

**I TARTIBLI DIFFERENSIAL TENGLAMALARNING AYRIM IQTISODIY
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Annotatsiya. *Maqolada I tartibli differensial tenglamalar qaralib, bu tenglamalarni demografiya, marketing va iqtisodiyot masalalarini yechishga tatbiqlari keltirilgan.*

Kalit so'zlar: Bir jinsli I tartibli tenglama, To'liq differensial tenglama, I tartibli chiziqli differensial tenglama, I tartibli chiziqli bir jinsli differensial tenglama

Annotation. *Homogeneous I-order equation, Total differential equation, Linear differential equation of order I, linear homogeneous differential equation of order I*

Kirish

Noma'lum funksiyaning hosilalari qatnashgan tenglama differensial tenglama deb ataladi. Differensial tenglamalardan fizika, iqtisodiyot, kimyo, mexanika va boshqa fanlarga doir juda ko'p masalalarni yechishda keng qo'llaniladi. Vaqt bilan bog'liq turli texnologik va iqtisodiy jarayonlar ham matematik usulda differensial tenglamalar orqali tavsiflanadi. Differensial tenglama tartibi unda qatnashgan noma'lum funksiya hosilasining eng katta tartibi bilan aniqlanadi. Differensial tenglamalar yechimining mavjudlik sