	35,0	—	—
19	9,0	13,0	—	25,0	—	1,4
20	12,0	6,0	—	32,0	—	0,8
21	6,0	10,0	—	30,0	—	1,5
22	12,0	20,0	—	30,0	24,0	2,0
23	8,0	14,0	—	25,0	—	1,0
24	9,0	15,0	—	28,0	—	1,2
25	9,0	15,0	12,0	24,0	35,0	—
26	6,0	12,0	16,0	26,0	—	1,5
27	10,0	16,0	—	32,0	—	1,4
28	7,0	10,0	14,0	26,0	—	1,3
29	5,0	13,0	—	30,0	—	2,0
30	18,0	7,0	12,0	16,0	—	—

Masalani bajarish tartibi. Berilgan: yig'ma balkaning sxemasi (1-rasm); P_1=12,0 kN; P_2=20,0 kN; M=50,0 kNm; q=2,0 kN/m.



1-rasm.

Yechim. Yig'ma balka sharnirlar yordamida ulangan oddiy balkalar tizimini namoyon qiladi. Shuning uchun bu balkalarni ulovchi sharnirlardagi bosimni hisobga olgan holda, har bir oddiy balkaga qo'yilgan muvozanatlashuvchi kuchlar sistemasini ko'rib chiqamiz.

DE balkadan boshlaymiz (2-rasm), bu balkaga qo'yilgan noma'lum kuchlar

soni ($\overset{p}{R}_E, \overset{p}{X}_D, \overset{p}{Y}_D$) muvozanat tenglamalari soniga teng:

$$\sum M_{iD} = 0; \qquad R_E \cdot 4 - P_2 \cdot 2 \cdot \cos 30^0 - Q_1 \cdot 1 = 0; \quad (1)$$

bu yerda $Q_1 = q \cdot 2 = 2 \cdot 2 = 4kN;$

$$\sum X_i = 0; \qquad X_D - P_2 \cdot \cos 60^0 = 0; \qquad (2)$$

$$\sum Y_i = 0; \qquad Y_D - Q_1 - P_2 \cdot \cos 30^0 + R_E = 0; \qquad (3)$$

(1) tenglamadan

$$R_E = \frac{P_2 \cdot 2 \cdot \cos 30^0 + Q_1 \cdot 1}{4} = \frac{20 \cdot (2\sqrt{3}/2) + 4 \cdot 1}{4} = 9{,}66\,kN.$$

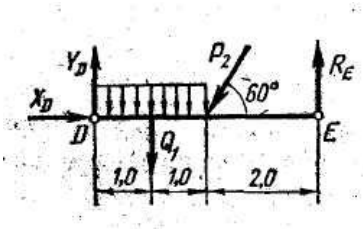
(2) tenglamadan

$$X_D = P_2 \cdot \cos 60^0 = 20 \cdot 0{,}5 = 10{,}0\,kN.$$

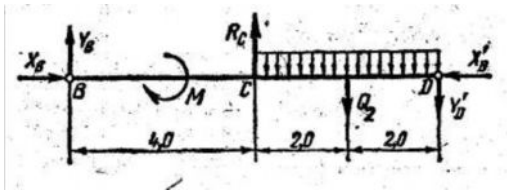
(3) tenglamadan

$$Y_D = Q_1 + P_2 \cdot \cos 30^0 - R_E = 4 + 20 \cdot (2\sqrt{3}/2) - 9{,}66 = 11{,}6\,kN.$$

2-rasm.



3-rasm.



BD balka uchun (3-rasm)

$$\sum M_{iB} = 0; \qquad -M + R_C \cdot 4 - Q_2 \cdot 6 - Y'_D \cdot 8 = 0; \qquad (4)$$

bu yerda $Q_2 = q \cdot 4 = 2 \cdot 4 = 8kN;$

$$\sum X_i = 0; \qquad X_B - X'_D = 0; \qquad (5)$$

$$\sum Y_i = 0; \qquad Y_B + R_C - Q_2 - Y'_D = 0; \qquad (6)$$

(4) tenglamadan

$$R_C = \frac{M + Q_2 \cdot 6 - Y'_D \cdot 8}{4} = \frac{50 + 8 \cdot 6 + 11{,}6 \cdot 8}{4} = 47{,}7\,kN.$$

(5) tenglamadan

$$X_B = X'_D = 10{,}0\,kN;$$

(6) tenglamadan

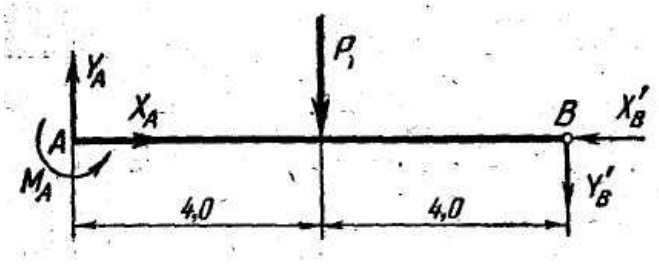
$$Y_B = -R_C + Q_2 + Y'_D = -47{,}7 + 8 + 11{,}6 = -28{,}1\,kN.$$

AB balka uchun (4-rasm):

$$\sum M_{iA} = 0; \qquad M_A - P_1 \cdot 4 - Y'_B \cdot 8 = 0; \qquad (7)$$

$$\sum X_i = 0; \qquad X_A - X'_B = 0; \qquad (8)$$

$$\sum Y_i = 0; \qquad Y_A - P_1 - Y'_B = 0; \qquad (9)$$



4-rasm.

(7) tenglamadan

$$M_A = P_1 \cdot 4 + Y_B^{'} \cdot 8 = 12 \cdot 4 - 28{,}1 \cdot 8 = -177\, kNm.$$

(8) tenglamadan

$$X_A = X_B^{'} = 10{,}0\, kN.$$

(9) tenglamadan

$$Y_A = P_1 + Y_B^{'} = 12 - 28{,}1 = -16{,}1 kN.$$

O'tkazilgan hisoblarning to'g'riligini tekshirish uchun shunga ishonch hosil qilish kerakki, butun konstruksiyaga qo'yilgan kuchlar uchun istalgan muvozanat tenglamasi o'rinli bo'lishi kerak, masalan:

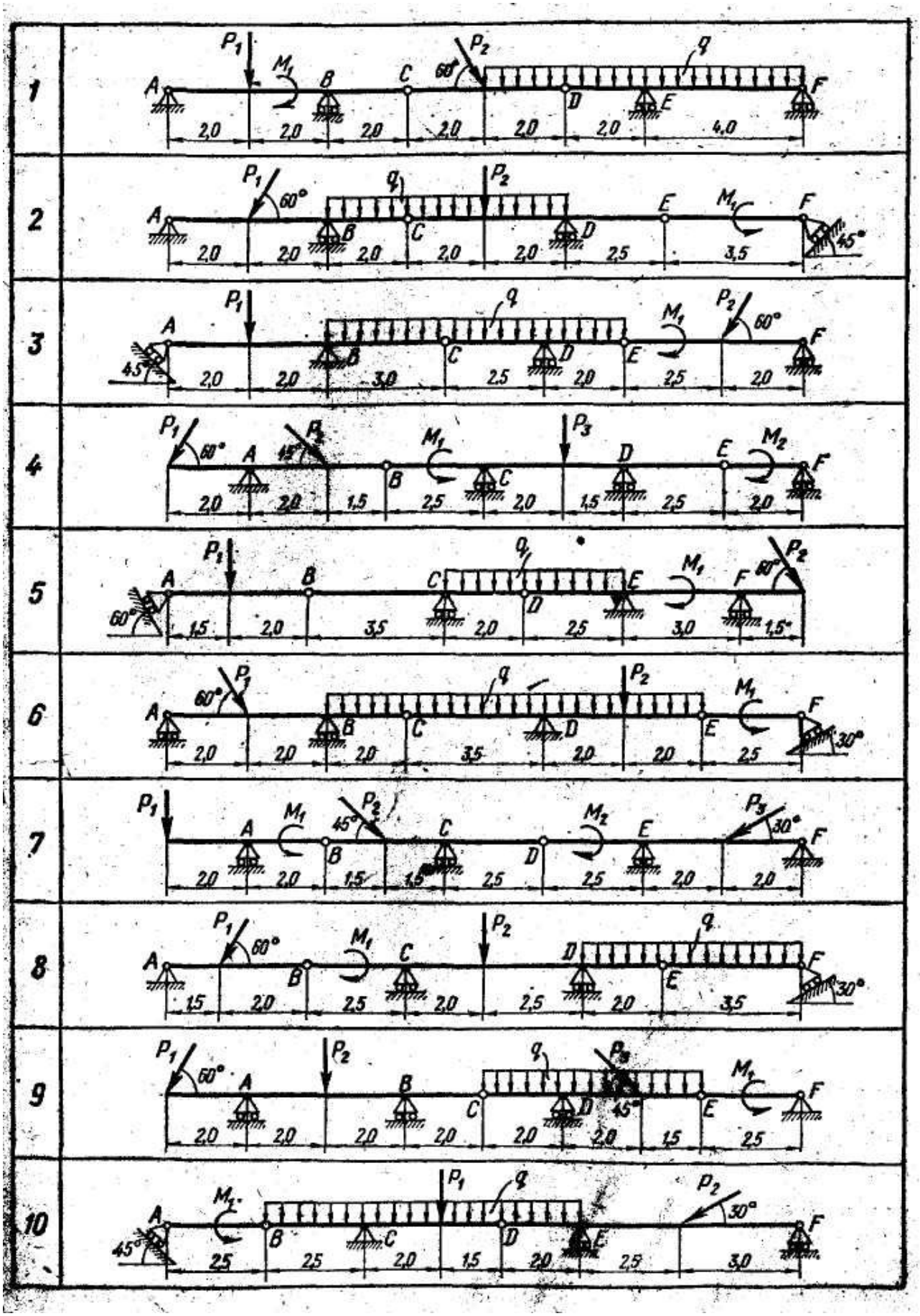
$$\sum Y_i = 0; \qquad Y_A - P_1 + R_C - Q_2 - Q_1 - P_2 \cos 30^0 + R_E = 0;$$

$$-16{,}1 - 12 + 47{,}7 - 8 - 4 - 20 \cdot (\sqrt{3}/2) + 9{,}66 \approx -57{,}4 + 57{,}4 = 0.$$

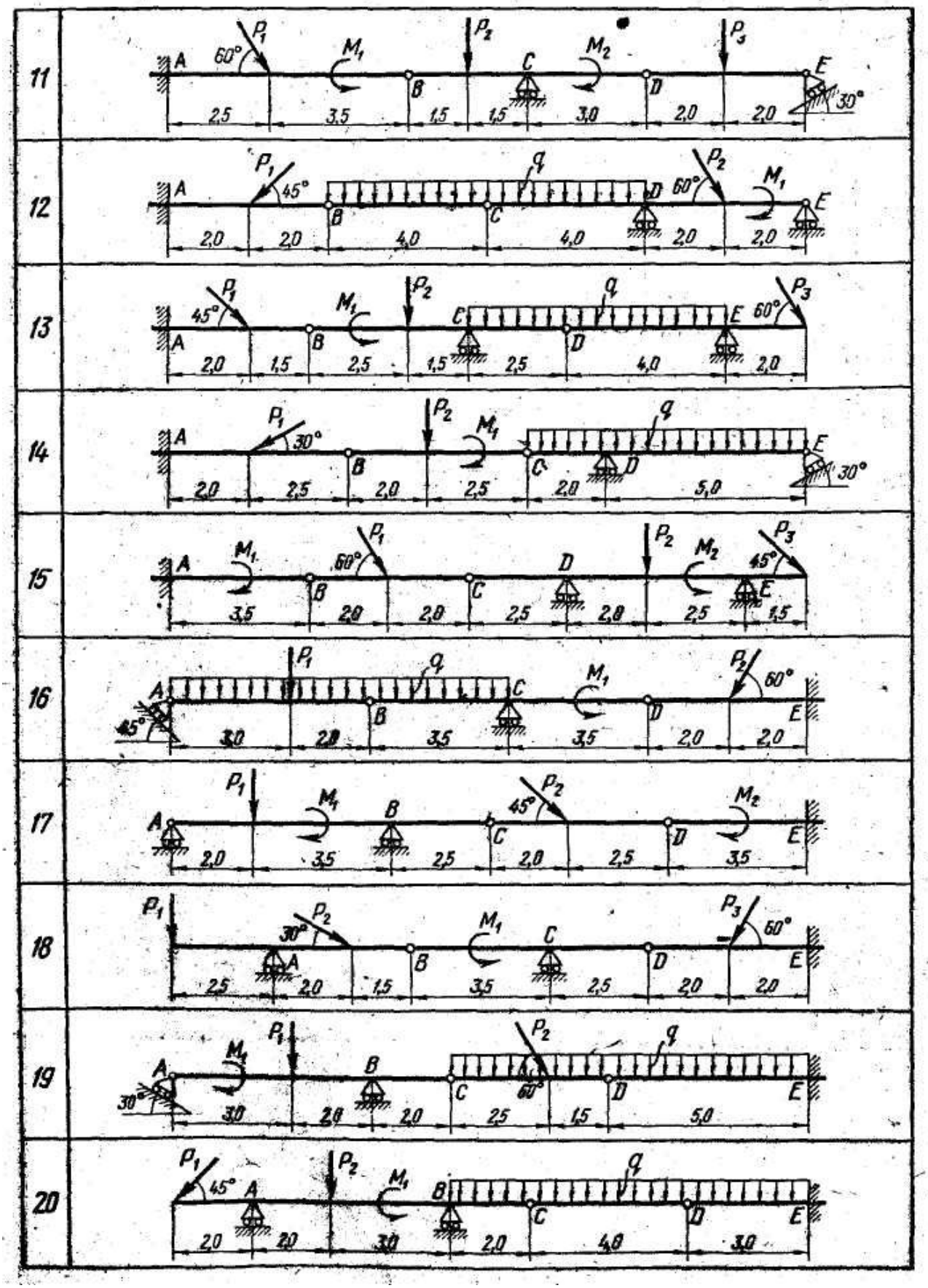
Hisob natijalari 4-jadvalda keltirilgan.

4-jadval

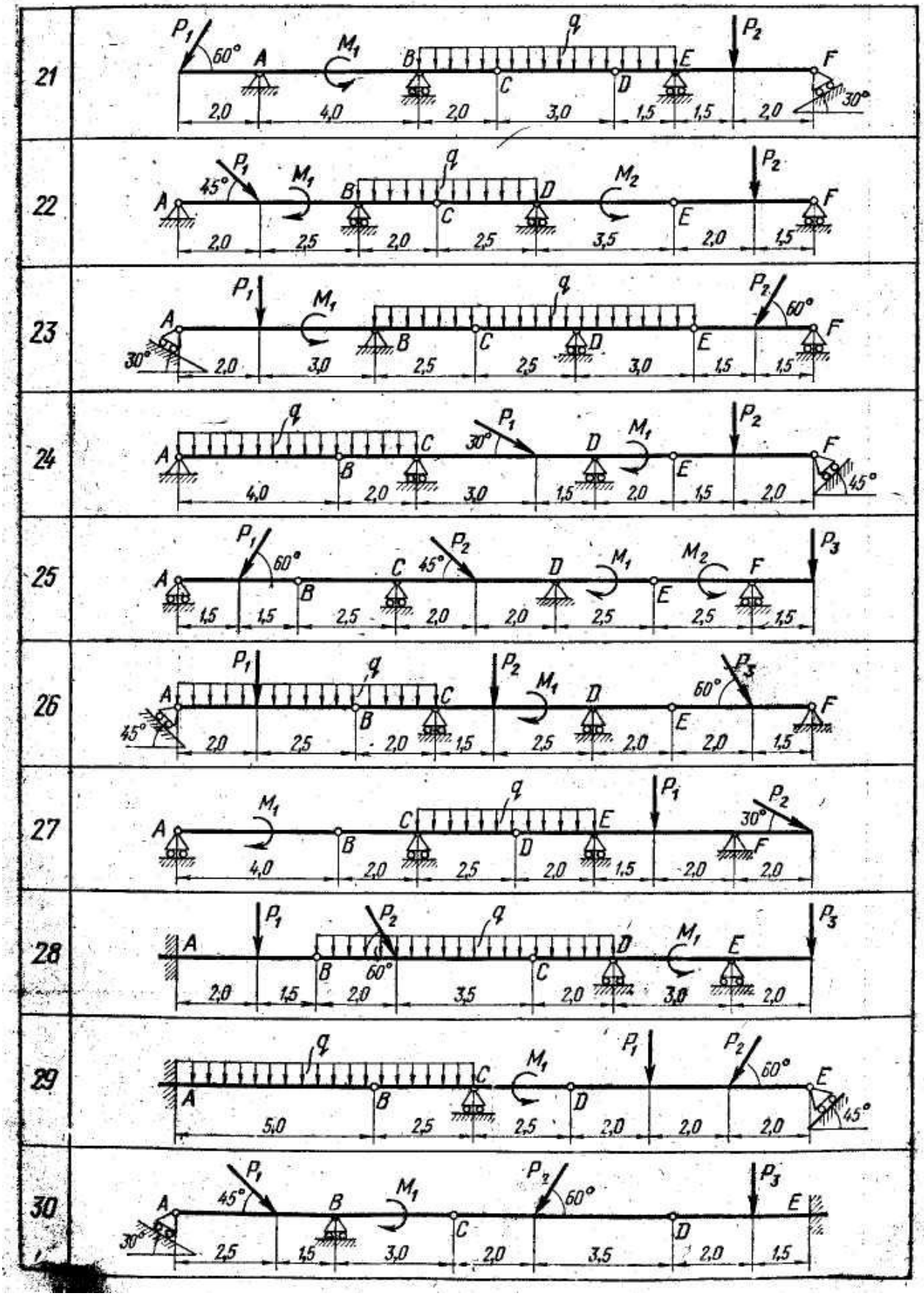
X_A	Y_A	M_A	R_C	R_E	X_B	Y_B	X_D	Y_D
10,0 kN	-16,1 kN	-177 kNm	47,7 kN	9,66 kN	10,0 kN	-28,1 kN	10,0 kN	11,6 kN


1
P1
M1
P2
q
A
B
C
D
E
F
60°
2,0
2,0
2,0
2,0
2,0
2,0
4,0
2
P1
60°
q1
P2
M1
45°
2,5
3,5
3
45°
3,0
2,5
4
P3
M2
1,5
5
6
30°
3,5
7
8
9
10
25
1,5

5-rasm.



6-rasm.


21
P1 60° A M1 B q C D E P2 F 30°
2,0 4,0 2,0 3,0 1,5 1,5 2,0
22
P1 45° M1 A B q C D M2 E P2 F
2,0 2,5 2,0 2,5 3,5 2,0 1,5
23
P1 M1 A q P2 60° F
30° B C D E
2,0 3,0 2,5 2,5 3,0 1,5 1,5
24
q A B C P1 30° D M1 P2 E F 45°
4,0 2,0 3,0 1,5 2,0 1,5 2,0
25
P1 60° A B C P2 45° D M1 E M2 F P3
1,5 1,5 2,5 2,0 2,0 2,5 2,5 1,5
26
P1 q A B C P2 M1 D 60° P3 E F
45° 2,0 2,5 2,0 1,5 2,5 2,0 2,0 1,5
27
M1 A B C q E P1 30° P2 D F
4,0 2,0 2,5 2,0 1,5 2,0 2,0
28
P1 P2 q A B 60° C D M1 E P3
2,0 1,5 2,0 3,5 2,0 3,0 2,0
29
q A B C M1 P1 P2 60° D E 45°
5,0 2,5 2,5 2,0 2,0 2,0
30
P1 45° A B M1 C P2 60° D P3 E
30° 2,5 1,5 3,0 2,0 3,5 2,0 1,5

7-rasm.

Xisob-grafika ishi №4

Yig'ma konstruksiya tayanch reaksiyalarini aniqlash (ikki jism sistemasi). (Statika bo'limi)

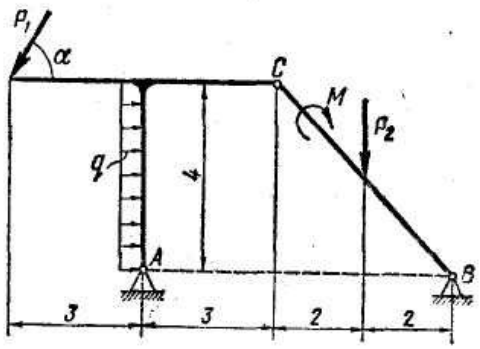
Yig'ma konstruksiyaning oraliq sharniridagi tayanch reaksiyalari va bosimi topilsin. Konstruksiyalar sxemalari 4-6 rasmlarda tasvirlangan (o'lchamlar - metrda), yuklanish 4-jadvalda keltirilgan.

4-jadval.

Номер варианта (рис. 27—29)	P_1 кН	P_2 кН	M, кНм	q, кН/м	Номер варианта (рис. 27—29)	P_1 кН	P_2 кН	M, кНм	q, кН/м
1	6,0	—	25,0	0,8	16	8,0	11,0	31,0	0,8
2	5,0	8,0	26,0	—	17	9,0	15,0	26,0	1,1
3	8,0	10,0	33,0	1,1	18	7,0	16,0	27,0	0,8
4	10,0	—	25,0	1,3	19	6,0	18,0	35,0	1,4
5	12,0	—	27,0	1,0	20	7,0	16,0	32,0	0,8
6	14,0	12,0	—	0,9	21	8,0	17,0	30,0	1,2
7	16,0	8,0	18,0	1,4	22	5,0	6,0	34,0	1,5
8	12,0	6,0	20,0	1,0	23	14,0	10,0	36,0	1,2
9	14,0	—	28,0	1,4	24	10,0	13,0	28,0	1,3
10	8,0	—	26,0	0,9	25	11,0	10,0	33,0	1,0
11	15,0	10,0	29,0	1,0	26	15,0	15,0	18,0	1,4
12	15,0	8,0	28,0	1,5	27	11,0	14,0	36,0	1,5
13	7,0	6,0	15,0	1,1	28	12,0	12,0	30,0	1,1
14	5,0	—	30,0	0,9	29	10,0	9,0	35,0	1,3
15	6,0	10,0	24,0	1,5	30	9,0	10,0	29,0	1,5

Masalani bajarishga doir misol. Berilgan: konstruksiya sxemasi (1-rasm); P_1=10,0 kN; P_2=12,0 kN; M=25,0 kNm; q=2,0 kN/m; $\alpha = 60^0$.

Oraliq sharnirdagi tayanch reaksiyalari va bosim topilsin.



1-rasm.

Yechim. Avvalo butun konstruksiyaga qo'yilgan muvozanatlashuvchi kuchlar sistemasini ko'rib chiqamiz (2-rasm), bu esa A va B tayanchlar reaksiyalarining vertikal tashkil qiluvchilarini aniqlash imkonini beradi.

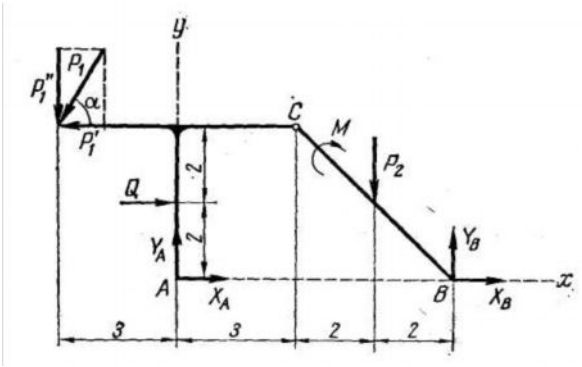
P_1 kuch momentini hisoblashni osonlashtirish uchun uni P_1' va P_1'' tashkil qiluvchilarga ajratamiz:

$$P_1' = P_1 \cos\alpha = 10 \cdot 0{,}5 = 5kN; \qquad P_1'' = P_1 \sin\alpha = 10 \cdot 0{,}866 = 8{,}66kN.$$

Muvozanat tenglamalari quyidagicha ko'rinishda bo'ladi:

$$\sum M_{iA} = 0; \qquad P_1' \cdot 4 + P_1'' \cdot 3 - Q \cdot 2 - M - P_2 \cdot 5 + Y_B \cdot 7 = 0; \qquad (1)$$

bu yerda $Q_1 = q \cdot 4 = 2 \cdot 4 = 8kN;$



2-rasm.

$$\sum Y_i = 0; \qquad -P_1'' + Y_A - P_2 + Y_B = 0; \qquad (2)$$

$$\sum X_i = 0; \qquad X_A + X_B - P_1' + Q = 0; \qquad (3)$$

(1) tenglamadan

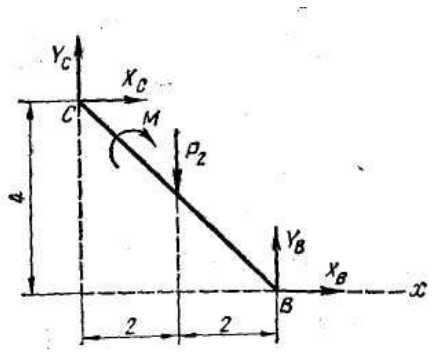
$$Y_B = \frac{-P_1' \cdot 4 + P_1'' \cdot 3 + Q \cdot 2 + M + P_2 \cdot 5}{7} = \frac{-5 \cdot 4 - 8{,}66 \cdot 3 + 8 \cdot 2 + 25 + 12 \cdot 5}{7} = 7{,}86kN.$$

(2) tenglamadan

$$Y_A = P_1'' + P_2 - Y_B = 8{,}66 + 12 - 7{,}86 = 12{,}8kN.$$

Tarkibida ikkita noma'lum bo'lgan (3) tenglama, ushbu noma'lumlarning son qiymatini aniqlash imkonini bermaydi va faqatgina ular orasidagi bog'lanishni ifodalay oladi.

Endi konstruksiyaning o'ng qismiga qo'yilgan muvozanatlashuvchi kuchlar sistemasini ko'rib chiqamiz (3-rasm).



3-rasm.

$$\sum M_{ic} = 0; \qquad -M + P_2 \cdot 2 + X_B \cdot 4 + Y_B \cdot 4 = 0; \qquad (4)$$

$$\sum X_i = 0; \qquad X_B + X_C = 0; \qquad (5)$$

$$\sum Y_i = 0; \qquad Y_C - P_2 + Y_B = 0; \qquad (6)$$

(4) tenglamadan

$$X_B = \frac{M + P_2 \cdot 2 - Y_B \cdot 4}{4} = \frac{25 + 12 \cdot 2 - 7{,}86 \cdot 4}{4} = 4{,}39kN.$$

(5) tenglamadan

$$X_C = -X_B = -4{,}39kN;$$

(6) tenglamadan

$$Y_C = P_2 - Y_B = 12 - 7{,}86 = 4{,}14kN.$$

(3) tenglamadan

$$X_A = -X_B + P_1^{'} - Q = -4{,}39 + 5 - 8 = -7{,}39\,kN.$$

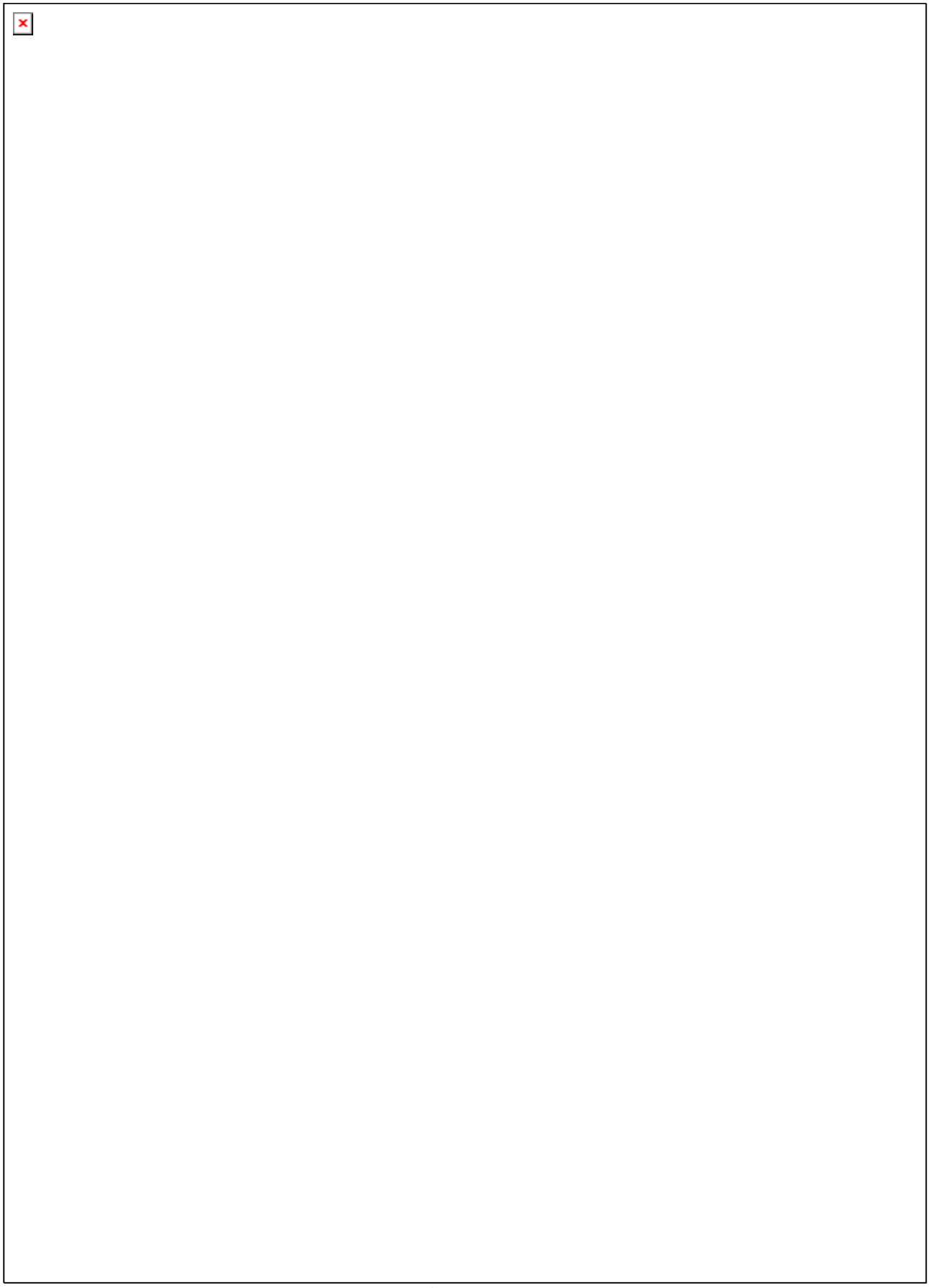
O'tkazilgan hisoblarning to'g'riligini tekshirish uchun shunga ishonch hosil qilish kerakki, butun konstruksiyaga qo'yilgan kuchlar uchun istalgan muvozanat tenglamasi o'rinli bo'lishi kerak (2-rasm), masalan:

$$\sum M_{iB} = 0; \quad P_1^{'} \cdot 4 + P_1^{''} \cdot 10 - Q \cdot 2 - Y_A \cdot 7 - M + P_2 \cdot 2 =$$
$$= 5 \cdot 4 + 8{,}66 \cdot 10 - 8 \cdot 2 - 12{,}8 \cdot 7 - 25 + 12 \cdot 2 = 130{,}6 - 130{,}6 = 0.$$

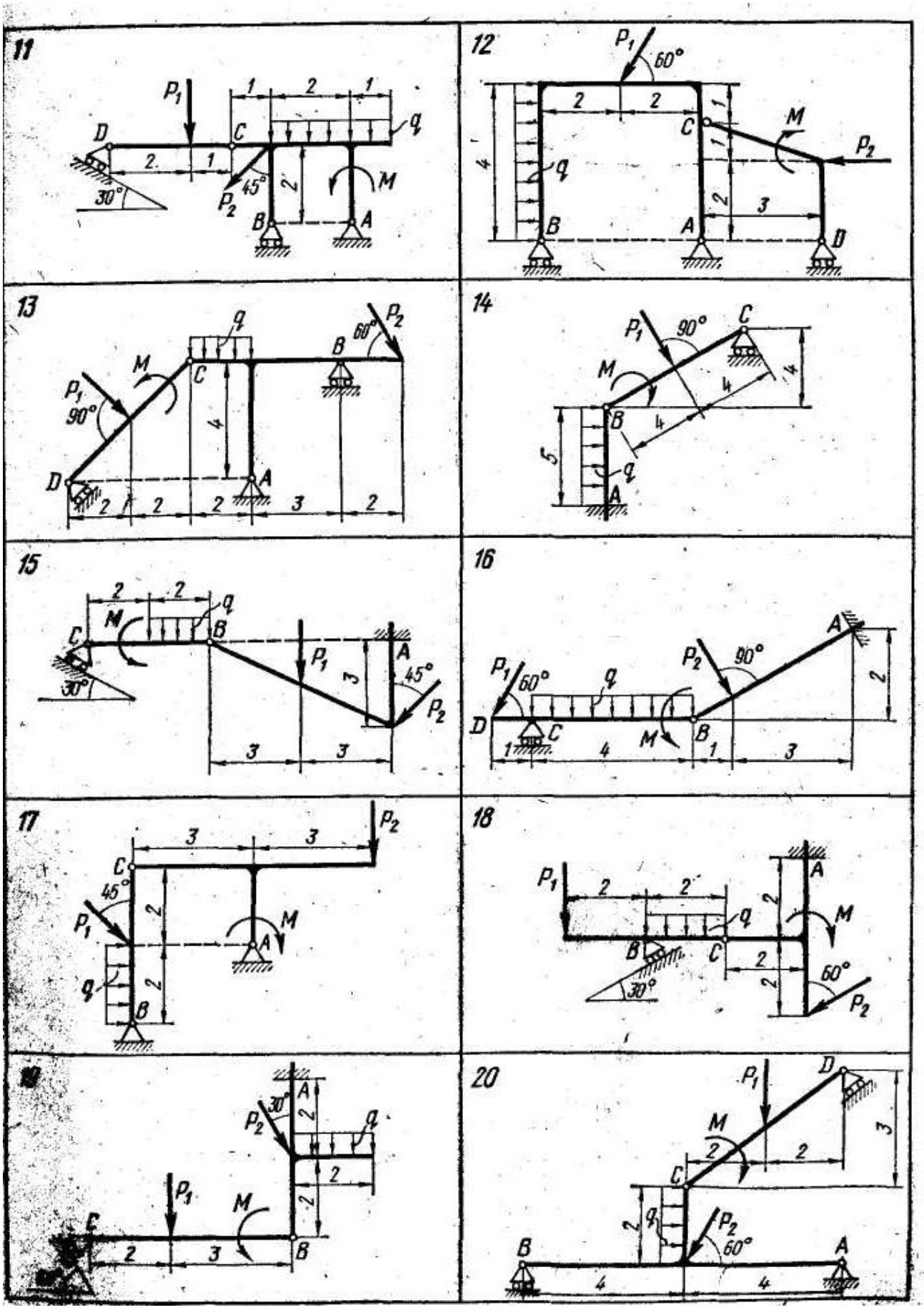
Hisob natijalari 5-jadvalda keltirilgan.

5-jadval

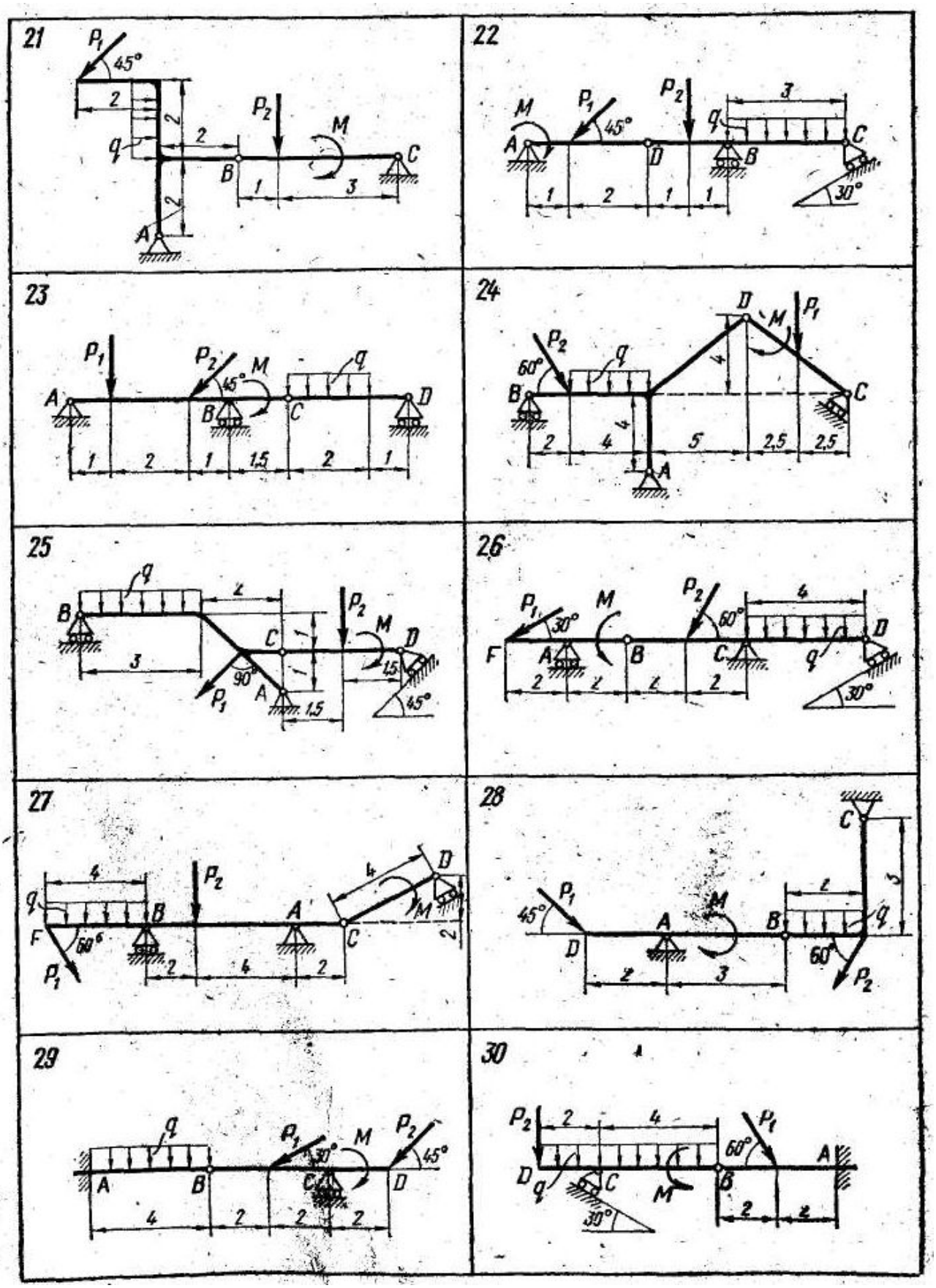
Kuchlar, kN					
X_A	Y_A	X_B	Y_B	X_C	Y_C
-7,39	12,8	4,39	7,86	-4,39	4,14



4-rasm.



5-rasm.



6-rasm.

Xisob-grafika ishi №5.

Nuqta harakat tenglamalarini tuzish va uning tezliklari va tezlanishlarini aniqlash. (Kinematika bo'limi)

Mexanizmning berilgan nuqtasi uchun harakat tenglamalari tuzilsin, uning trayektoriya uchastkasi chizilsin va $t = t_1$ vaqt oni uchun nuqtaning tezligi, to'liq, urinma va normal tezlanishi, shuningdek muvofiq nuqtadagi trayektoriya egrilik radiusi aniqlansin.

Mexanizmlar sxemalari 4-6 rasmlarda tasvirlangan, hisoblar uchun kerakli berilganlar esa 6-jadvalda keltirilgan.

6-jadval.

Номер варианта (рис. 74—76)	Размеры звеньев механизма, см			$\varphi = \varphi(t)$, рад	$s = s(t)$, см	t_1, с
	l	R	r			
1	15	—	—	$2\pi t$	—	1/6
2	—	50	—	$3\pi t$	—	1/9
3	54	—	30	πt	—	1/2
4	—	—	30	$6\pi t$	—	1/12
5	40	—	15	πt	—	1/6
6	60	—	—	—	$60\sqrt{2}\sin 2\pi t$	1/12
7	—	250	50	$5\pi t$	—	1/15
8	10	—	—	$3\pi t$	—	1/12
9	60	—	35	πt	—	1/6
10	40	—	—	—	$40\sin \pi t$	1/4
11	60	—	24	$2\pi t$	—	1/6
12	45	—	—	—	$30\sqrt{3}\cos \pi t$	1/3
13	—	50	—	$5\pi t$	—	1/15
14	20	—	—	$2\pi t$	—	1/12
15	60	—	40	$3\pi t$	—	1/12
16	40	—	—	—	$40\sin 3\pi t$	1/9
17	42	—	30	$3\pi t$	—	1/12
18	40	—	—	—	$80\sin 2\pi t$	1/6
19	—	50	—	$4\pi t$	—	1/16
20	60	—	22	$2\pi t$	—	1/6
21	—	28	12	πt	—	1/6
22	45	—	—	—	$45\sin \pi t$	1/3
23	42	—	—	—	$42\cos 2\pi t$	1/6
24	45	—	—	—	$45\sqrt{2}\sin \pi t$	1/6
25	60	—	21	πt	—	1/3
26	30	—	—	—	$20\sqrt{3}\sin 3\pi t$	1/18
27	—	23	10	$2\pi t$	—	1/8
28	—	45	30	$3\pi t$	—	1/4
29	50	—	—	—	$100\cos 2\pi t$	1/8
30	60	—	24	$3\pi t$	—	1/12

Topshiriqni bajarishga doir misol. Berilganlar: mexanizm sxemasi (1-rasm); $\varphi = \pi t\ rad$; $r = 20\,sm$; $R = 100\,sm$; $t_1 = 1/3\ s$.

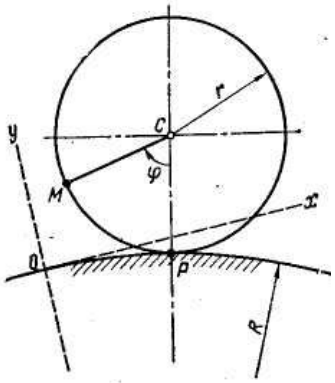
Yechim. $OP = MP$ bo'lganidan

$$R\alpha = r \cdot \varphi\ ;\ \alpha = r \cdot \varphi / R = 0{,}2\pi t\ .$$

$$t_1 = 1/3\ s \quad \varphi = 60°\ ,\ \alpha = 12°\ .$$

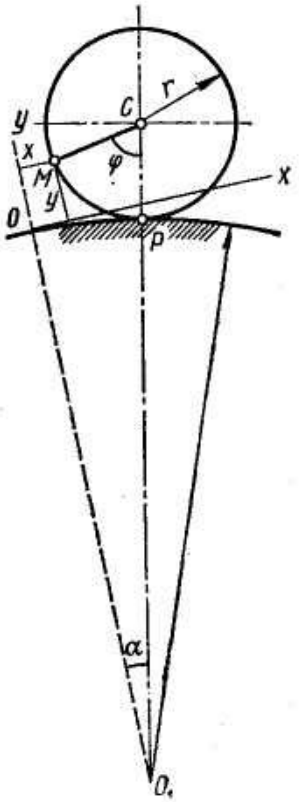
M nuqta harakat tenglamasi (2-rasm):

$$X = (R + r)\sin\alpha - r\sin(\varphi + \alpha);$$

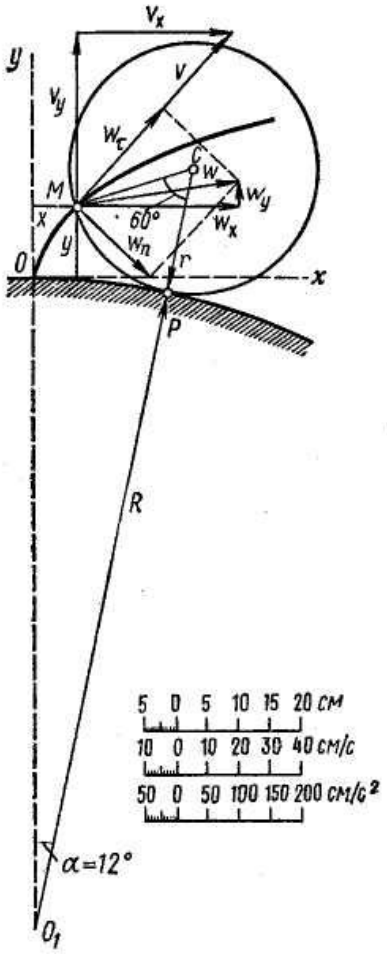


1-rasm.

2-rasm.



3-rasm.



$$Y = (R + r)\cos\alpha - R - r\cos(\varphi + \alpha)$$

yoki tugallangan ko'rinishda

$$\left.\begin{aligned} X &= 20(6\sin 0{,}2\pi t - \sin 1{,}2\pi t)\, sm; \\ Y &= 20(6\cos 0{,}2\pi t - \cos 1{,}2\pi t - 5)\, sm. \end{aligned}\right\} \quad (1)$$

Bu tenglamalar nuqta trayektoriyasining parametrik tenglamalari – epitsikloidalar hisoblanadi.

Nuqta tezligining koordinata o'qlariga proyeksiyalari:

$$v_x = \dot{X} = 24\pi(\cos 0{,}2\pi t - \cos 1{,}2\pi t)\ sm/s;$$

$$v_y = \dot{Y} = 24\pi(-\sin 0{,}2\pi t + \sin 1{,}2\pi t)\ sm/s\,.$$

Tezlik moduli

$$v = \sqrt{v_x^2 + v_y^2} = 24\pi\sqrt{2 - 2(\cos 0{,}2\pi t \cdot \cos 1{,}2\pi t + \sin 0{,}2\pi t \cdot \sin 1{,}2\pi t)} = 24\pi\sqrt{2(1 - \cos \pi t)}$$

yoki tugallangan ko’rinishda

$$v = 48\pi\left|\sin\frac{\pi t}{2}\right| sm/s. \qquad (2)$$

Nuqta tezlanishining koordinata o’qlariga proyeksiyalari

$$w_x = \ddot{x} = 4{,}8\pi^2(-\sin 0{,}2\pi t + 6\sin 1{,}2\pi t)\ sm/s^2;$$

$$w_y = \ddot{y} = 4{,}8\pi^2(-\cos 0{,}2\pi t + 6\cos 1{,}2\pi t)\ sm/s^2.$$

Tezlanish moduli

$$w = \sqrt{w_x^2 + w_y^2} = 4{,}8\pi^2\sqrt{37 - 12(\sin 0{,}2\pi t \cdot \sin 1{,}2\pi t + \cos 0{,}2\pi t \cdot \cos 1{,}2\pi t)}$$

yoki

$$w = 4{,}8\pi^2\sqrt{37 - 12\cos\pi t)}\ sm/s^2.$$

Nuqta tezligining moduli uchun berilgan misolda oddiy ifoda olinganligi uchun, urinma tezlanish modulini

$$w_\tau = \left|\frac{v_x w_x + v_y w_y}{v}\right|,$$

formula bo’yicha emas, balki (2) ifodani bevosita differensiallash bilan topamiz:

$$w_\tau = \left|\frac{dv}{dt}\right|$$

yoki

$$w_\tau = 24\pi^2\left|\cos\frac{\pi t}{2}\right| sm/s^2.$$

Nuqta tezligi va tezlanishi modullari, ularning koordinata o’qlariga proyeksiyalari, shuningdek berilgan vaqt oni $t = 1/3\,s$ uchun hisoblangan urinma va normal tezlanish 7-jadvalda keltirilgan.

7-jadval

Tezlik, sm/s			Tezlanish, sm/s^2					Egrilik radiusi, sm
v_x	v_y	v	w_x	w_y	w	w_τ	w_n	ρ
50,4	56,0	75,4	260	41	263	204	166	34,3

Nuqtaning normal tezlanishi

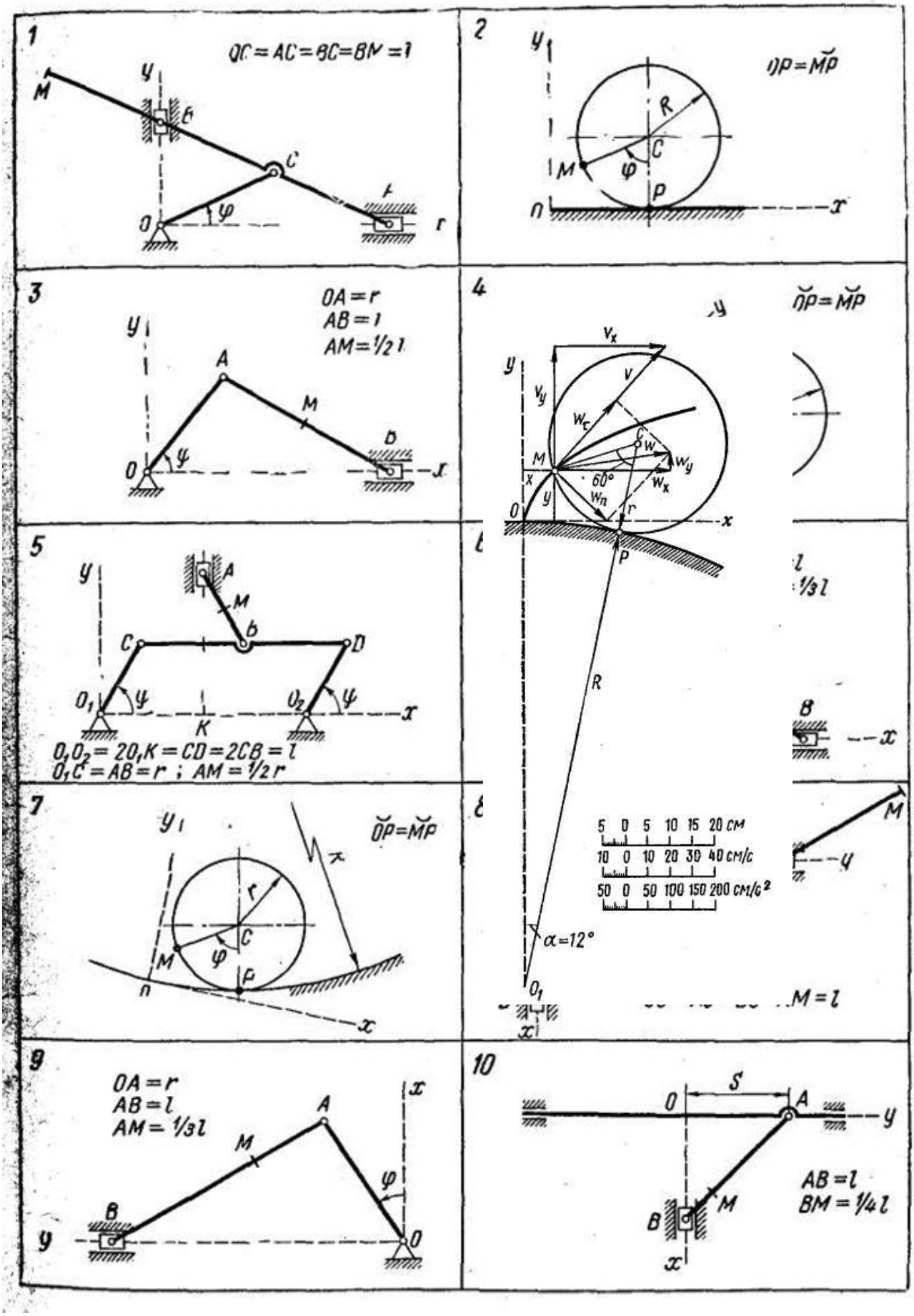
$$w_n = \sqrt{w^2 - w_\tau^2} = \sqrt{263^2 - 204^2)} = 166 sm/s^2.$$

Egrilik radiusi

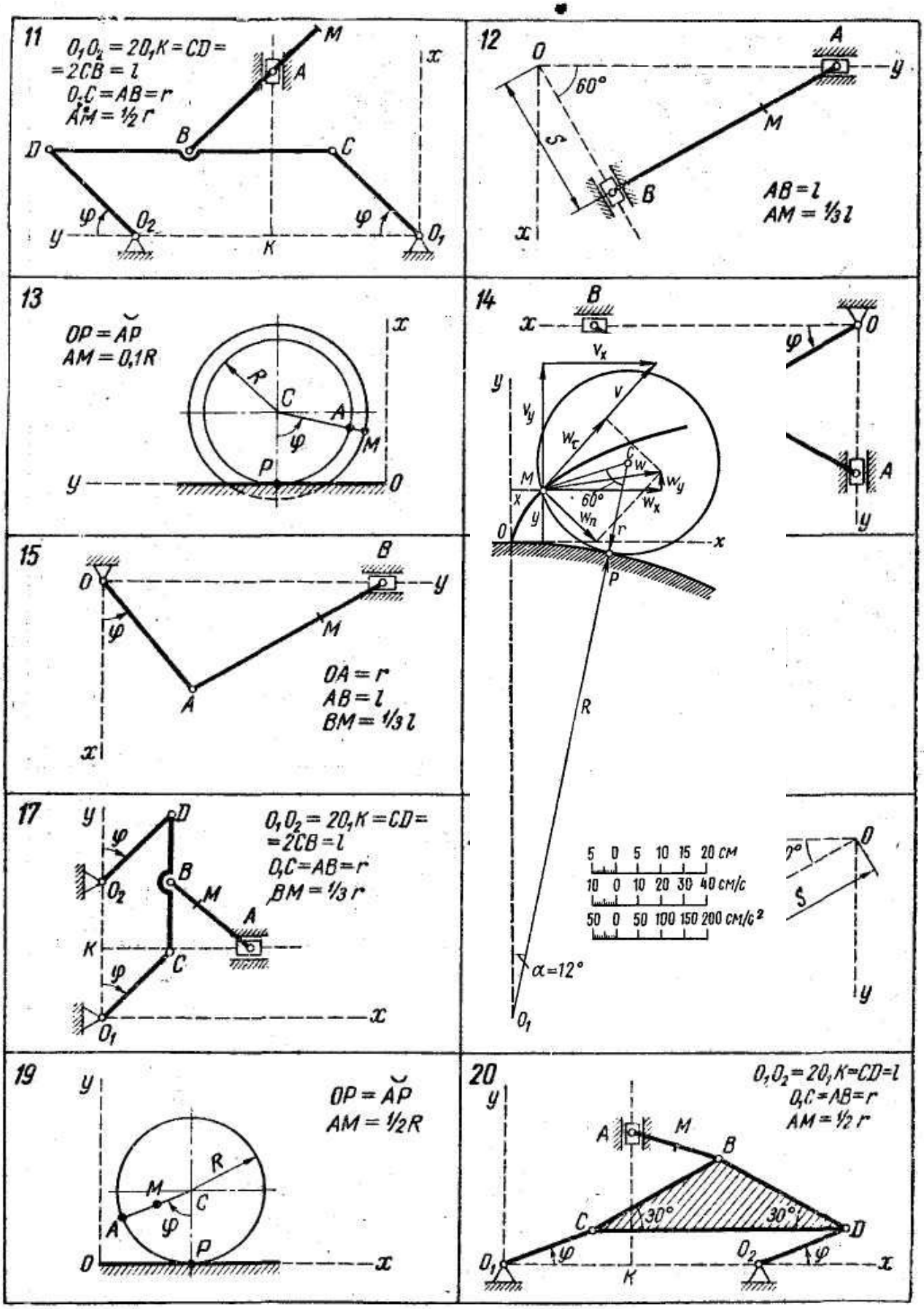
$$\rho = v^2/w_n = 75{,}4^2/166 = 34{,}3 sm.$$

Shuningdek w_n va ρ larning qiymatlari ham 7-jadvalda keltirilgan.

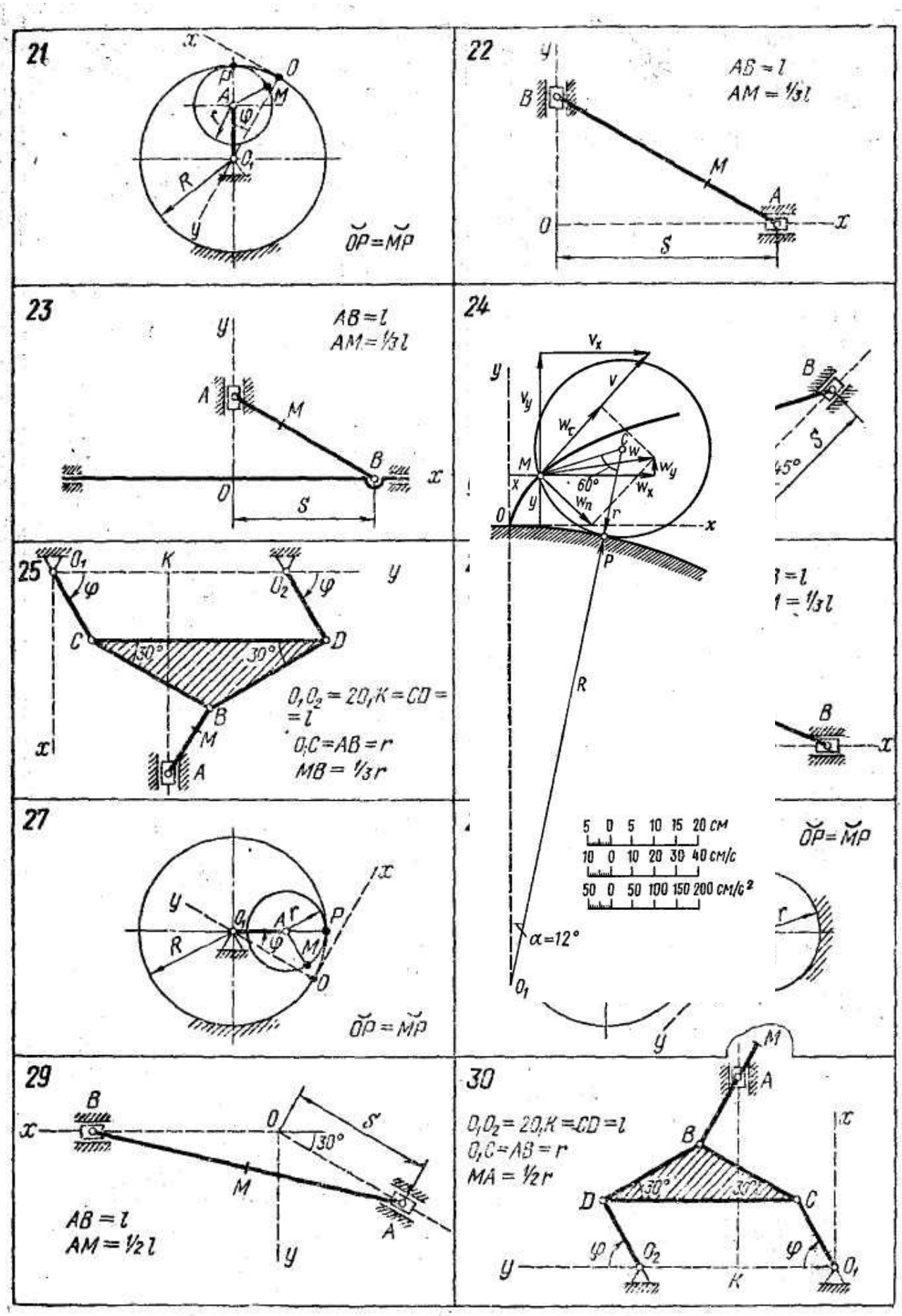
Chizmada (3-rasm) (1) tenglamalar bo’yicha qurilgan M nuqta trayektoriyasi uchastkasi, shuningdek uning tezligi, tezlanishi va ularning barcha tashkil qiluvchilari ko’rsatilgan. Xuddi shu tarzda hisoblarning to’g’riligi grafik usulda tekshiriladi.


1
OC = AC = BC = BM = l
2
OP = MP
3
OA = r
AB = l
AM = 1/2 l
4
OP = MP
5
O1O2 = 2O1K = CD = 2CB = l
O1C = AB = r ; AM = 1/2 r
7
OP = MP
9
OA = r
AB = l
AM = 1/3 l
10
AB = l
BM = 1/4 l
5 0 5 10 15 20 см
10 0 10 20 30 40 см/с
50 0 50 100 150 200 см/с²
α = 12°

4-rasm.


11
$O_1O_2 = 2O_1K = CD =$
$= 2CB = l$
$O_2C = AB = r$
$AM = \frac{1}{2}r$
12
$AB = l$
$AM = \frac{1}{3}l$
13
$OP = \breve{AP}$
$AM = 0{,}1R$
14
15
$OA = r$
$AB = l$
$BM = \frac{1}{3}l$
17
$O_1O_2 = 2O_1K = CD =$
$= 2CB = l$
$O_1C = AB = r$
$BM = \frac{1}{3}r$
19
$OP = \breve{AP}$
$AM = \frac{1}{2}R$
20
$O_1O_2 = 2O_1K = CD = l$
$O_1C = AB = r$
$AM = \frac{1}{2}r$
5 0 5 10 15 20 см
10 0 10 20 30 40 см/с
50 0 50 100 150 200 см/с²
$\alpha = 12°$

5-rasm.


21
OP=MP
22
AB=l
AM=1/3l
23
AB=l
AM=1/3l
24
25
O1O2=2O1K=CD=l
O1C=AB=r
MB=1/3r
27
OP=MP
5 0 5 10 15 20 см
10 0 10 20 30 40 см/с
50 0 50 100 150 200 см/с²
α=12°
29
AB=l
AM=1/2l
30
O1O2=2O1K=CD=l
O1C=AB=r
MA=1/2r

6-rasm.

Xisob-grafika ishi №6.

Ilgarilanma va aylanma harakatda qattiq jism nuqtalarining tezliklari va tezlanishlarini aniqlash.

(Kinematika bo'limi)

Berilgan tenglama bo'yicha to'g'ri chiziqli ilgarilanma harakatlanayotgan yuk 1 ning tezligi, shuningdek yuk S ga teng yo'lni o'tish onidagi M mexanizmning nuqtalari aylanma, markazga intiluvchi va to'liq tezlanishlari aniqlansin. Mexanizmlar sxemalari 3-5 rasmlarda tasvirlangan, hisoblar uchun kerakli berilganlar esa 8-jadvalda keltirilgan.

8-jadval.

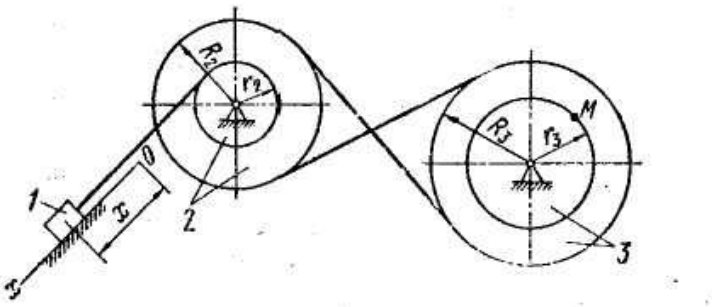
Номер варианта (рис. 80—82)	Радиусы, см				Уравнение движения груза 1 $x = x(t)$ (x — в см, t — в с)	s, м
	R_2	r_2	R_3	r_3		
1	60	45	36	—	$10+100\ t^2$	0,5
2	80	—	60	45	$80\ t^2$	0,1
3	100	60	75	—	$18+70\ t^2$	0,2
4	58	45	60	—	$50\ t^2$	0,5
5	80	—	45	30	$8+40\ t^2$	0,1
6	100	60	30	—	$5+60\ t^2$	0,5
7	45	35	105	—	$7+90\ t^2$	0,2
8	35	10	10	—	$4+30\ t^2$	0,5
9	40	30	15	—	$3+80\ t^2$	0,2
10	15	—	40	35	$70\ t^2$	0,4
11	40	25	20	—	$5+40\ t^2$	0,3
12	20	15	10	—	$2+50\ t^2$	0,1
13	30	20	40	—	$60\ t^2$	0,4
14	15	10	15	—	$6+20\ t$	0,1
15	15	10	15	—	$8+40\ t^2$	0,3
16	20	15	15	—	$3+40\ t^2$	0,4
17	15	10	20	—	$80\ t^2$	0,6
18	20	15	10	—	$4+20\ t$	0,3
19	15	10	20	—	$5+80\ t^2$	0,2
20	25	15	10	—	$50\ t^2$	0,3
21	20	10	30	10	$4+90\ t^2$	0,5
22	40	20	35	—	$10+40\ t^2$	0,5
23	40	30	30	15	$7+40\ t$	0,6
24	30	15	40	20	$90\ t^2$	0,2
25	50	20	60	—	$2+50\ t$	0,5
26	32	16	32	16	$5+60\ t^2$	0,1
27	40	18	40	18	$6+30\ t^2$	0,3
28	40	20	40	15	$50\ t^2$	0,4
29	25	20	50	25	$3+30\ t$	0,6
30	30	15	20	—	$5+60\ t^2$	0,2

Topshiriqni bajarishga doir misol. Berilganlar: mexanizm sxemasi (1-rasm); $X = 2 + 70t^2\ sm$; $(t - s\,da)$; $R_2 = 50\,sm$; $r_2 = 30\,sm$; $R_3 = 60\,sm$; $r_3 = 40\,sm$; $S = 40\,sm$.

Yechim. Yuk tomonidan o'tilgan S yo'l $40\,sm$ ga teng bo'ladigan vaqt oni τ ni topamiz:

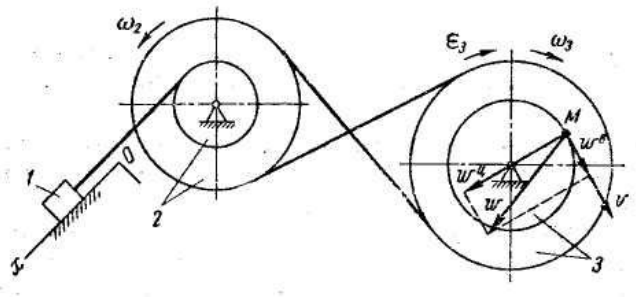
$$S = X_{(t=\tau)} - X_{(t=0)} = 70t^2,$$

bu yerda



$$\tau = \sqrt{S/70} = \sqrt{40/70} = 0{,}76s\ .$$

1-rasm.



2-rasm.

Harakat tenglamasini vaqt bo'yicha differensiallab, yukning tezligini topamiz:

$$v_1 = \left|\dot{X}\right| = 140t\ sm/s\ .$$

2 zvenoning burchak tezligi

$$\omega_2 = v_1/r_2 = 140t/30 = (14/3)\cdot t\ s^{-1}\ .$$

Moslanuvchan uzatish bilan bog'langan 2 va 3 g'ildiraklar burchak tezliklari ularning radiuslariga teskari proporsional bo'ladi, ya'ni

$$\omega_2/\omega_3 = R_3/R_2\ ,$$

bu yerda

$$\omega_3 = (R_2/R_3)\cdot\omega_2 = (50/60)\cdot(14/3)\cdot t = (35/9)\cdot t\ s^{-1}\ .$$

Burchak tezlanish

$$\varepsilon_3 = \dot{\omega}_3 = 35/9\ s^{-2} = const\ .$$

M nuqtaning tezligi

$$v = r_3\omega_3 = 40\ \omega_3$$

ga teng va radiusga perpendikulyar holda g'ildirak 3 ning aylanish tomoniga yo'nalgan bo'ladi.

M nuqtaning aylanma tezlanishi

$$w^B = r_3\varepsilon_3 = 40\varepsilon_3$$

ga teng va tezlik bilan bir xil yo'nalishga ega bo'ladi, chunki ko'rib chiqilayotgan misolda g'ildirakning aylanishi tezlanuvchan.

M nuqtaning markazga intilma tezlanishi

$$w^{II} = r_3\omega_3^2 = 40\omega_3^2$$

ga teng va radius bo'ylab g'ildirak markaziga yo'nalgan.

To'liq tezlanish

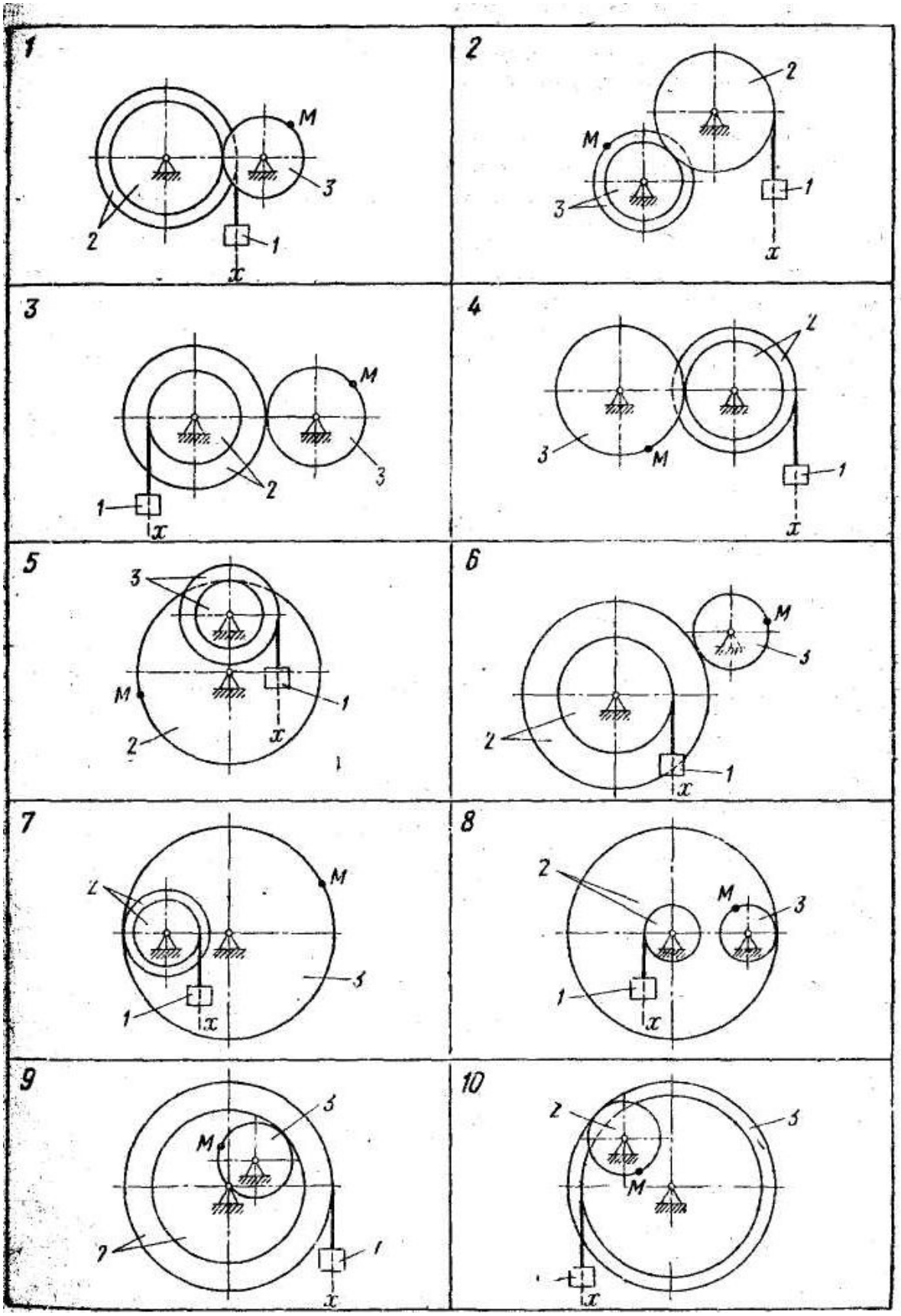
$$w = \sqrt{(w^B)^2 + (w^{II})^2}\ .$$

$t = \tau$ vaqt oni uchun bu miqdorlarning qiymatlari 9-jadvalda keltirilgan.

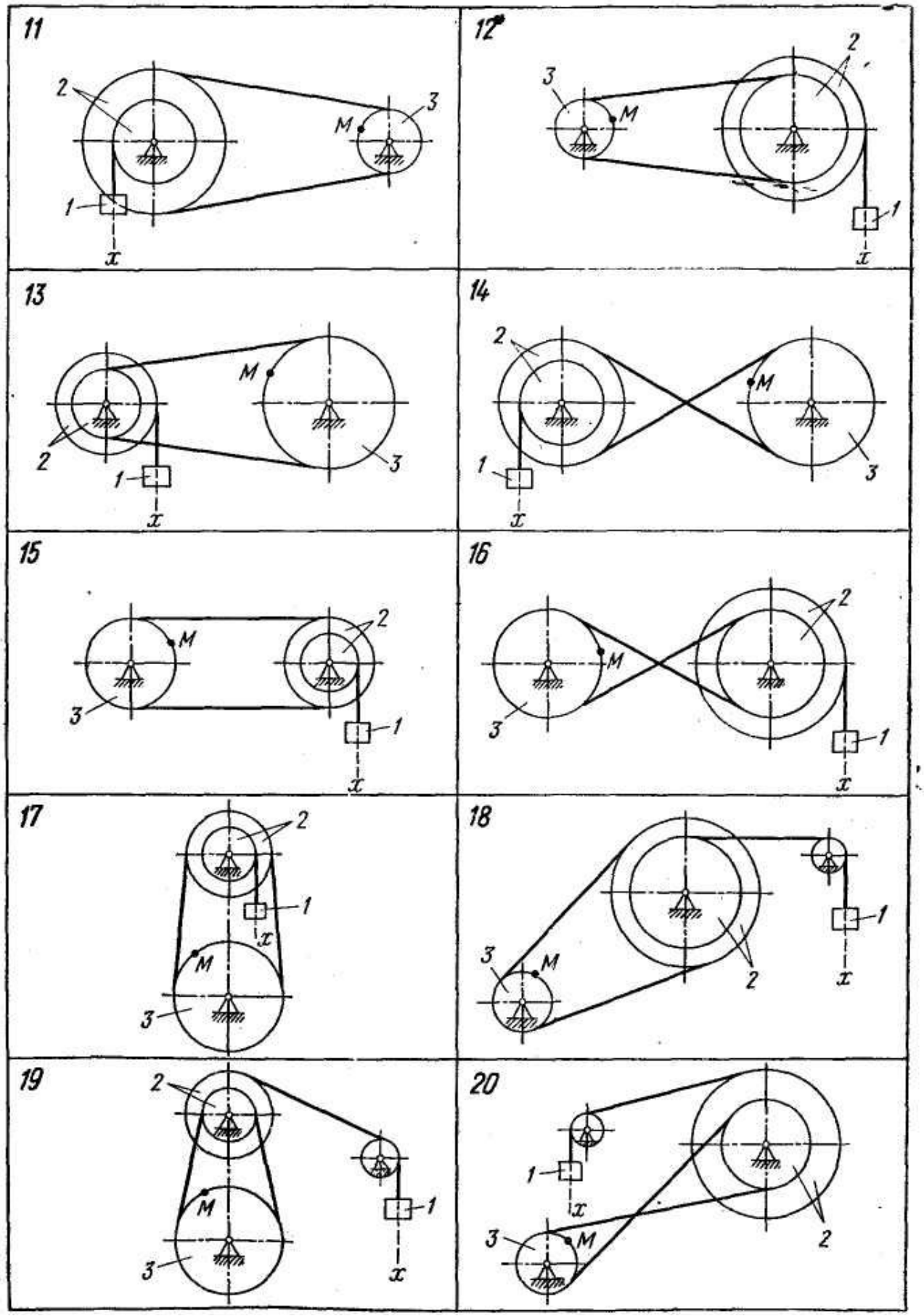
9-jadval.

ω_3, s^{-1}	ε_3, s^{-2}	$v, sm/s$	Tezlanish, sm/s^2		
			w^B	$w^{Ц}$	w
2,94	3,89	118	156	346	379

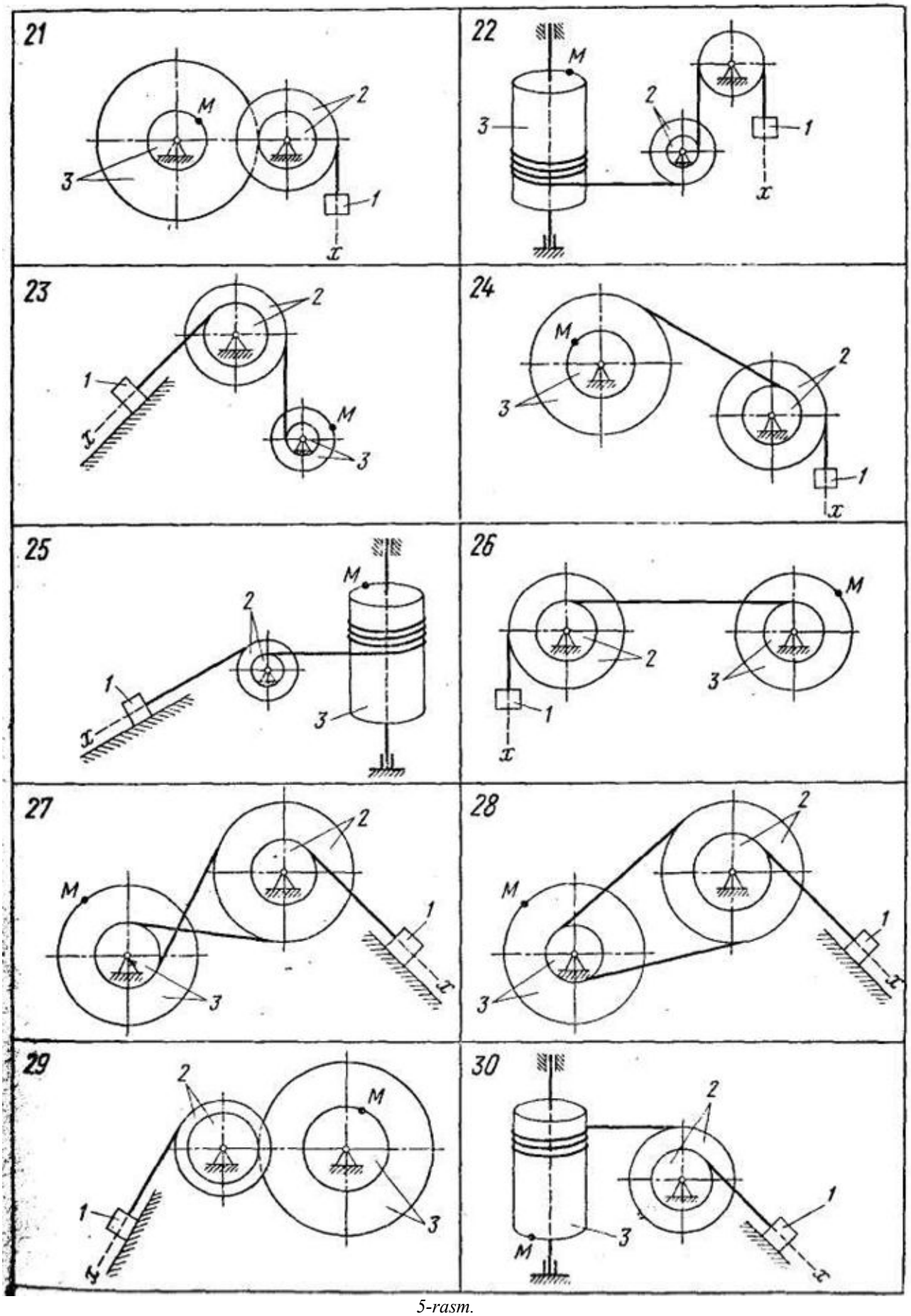
M nuqtaning tezligi va tezlanishlari 2-rasmda ko'rsatilgan.


1
M
3
2
1
x
2
2
M
1
3
x
3
M
3
2
1
x
4
2
3
M
1
x
5
3
M
1
2
x
6
M
3
2
1
x
7
2
M
3
1
x
8
2
M
3
1
x
9
3
M
2
1
x
10
2
3
M
x

3-rasm.


11
2
M
3
1
x
12
2
3
M
1
x
13
M
2
3
1
x
14
2
M
1
3
x
15
M
2
3
1
x
16
2
M
3
1
x
17
2
1
x
M
3
18
1
3
M
2
x
19
2
M
1
3
x
20
1
x
3
M
2

4-rasm.


21
M
2
3
1
x
22
M
3
2
1
x
23
2
1
x
M
3
24
M
3
2
1
x
25
M
2
1
x
3
26
M
2
3
1
x
27
2
M
1
x
3
28
2
M
1
x
3
29
2
M
1
x
3
30
2
1
3
M

5-rasm.

Xisob-grafika ishi №7.
O'zgarmas kuch ta'sirida bo'lgan moddiy nuqta harakati differensial tenglamalarini integrallash.
(Dinamika bo'limi)

1-5 variantlar (2-rasm, sxema 1). Jism gorizontal bilan α burchak hosil qiluvchi qiya tekislikda t sekund davomida A nuqtadan AB uchastka bo'ylab harakatlanadi. Uning boshlang'ich tezligi v_0, jism bilan tekislik orasidagi ishqalanish koeffitsiyenti f. B nuqtada jism v_1 tezlik bilan tekislikdan tushib ketadi va T sek davomida havoda bo'lib, gorizontal bilan β burchak hosil qiluvchi BD tekislikka C nuqtada v_2 tezlik bilan tushadi. Masalani yechishda jismni moddiy nuqta deb qarab, havo qarshiligi hisobga olinmasin. AB uchastka uzunligi l.

1-variant. Berilgan: $\alpha = 30°$; $v_0 = 0$; $f = 0{,}2$; $l = 10\,m$; $\beta = 60°$; t va h topilsin.

2-variant. Berilgan: $\alpha = 45°$; $v_0 = 2\,m/s$; $f = 0{,}2$; $h = 4\,m$; $\beta = 45°$; l aniqlansin va BC uchastkadagi nuqta trayektoriyasi tenglamasi topilsin.

3-variant. Berilgan: $\alpha = 30°$; $v_0 = 2{,}5\,m/s$; $f = 0{,}1$; $l = 8\,m$; $d = 10\,m$; $\beta = 60°$; v_1 va t topilsin.

4-variant. Berilgan: $v_0 = 0$; $t = 2\,s$; $l = 9{,}8\,m$; $f = 0$; $\beta = 60°$; α va T topilsin.

5-variant. Berilgan: $\alpha = 30°$; $v_0 = 0$; $t = 3\,s$; $l = 9{,}8\,m$; $\beta = 45°$; f va v_2 topilsin.

6-10 variantlar (2-rasm, sxema 2). Chang'ichi gorizontga α burchak qiyalikdagi AB uchastkaning A nuqtasiga v_0 tezlik bilan keladi. Uchastka uzunligi l. AB ucastkada chang'ining ishqalanish koeffitsiyenti f. Chang'ichi A nuqtadan B nuqtagacha t sekundda yetib keladi va B nuqtada v_1 tezlik bilan tramplindan sakraydi. T vaqtdan keyin u gorizont bilan β burchak hosil qiluvchi C nuqtaga v_2 tezlik bilan tushadi. Masalani yechishda chang'ichini moddiy nuqta deb, havo qarshiligi hisobga olinmasin.

6-variant. Berilgan: $\alpha = 20°$; $f = 0{,}1$; $t = 0{,}2\,s$; $h = 40\,m$; $\beta = 30°$; l va v_2 topilsin.

7-variant. Berilgan: $\alpha = 15°$; $f = 0{,}1$; $v_0 = 16\,m/s$; $l = 5\,m$; $\beta = 45°$; T va v_1 topilsin.

8-variant. Berilgan: $v_0 = 21\,m/s$; $f = 0$; $t = 0{,}3\,s$; $v_1 = 20\,m/s$; $\beta = 60°$; α va d topilsin.

9-variant. Berilgan: $\alpha = 15°$; $f = 0{,}1$; $t = 0{,}3\,s$; $h = 30\sqrt{2}\,m$; $\beta = 45°$; v_1 va v_0 topilsin.

10-variant. Berilgan: $\alpha = 15°$; $f = 0$; $v_0 = 12\,m/s$; $d = 50\,m$; $\beta = 60°$; t va BC uchastkada chang'ichi trayektoriyasi tenglamasi topilsin.

11-15 variantlar (2-rasm, sxema 3). Gorizont bilan α burchak hosil qiluvchi l uzunlikdagi AB qiya tekislikda mototsiklchi t sekund davomida v_0 tezlik bilan ko'tarilmoqda. Butun AB uchastkada mototsikl o'zgarmas P kuch ta'sirida v_1 tezlikka erishadi. Havoda T sekund davomida bo'lib, d kenglikdagi jardan sakraydi va C nuqtaga v_2 tezlik bilan tushadi. Mototsikl va mototsiklchi massasi m. Masalani yechishda mototsiklni moddiy nuqta deb, havo qarshiligi hisobga olinmasin.

11-variant. Berilgan: $\alpha = 30°$; $P \neq 0$; $l = 40\,m$; $v_0 = 0$; $v_1 = 4{,}5\,m/s$; $d = 3\,m$; t va h

topilsin.

12-variant. Berilgan: $\alpha = 30°$; $P = 0$; $l = 40\,m$; $v_1 = 4{,}5\,m/s$; $h = 1{,}5\,m$; v_0; va d topilsin.

13-variant. Berilgan: $\alpha = 30°$; $m = 400\,kg$; $v_0 = 0$; $t = 20\,s$; $d = 3\,m$; $h = 1{,}5\,m$; P va l topilsin.

14-variant. Berilgan: $\alpha = 30°$; $m = 400\,kg$; $P = 2{,}2\,kN$, $v_0 = 0$; $l = 40\,m$; $d = 5\,m$; v_1 va v_2 topilsin.

15-variant. Berilgan: $\alpha = 30°$; $P = 2\,kN$; $l = 50\,m$; $v_0 = 0$; $l = 50\,m$; $h = 2\,m$; $d = 4\,m$; T va m topilsin.

16-20 variantlar (2-rasm, sxema 4). Jism A nuqtadan uzunligi l bo'lgan AB uchastka bo'ylab gorizont bilan α burchak hosil qiluvchi qiya tekislikda harakatlanadi. Uning boshlang'ich tezligi v_A, ishqalanish koeffitsiyenti f. Jism t vaqtdan keyin B nuqtada v_B tezlik bilan qiyalikni tark qilib, C nuqtada v_C tezlik bilan gorizontal tekislikka tushadi. Shu vaqtda u T sekund davomida havoda bo'lgan. Masalani yechishda jismni moddiy nuqta deb, havo qarshiligi hisobga olinmasin.

16-variant. Berilgan: $\alpha = 30°$; $f = 0{,}1$; $v_A = 1\,m/s$; $t = 1{,}5\,s$; $h = 10\,m$; v_B va d topilsin.

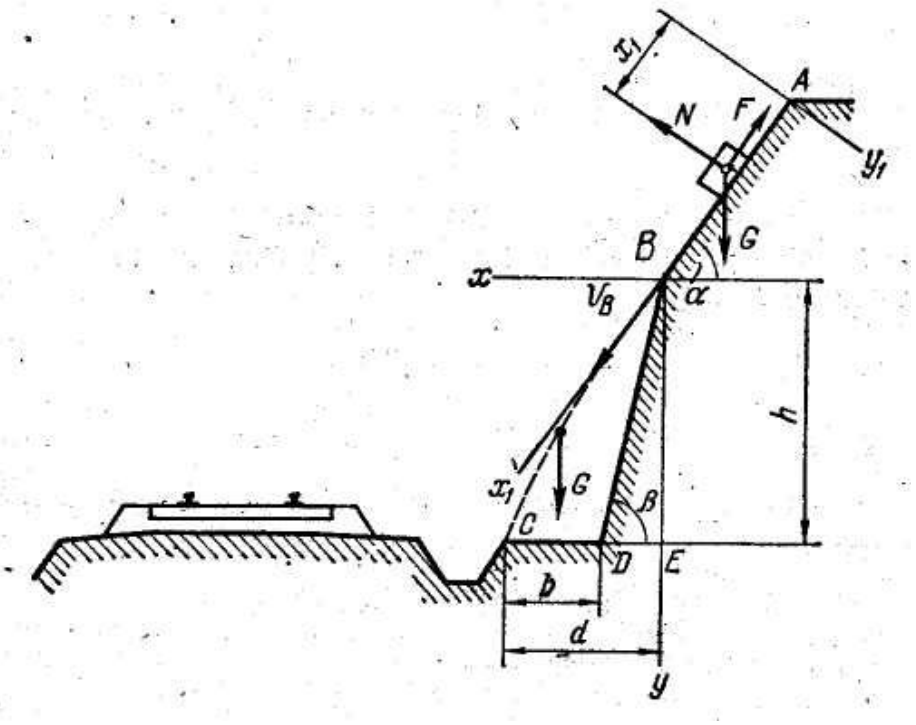
17-variant. Berilgan: $v_A = 0$; $\alpha = 45°$; $t = 2\,s$; $l = 10\,m$; f va nuqtaning BC uchastkadagi trayektoriya tenglamasi topilsin.

18-variant. Berilgan: $f = 0$; $v_A = 0$; $t = 2\,s$; $l = 9{,}81\,m$; $h = 20\,m$; α va T topilsin.

19-variant. Berilgan: $v_A = 0$; $\alpha = 30°$; $f = 0{,}2$; $l = 10\,m$; $d = 12\,m$; t va h topilsin.

20-variant. Berilgan: $v_A = 0$; $\alpha = 30°$; $f = 0{,}2$; $l = 6\,m$; $h = 4{,}5\,m$; t va v_C topilsin.

Topshiriqni bajarishga doir misol (1-rasm). Qoyalar oralab o'tuvchi temir yo'l relslari oralig'iga qoya qiyaliklaridan tosh tushmasligi uchun DC "yo'lakcha" qo'yiladi. Toshni eng yuqori A nuqtadan boshlang'ich tezliksiz tushadi deb hisoblab, "yo'lakcha" eng kichik b enini va toshning C nuqtaga tushish tezligi v_C topilsin. Tosh α qiyalikdagi l uzunlikdagi AB uchastka bo'ylab t sekund harakatlanadi.



1-rasm.

Hisoblashlarda havo qarshiligi hisobga olinmasin, sirpanish koeffitsiyenti f o'zgarmas deb hisoblansin.

Berilgan: $v_A = 0$; $\alpha = 60^0$; $l = 4m$; $\mathrm{t} = 1\,\mathrm{sek}$; $\mathrm{h} = 5\,\mathrm{m}$; $\beta = 75^0$; $\mathrm{f} \neq 0$.

Topish kerak: v_C va b larni.

Yechim. AB uchastka bo'ylab tosh harakatini qaraymiz. Toshni moddiy nuqta deb olib, unga ta'sir qiluvchi $\vec{N}, \vec{G}, \vec{F}$ kuchlarni chizmada tasvirlaymiz va shu uchastka uchun harakat differensial tenglamalarini tuzamiz:

$$m\ddot{X}_1 = \sum X_{i1}, \quad m\ddot{X}_1 = G\sin\alpha - F.$$

Ishqalanish kuchi $F = fN$, bunda $N = G\cos\alpha$.

Shunday qilib

$$m\ddot{X}_1 = G\sin\alpha - fG\cos\alpha$$

yoki

$$\ddot{X}_1 = g\sin\alpha - fg\cos\alpha.$$

Differensial tenglamalarni ikki marta integrallab

$$\dot{X}_1 = g(\sin\alpha - f\cos\alpha)t + C_1,$$

$$X_1 = [g(\sin\alpha - f\cos\alpha)/2]t^2 + C_1 t + C_2.$$

C_1 va C_2 o'zgarmaslarni aniqlash uchun masala boshlang'ich shartlaridan foydalanamiz. $t = 0$ da $X_{1_0} = 0$ va $\dot{X}_{1_0} = 0$.

$t = 0$ uchun integrallashdan olingan tenglamalar tuzamiz:

$$\dot{X}_{1_0} = C_1, \quad X_{1_0} = C_2.$$

Unda $C_1 = 0$ va $C_2 = 0$.

Shunday qilib

$$\dot{X}_1 = g(\sin\alpha - f\cos\alpha)t,$$

$$X_1 = [g(\sin\alpha - f\cos\alpha)/2]t^2.$$

Tosh uchastkadan chiqib ketadigan t_1 vaqt uchun $\dot{X}_1 = v_B$, $X_1 = l$.

Unda

$$v_B = g(\sin\alpha - f\cos\alpha)t\,,$$
$$l = [g(\sin\alpha - f\cos\alpha)/2]t^2\,.$$

Bundan $v_b = 2l/t_1$ yoki $v_b = (2\cdot 4)/1 = 8m/s$.

Toshning B nuqtadan C nuqtagacha harakatini qaraymiz. Nuqtaga $\vec{G}$ kuch ta'sir qiladi deb, uning harakat differensial tenglamalarini tuzamiz:

$$m\ddot{X} = 0\,,\ m\ddot{Y} = G\,.$$

Tenglamalardan birinchisini integrallab

$$\dot{X} = C_3\,,\ X = C_3 t + C_4\,.$$

$t=0$ da $X_0=0$, $\dot{X}_0 = v_B\cos\alpha$ boshlang'ich shartlardan $t=0$ uchun $\dot{X}_0 = C_3;\ X_0 = C_4$.

Bundan $C_3 = v_B\cos\alpha$, $C_4=0$.

Unda

$$\dot{X} = v_B\cos\alpha;\ X = v_B\cos\alpha\, t\,.$$

$m\ddot{Y} = G$ tenglamani integrallab

$$\dot{Y} = gt + C_5,\ Y = {gt^2}/{2} + C_5 t + C_6\,.$$

$t=0$ da $Y_0=0$, $\dot{Y}_0 = v_B\sin\alpha$ boshlang'ich shartlardan $t=0$ uchun $\dot{Y}_0 = C_5;\ Y_0 = C_6$.

Bundan $C_5 = v_B\sin\alpha$, $C_6=0$.

Unda

$$\dot{Y} = gt + v_B\sin\alpha\,,\ \ Y = {gt^2}/{2} + v_B\sin\alpha\, t\,.$$

Shunday qilib, tosh harakat tenglamasi

$$X = v_B\cos\alpha\, t\,,\ \ Y = {gt^2}/{2} + v_B\sin\alpha\, t$$

Harakat tenglamalaridan t ni chiqarib, toshning trayektoriya tenglamasini topamiz. Birinchi tenglamadan t ni topib, ikkinchi tenglamaga qo'ysak, parabola tenglamasi hosil bo'ladi:

$$Y = \frac{gX^2}{2v_B^2\cos^2\alpha} + X\,tg\alpha\ .$$

Toshning tushish paytida

$$Y=h=5\ m,\ X=d,$$

unda

$$5 = \frac{9{,}81d^2}{2{,}8^2\cdot 0{,}5^2} + d\sqrt{3}\,.$$

Bundan $d_{1,2} = -2{,}82 \pm 4{,}93$ va $d_1 = 2{,}11m$, $d_2 = -7{,}75m$.

Nuqta trayektoriyasi musbat absissali parabola tarmog'i bo'lganidan $d = 2{,}11m$.

Uchastka maksimal eni

$$b = d - ED = d - {h}/{tg75^\circ} = 2{,}11 - {5}/{3{,}73} = 0{,}77m\,.$$

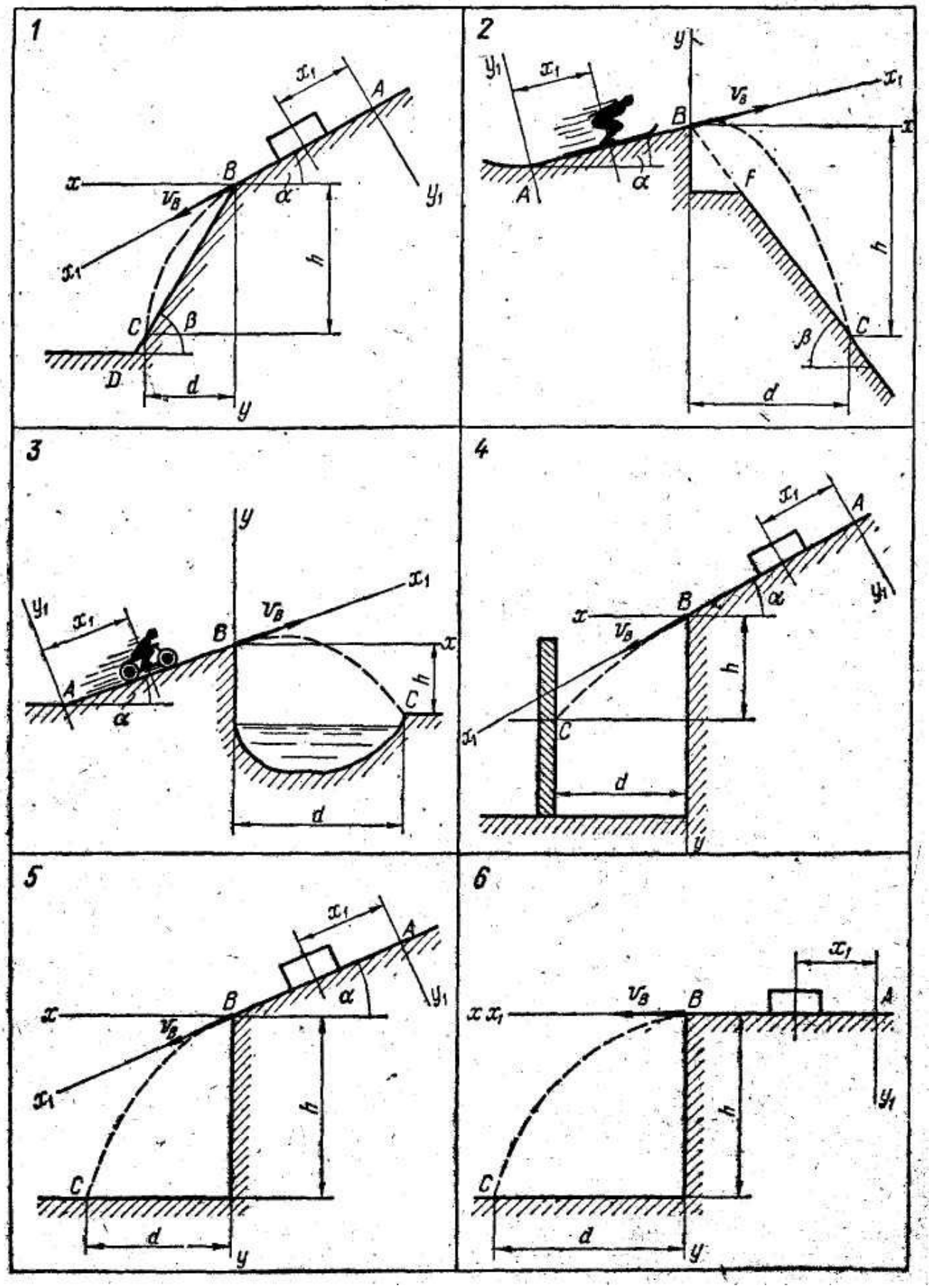
$X = v_B\cos\alpha\, t$ tenglamadan toshning B nuqtadan C nuqtagacha harakat vaqtini topamiz: $\dot{X} = v_B\cos\alpha$, $\dot{Y} = gt + v_B\sin\alpha$;

Unda

$$v = \sqrt{\dot{X}^2 + \dot{Y}^2}\,.$$

Toshning tushish vaqti $t=T=0{,}53s$ uchun

$$v_C = \sqrt{(v_B\cos\alpha)^2 + (gt + v_B\sin\alpha)^2} = \sqrt{(8\cdot 0{,}5)^2 + (9{,}81\cdot 0{,}53 + 8\cdot 0{,}87)^2} = 12{,}8m/s\,.$$



2-rasm.

Xisob-grafika ishi №8.
Moddiy nuqta tezligini harakat miqdorining o'zgarishi haqidagi teoremani qo'llab aniqlash.
(Dinamika bo'limi)

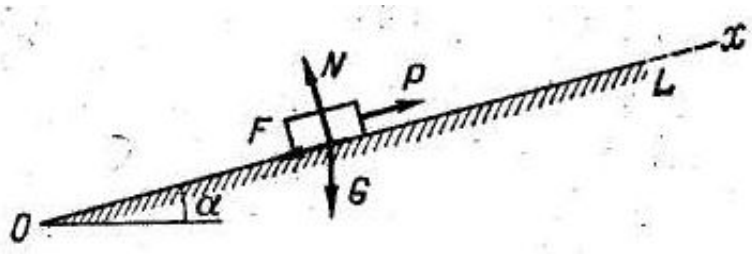
Massasi m bo'lgan jism gorizontga α burchak ostidagi qiya tekislikda yuqoriga tomon v_0 tezlik bilan P kuch ta'sirida harakatlanmoqda. P kuchning $P=P(t)$ o'zgarish qonunini va ishqalanish koeffitsiyenti f ni bilgan holda t_1, t_2, t_3 vaqtlardagi jismning v_1, v_2, v_3 tezliklarini aniqlash kerak. t_1 vaqt uchun olingan natijani harakat differensial tenglamalari tuzib tekshirilsin. Yechim uchun zarur ma'lumotlar 1-jadvalda berilgan.

P kuchning t_0, t_1, t_2, t_3 vaqtlardagi P_0, P_1, P_2, P_3 qiymatlari bo'yicha $P=P(t)$ o'zgarish grafigini tuzishda berilgan vaqtlar oralig'ida kuch chiziqli o'zgaradi deb hisoblansin. 1-jadvalda P kuchning qiymati kasr ko'rinishida berilganligi, kuch modulining berilgan vaqt oralig'ida "sakrash" xususiyatiga ega ekanligini ko'rsatadi: suratda vaqt oralig'ining oxiridagi kuch moduli, maxrajda esa keyingi vaqt oralig'ining boshidagi kuch moduli ko'rsatilgan.

1-jadval.

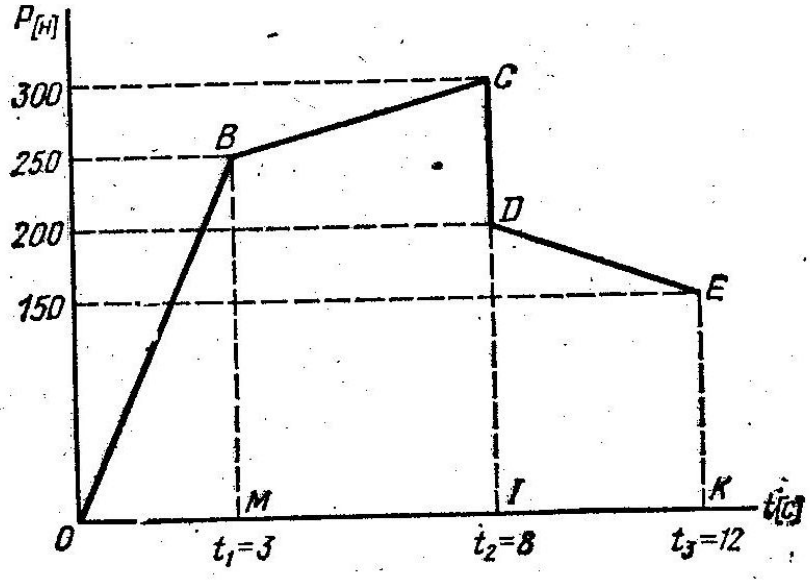
Номер варианта	m, кг	v_0, м/с	t_1	t_2	t_3	P_0	P_1	P_2	P_3	α град	f
			с			Н					
1	35	5,4	4	10	18	100	200	150	250	25	0,10
2	20	0	6	10	15	200	160	160	180	37	0,25
3	25	0	4	10	16	200	200/120	120	0	21	0,10
4	10	4,5	5	10	16	0	180	40	100	32	0,12
5	16	9,0	4	8	16	120	120/0	0	160	24	0,08
6	40	4,0	4	8	12	400	300	300	0	40	0,06
7	20	8,0	5	8	11	0	300	0	0	25	0,20
8	16	7,6	6	11	13	75	200	0	0	23	0,12
9	12	0	6	10	14	100	140	0	0	20	0,20
10	50	12,0	2	6	12	0	300	200	200	27	0,08
11	10	5,0	6	10	16	50	100	100	200	35	0,24
12	12	3,0	3	8	14	60	180	120	120	42	0,15
13	10	8,0	4	12	16	0	150	150	100	30	0,18
14	20	8,5	5	8	15	40	100	150	0	23	0,07
15	14	9,0	7	12	18	0	140	0	100	18	0,15
16	20	3,0	5	9	17	300	150	100	100	39	0,12
17	24	10,0	6	10	15	0	180	60	140	15	0,20
18	15	13,0	8	16	20	110	150	0	90	26	0,22
19	15	7,2	3	10	16	150	110	90	120	30	0,30
20	22	8,2	2	9	11	70	110	110	50	15	0,15
21	13	10,0	8	12	16	0	200/0	0/200	100	28	0,14
22	11	6,0	7	9	14	160	0	0/100	120	31	0,11
23	12	4,5	5	10	16	50	120	40	80	21	0,22
24	10	7,0	4	14	29	100	50	50	0	18	0,09
25	18	0	8	10	16	180	160/0	0/140	180	33	0,17
26	8	9,0	4	8	12	0	150	0	120	45	0,10
27	17	5,0	7	10	18	190	170/0	100	280	38	0,21
28	9	7,5	4	12	17	0	140/70	100/70	70	26	0,20
29	20	9,5	5	6	11	0	400	400/100	200	15	0,25
30	10	10,2	6	7	10	120	70	0	120	33	0,15

Topshiriqni bajarishga doir misol. Berilgan: $m=40kg;\ v_0=10m/s;\ t_1=3s;\ t_2=8s;\ t_3=12s;\ P_0=0;\ P_1=250N;\ P_2=300/200N;\ P_3=150N;\ \alpha=30°;\ f=0,1.$
Topish kerak: v_1 -? v_2 -? v_3 -?
Yechim. 1-rasmda jismga ta'sir qiluvchi kuchlarni tasvirlaymiz. Bular: G – og'irlik kuchi, N – tekislik normal reaksiyasi, P – tortish kuchi va F – ishqalanish kuchi.



1-rasm.

$P_0,\ P_1,\ P_2, P_3$ qiymatlari bo'yicha $P=P(t)$ o'zgarish grafigini quramiz (2-rasm).



2-rasm.

1. Moddiy nuqta deb qabul qilingan jism uchun *0* dan t_1 gacha bo'lgan vaqt oralig'I uchun harakat miqdorining o'zgarishi haqidagi teoremani x o'qdagi proyeksiyada ifodalab yozamiz:

$$mv_{1x} - mv_{0x} = \sum S_{ix} . \qquad (1)$$

Bunda $\sum S_{ix} = -Gt_1 \sin\alpha - Ft_1 + S_{Px}$.

P o'zgaruvchi kuchning t_1 vaqtdagi impulsi proyeksiyasi quyidagicha aniqlanadi:

$$S_{Px} = \int_0^{t_1} Pdt .$$

Ushbu integral $P=P(t)$ o'zgarish grafigidagi OBM uchburchak yuzi orqali ifodalanadi:

$$S_{Px} = (3 \cdot 250)/2 = 375\,N \cdot s .$$

Ishqalanish kuchi $F = fN = fG\cos\alpha$ ekanligidan (1) tenglama quyidagicha o'zgaradi:

$$mv_{1x} - mv_{0x} = -mgt_1 \sin\alpha - fmgt_1 \cos\alpha + 375 ,$$

bundan

$$v_{1x} = v_{0x} - gt_1 \sin\alpha - fgt_1 \cos\alpha + 375/m ,$$

yoki

$$v_{1x} = 10 - 9{,}81 \cdot 3 \cdot 0{,}5 - 0{,}1 \cdot 9{,}81 \cdot 3 \cdot 0{,}87 + 375/40 = 10 - 14{,}72 - 2{,}56 + 9{,}38 = 2{,}10\,m/s .$$

Demak $v_1 = v_{1x} = 2{,}10\,m/s$.

2. t_2 vaqtdagi tezlikni aniqlash uchun t_2-t_1 vaqt oralig'ida harakat miqdorining o'zgarishi haqidagi teoremani ifodalovchi tenglamani tuzamiz:

$$mv_{2x} - mv_{1x} = \sum S_{ix} . \qquad (2)$$

Bunda $\sum S_{ix} = -G(t_2 - t_1)\sin\alpha - F(t_2 - t_1) + S_{Px}$.

O'zgaruvchan P kuchning t_2-t_1 vaqt oralig'idagi impulsi proyeksiyasi $P=P(t)$ o'zgarish grafigidagi $MBCI$ trapetsiya yuzi orqali ifodalanadi:

$$S_{Px} = [5(250 + 300)]/2 = 1375\,N \cdot s .$$

Unda (2) tenglama quyidagicha o'zgaradi:

$$mv_{2x} - mv_{1x} = -mg(t_2 - t_1)\sin\alpha - fmg(t_2 - t_1)\cos\alpha + 1375 ,$$

bundan

$$v_{2x} = v_{1x} - g(t_2 - t_1)\sin\alpha - fg(t_2 - t_1)\cos\alpha + 1375/m ,$$

yoki

$$v_{2x} = 2{,}10 - 9{,}81 \cdot 5 \cdot 0{,}5 - 0{,}1 \cdot 9{,}81 \cdot 5 \cdot 0{,}87 + 1375/40 = 2{,}10 - 24{,}52 - 4{,}27 + 34{,}38 = 7{,}68\,m/s .$$

Demak $v_2 = v_{2x} = 7{,}68\,m/s$.

3. t_3 vaqtdagi tezlikni aniqlash uchun t_3-t_2 vaqt oralig'ida harakat miqdorining o'zgarishi haqidagi teoremani ifodalovchi tenglamani tuzamiz:

$$mv_{3x} - mv_{2x} = \sum S_{ix} . \qquad (3)$$

Bunda $\sum S_{ix} = -G(t_3 - t_2)\sin\alpha - fG\cos\alpha(t_3 - t_2) + S_{Px}$.

O'zgaruvchan P kuchning t_3-t_2 vaqt oralig'idagi impulsi proyeksiyasi $P=P(t)$ o'zgarish grafigidagi $IDEK$ trapetsiya yuzi orqali ifodalanadi:

$$S_{Px} = [4(200 + 150)]/2 = 700\,N \cdot s .$$

Unda (3) tenglama quyidagicha o'zgaradi:

$$mv_{3x} - mv_{2x} = -mg(t_3 - t_2)\sin\alpha - fmg(t_3 - t_2)\cos\alpha + 700 ,$$

bundan

$$v_{3x} = v_{2x} - g(t_3 - t_2)\sin\alpha - fg(t_3 - t_2)\cos\alpha + 700/m ,$$

yoki

$$v_{3x} = 7{,}68 - 9{,}81 \cdot 4 \cdot 0{,}5 - 0{,}1 \cdot 9{,}81 \cdot 4 \cdot 0{,}87 + 700/40 = 7{,}68 - 19{,}62 - 3{,}41 + 17{,}5 = 2{,}15\,m/s .$$

Demak $v_3 = v_{3x} = 2{,}15\,m/s$.

4. t_1 vaqt uchun aniqlangan v_1 qiymatini differensial tenglama tuzib tekshirib ko'ramiz:

$$m\ddot{x} = \sum X_i .$$

Tenglama o'ng qismini o'zgartirib

$$m\ddot{x} = -G\sin\alpha - F + P ,$$

yoki

$$m\ddot{x} = -mg\sin\alpha - fmg\cos\alpha + P,$$

bundan

$$\ddot{x} = -g\sin\alpha - fg\cos\alpha + P/m.$$

Bu o'rinda $P = (250/3)\cdot t$ - *OB* to'g'ri chiziq tenglamasi. Shuning uchun

$$\ddot{x} = -g\sin\alpha - fg\cos\alpha + (25/12)\cdot t.$$

Olingan differensial tenglamani inregrallab quyidagini hosil qilamiz:

$$\dot{x} = -g(\sin\alpha + f\cos\alpha)\cdot t + (25/24)\cdot t^2 + C.$$

C ni aniqlash uchun masala boshlang'ich shartidan foydalanamiz:

$$t = 0;\ v_{0x} = \dot{x} = 10\,m/s.$$

t=0 uchun *C=10 m/s*, integrallashdan olingan tenglama tuzamiz. Shunday qilib, *0* dan t_1 gacha tezlikning o'zgarishini aniqlovchi tenglama kelib chiqadi:

$$\dot{x} = -g(\sin\alpha + f\cos\alpha)\cdot t + (25/24)\cdot t^2 + 10.$$

t=3s da

$$v_1 = \dot{x}_1 = -9{,}81(0{,}5 + 0{,}1\cdot 0{,}87)\cdot 3 + (25/24)\cdot 3^2 + 10 = 2{,}10\,m/s.$$

Xisob-grafika ishi №9
Qattiq jismning tekis harakatini o'rganish.
(Dinamika bo'limi)

m massali g'ildirakni sirpanishsiz dumalatadigan doimiy kuch *P* ning maksimal qiymati aniqlansin.

Shuningdek, ushbu hol uchun boshlang'ich paytdagi kooordinatasi $X_{C_0} = 0$ va tezligi $v_{C_0} = 0$ bo'lgan g'ildirak og'irlik markazi *C* ning harakat tenglamasi topilsin.

Topshiriq variantlari 2-4 rasmlarda tasvirlangan, yechim uchun zarur berilganlar esa 2-jadvalda keltirilgan.

Topshiriqda quyidagicha belgilashlar qabul qilingan:

i_C - g'ildirak tekisligiga perpendikulyar yo'nalgan markaziy o'qqa nisbatan inersiya radiusi;

R va *r* – katta va kichik doiralar radiuslari;

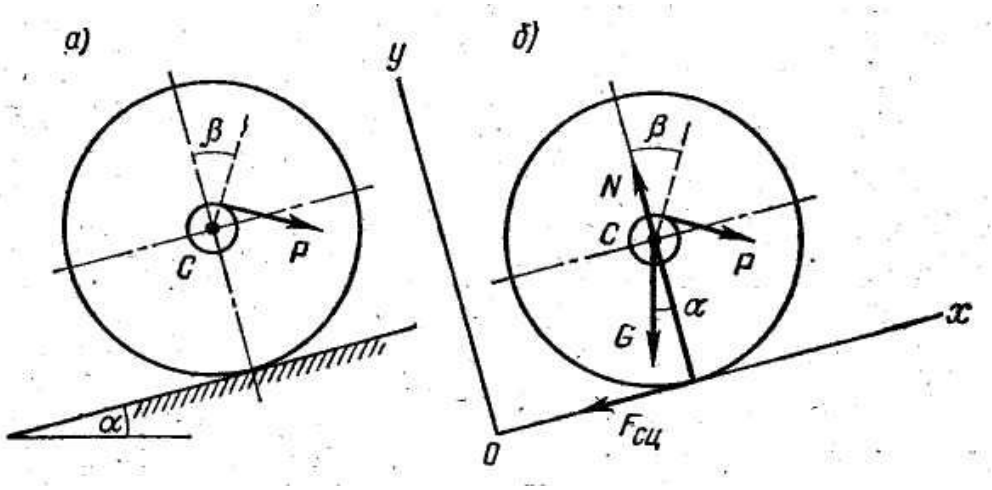
δ - dumalash ishqalanish koeffitsiyenti.

Izoh: inersiya radiuslari ko'rsatilmagan g'ildiraklar yaxlit bir jinsli disk deb hisoblansin.

2-jadval.

Номер варианта (рис. 176—178)	m, кг	i_C, см	R, см	r, см	α, град	β, град	$f_{сц}$	δ, см
1	300	50	80	40	20	—	0,35	1,0
2	200	40	60	30	—	—	0,20	0,8
3	180	50	60	20	30	—	0,10	0
4	220	30	70	25	30	30	0,20	0
5	240	40	60	15	—	—	0,10	1,0
6	200	—	50	—	15	—	0,20	0,5
7	200	45	60	25	30	15	0,25	0
8	150	40	70	25	15	—	0,50	0
9	250	—	—	—	—	30	0,15	0
10	150	40	50	15	20	—	0,30	0,7
11	200	30	50	20	30	—	0,20	0,6
12	220	—	—	—	30	30	0,25	0
13	140	—	—	—	—	30	0,10	0
14	300	—	—	—	30	—	0,15	0
15	180	20	50	20	—	15	0,15	0
16	180	30	50	35	—	—	0,15	0,9
17	160	50	60	20	15	20	0,30	0
18	260	—	50	—	—	—	0,10	1,0
19	200	50	60	20	—	20	0,10	0
20	250	40	50	30	20	—	0,25	0
21	200	—	40	—	30	—	0,25	1,2
22	150	30	50	20	—	—	0,25	1,2
23	200	30	60	30	30	15	0,40	0
24	240	30	70	30	15	—	0,15	0
25	100	—	—	—	—	60	0,10	0
26	150	—	—	—	30	15	0,15	0
27	120	—	30	—	—	—	0,40	1,5
28	150	30	60	25	15	—	0,30	0,8
29	200	—	—	—	—	20	0,30	0
30	160	—	40	—	20	—	0,20	0,7

Topshiriqni bajarishga doir misol. Berilgan: $m = 200\,kg$; $R = 60\,sm$; $r = 10\,sm$; $i_C = 50\,sm$; $\alpha = 15^0$; $\beta = 30^0$; $f_{il} = 0{,}10$; $\delta = 0$ (1-rasm, a).



1-rasm.

Yechim. G'ildirakka ta'sir qiluvchi kuchlar: g'ildirak og'irligi G, normal reaksiya N, kuch P va ilashish kuchi F_{il} (1-rasm, б) ($\delta \neq 0$ hol uchun dumalashga qarshilik qiluvchi kuchlar juftinining momentini ko'rsatish zarur).

P kuchning yo'nalishiga muvofiq gildirakning aylanishi soat milining

harakat yo'nalishi bo'yicha sodir bo'ladi, ya'ni g'ildirak qiya tekislik bo'ylab yuqoriga dumalanadi. F_{il} kuchni taxmin qilgan holda, rasmdagidek yo'naltiramiz. Bu kuchning haqiqiy yo'nalishi masalani yechish jarayonida aniqlanadi. Koordinata o'qlarini x o'qi g'ildirak harakatlanadigan tomonga yo'nalgan qilib tanlaymiz.

G'ildirak tekis harakati differensial tenglamalari:

$$m\ddot{x}_C = \sum X_i^E; \quad m\ddot{y}_C = \sum Y_i^E; \quad I_C\ddot{\varphi} = \sum M_{Ci}^E$$

yoki berilgan holda

$$m\ddot{x}_C = P\cos\beta - G\sin\alpha - F_{il}; \qquad (1)$$

$$m\ddot{y}_C = N - G\cos\alpha - P\sin\beta; \qquad (2)$$

$$I_C\ddot{\varphi} = \Pr + F_{il}R; \qquad (3)$$

(3) tenglamada kuch momentining ishorasi moment g'ildirakning aylanish yo'nalishiga mos bo'lsa musbat, aks holda manfiy deb qabul qilinadi.

$\mathrm{Y} = \mathrm{R} = \mathrm{const}$ bo'lgani uchun $\ddot{y}_C = 0$ bo'ladi va (2) tenglama quyidagi ko'rinishga keladi:

$$N = G\cos\alpha + P\sin\beta\,.$$

G'ildirakning sirpanishsiz dumalashida burchak tezlik:

$\omega = v_C / R$ yoki $\dot{\varphi} = \dot{x}_C / R$, bundan $\ddot{\varphi} = \ddot{x}_C / R$.

Shunday qilib, (3) tenglama quyidagi ko'rinishga keladi:

$$mi_C^2\ddot{x}_C / R = \Pr + F_{il}R \qquad (4)$$

$\ddot{x}_C$ ni qisqartirish uchun (1) ni (4) ga bo'lamiz:

$$\frac{R}{i_C^2} = \frac{P\cos\beta - G\sin\alpha - F_{il}}{\Pr + F_{il}R}$$

bundan

$$P = \frac{F_{il}(R^2 + i_C^2) + Gi_C^2\sin\alpha}{i_C^2\cos\beta - Rr} \qquad (5)$$

Ko'rinib turibdiki, (5) ifoda ilashish kuchining tanlangan yo'nalishi to'g'ri-noto'g'riligini baholash imkonini beradi. P kuchning maksimal qiymatga (izlanayotgan qiymatga) erishishi tabiiyki, ilashish kuchining o'sishi bilan kuzatiladi. Shuning uchun $P = aF_{il} + b$ ko'rinishga keltirilgan (5) tenglamada, a koeffitsiyent musbat bo'lishi lozim. Aks holda F_{il} ning yo'nalishini o'zgartirib, (1) va (3) differensial tenglamalarda kerakli o'zgarishlarni kiritish lozim bo'ladi.

Ilashish kuchining maksimal qiymati:

$$F_{il}^{\max} = f_{il}(G\cos\alpha + P\sin\beta).$$

F_{il} ning maksimal qiymatini (5) tenglamaga qo'yib va uni P ga nisbatan yechib, sirpanishsiz dumalaydigan g'ildirak uchun ushbu kuchning maksimal qiymatini topamiz:

$$P = \frac{G[(R^2 + i_C^2)f_{il}\cos\alpha + i_C^2\sin\alpha]}{i_C^2\cos\beta - Rr - (R^2 + i_C^2)f_{il}\sin\beta}$$

yoki

$$P = \frac{200\cdot[(0{,}6^2 + 0{,}5^2)\cdot 0{,}1\cdot 0{,}966 + 0{,}5^2\cdot 0{,}259]\cdot 9{,}81}{0{,}5^2\cdot 0{,}866 - 0{,}6\cdot 0{,}1 - (0{,}6^2 + 0{,}5^2)\cdot 0{,}1\cdot 0{,}5} = 196\cdot 9{,}81 = 1920\,N.$$

Ilashish kuchi

$$F_{il}^{\max} = f_{il}(G\cos\alpha + P\sin\beta) = 0{,}1\cdot(200\cdot 0{,}966 + 196\cdot 0{,}5)\cdot 9{,}81 = 29\cdot 9{,}81 = 284\,N.$$

G'ildirak markazi harakat differensial tenglamasi:

$$m\ddot{X}_C = P\cos\beta - G\sin\alpha - F_{il}^{\max}$$

yoki

$$200\ddot{X}_C = 1920\cdot 0{,}866 - 200\cdot 9{,}81\cdot 0{,}259 - 284,$$

bundan

$$\ddot{X}_C = 4{,}4\,m/s^2.$$

Shu differensial tenglamani ikki marta integrallab:

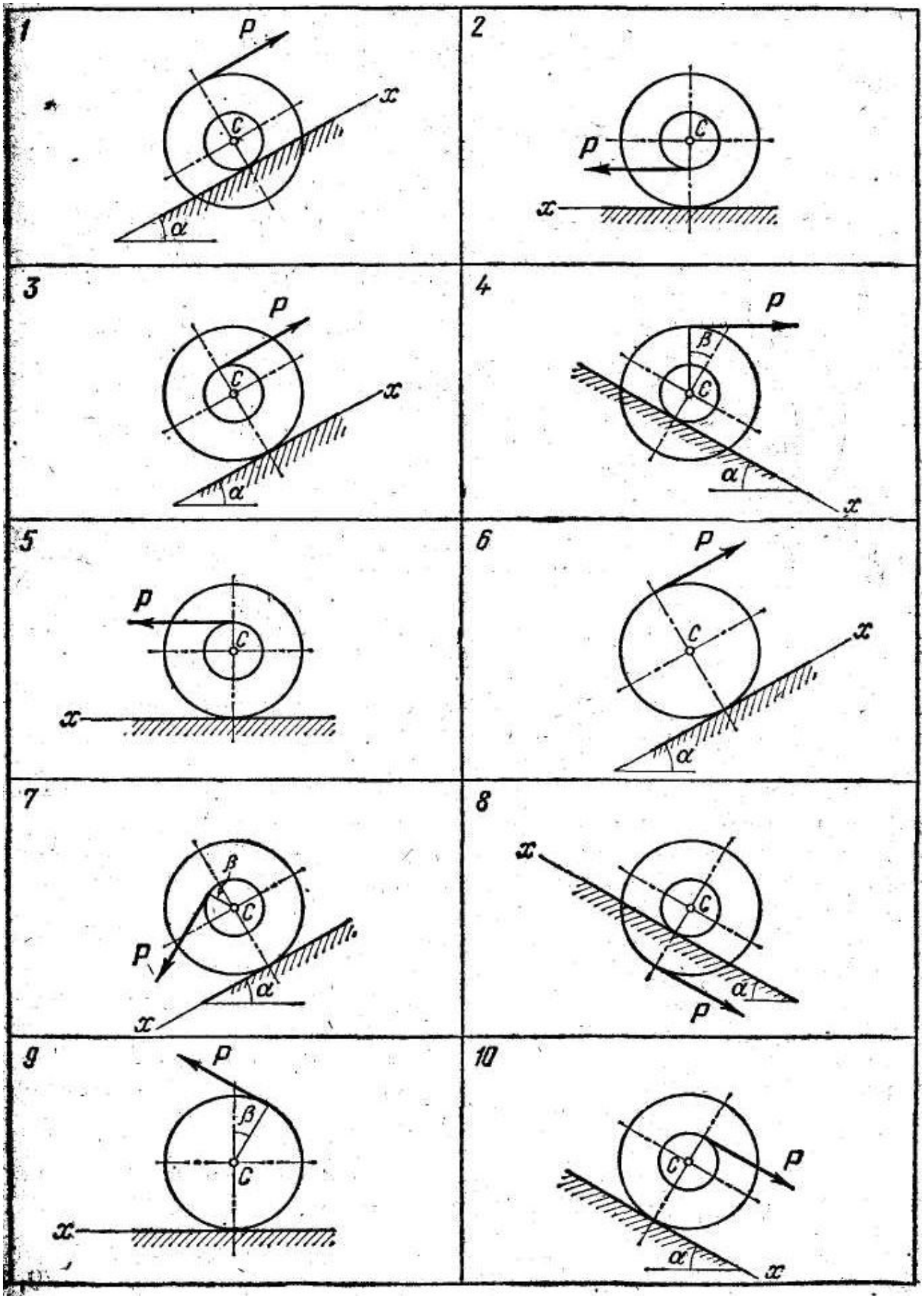
$$\dot{X}_C = 4{,}4t + C_1, \quad X_C = 2{,}2t^2 + C_1t + C_2.$$

$t = 0$ da $X_{C_0} = 0$ va $\dot{X}_{C_0} = 0$ ekanini hisobga olib, C_1 va C_2 integrallash doimiylarini aniqlaymiz:

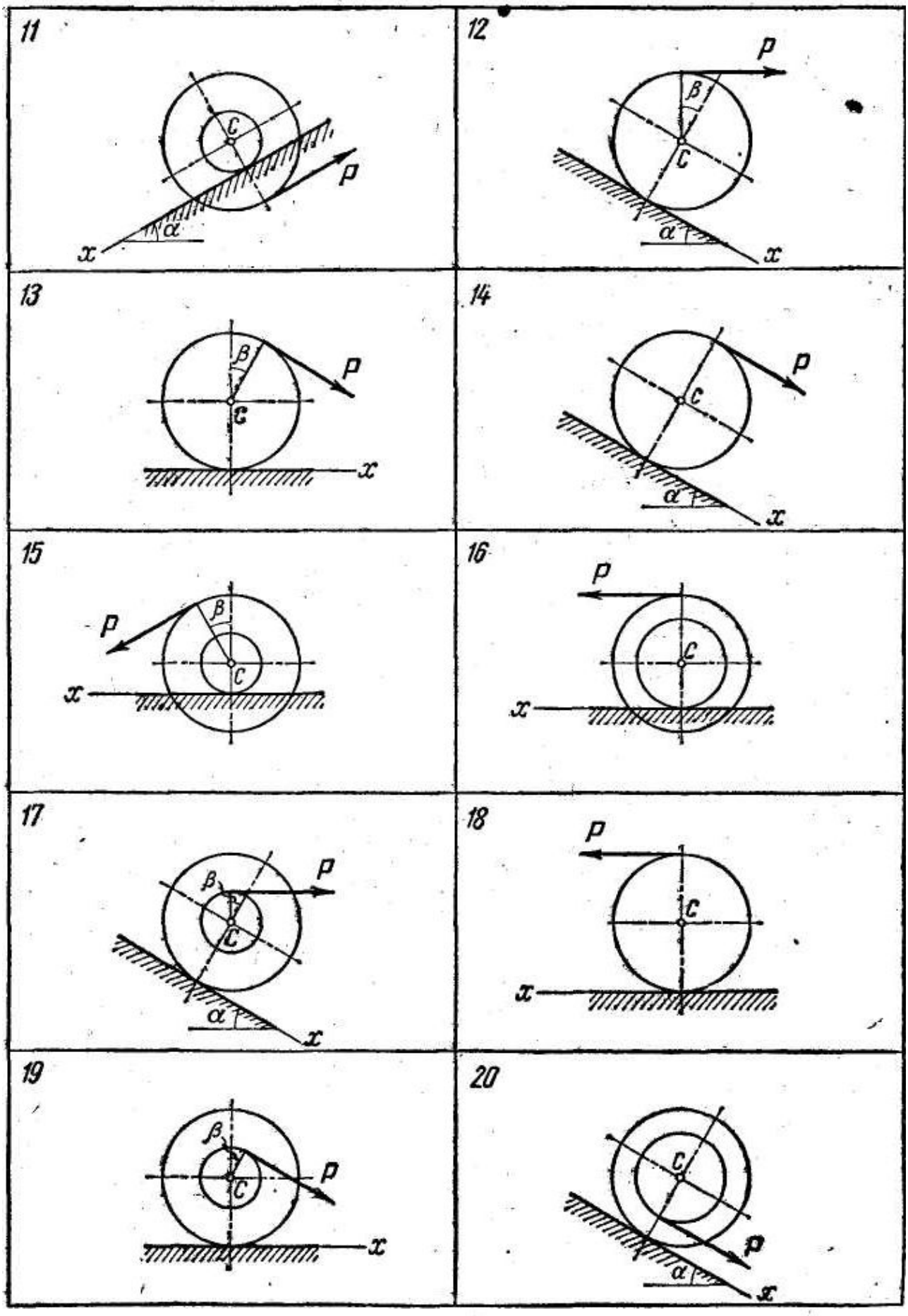
$$C_1 = 0 \text{ va } C_2 = 0.$$

O'z navbatida, g'ildirak markazining harakat tenglamasi:

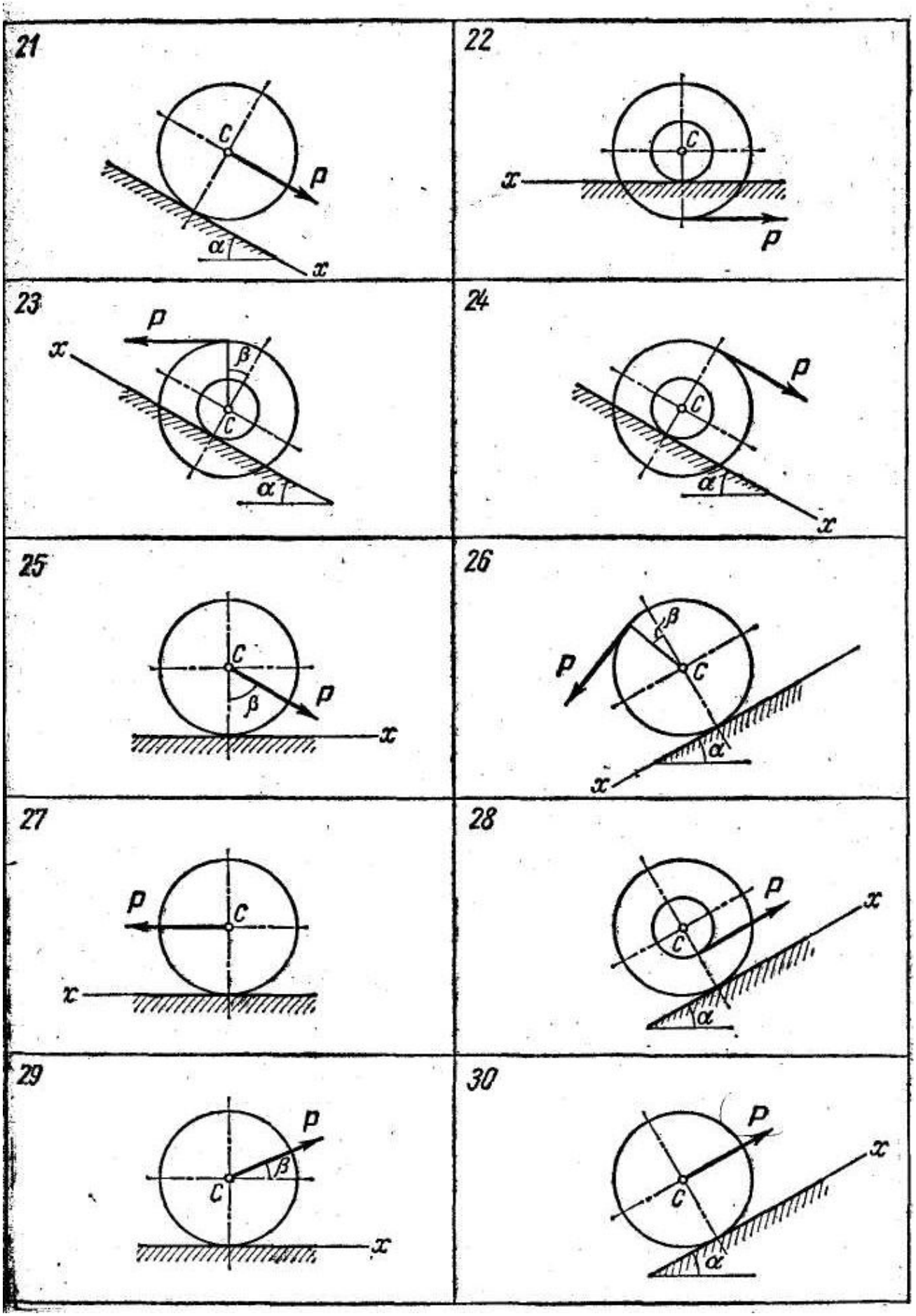
$$X_C = 2{,}2t^2\,(m).$$


1
P
x
C
α
2
C
P
x
3
P
C
x
α
4
P
β
C
α
x
5
P
C
x
6
P
C
x
α
7
β
C
P
α
x
8
x
C
α
P
9
P
β
C
x
10
C
P
α
x

2-rasm.


11
C
P
x
α
12
P
β
C
α
x
13
β
P
C
x
14
C
P
α
x
15
P
β
C
x
16
P
C
x
17
β
P
C
α
x
18
P
C
x
19
β
C
P
x
20
C
P
α
x

3-rasm.


21
C
P
α
x
22
C
x
P
23
P
x
β
C
α
24
C
P
α
x
25
C
β
P
x
26
β
P
C
α
x
27
P
C
x
28
C
P
x
α
29
P
β
C
x
30
P
C
x
α

4-rasm.

Foydalanilgan adabiyotlar.

1. Nabiyev A., Hasanov S. Materiallar qarshiligi. Oliy o'quv yurtlari uchun darslik. –T.: Fan. 2005. -380 b.
2. Mansurov Q.M. Materiallar qarshiligi kursi. Tehn. o'quv yurt. stud. uchun darslik. –T.: O'qituvchi. 1983. -504 b.
3. Феодосьев В.И. Сопротивление материаллов. Учебник для ВТУЗов. –М.: Наука, 1979. -560 с.
4. V.Q.Qachurin.Materiallar qarshiligidan masalalar to'plami. –T.: O'zbekiston, 1993, -336 b.
5. Smironov A.F. Materiallar qarshiligi. –T. O'qituvchi, 1988. -464 b.
6. Yablonskiy A.A. Sbornik zadaniy dlya kursovix rabot po teoreticheskoy mexanike.
   Uchebnoe posobie dlya vuzov. Moskva: Visshaya shkola-1985g.

Mundarija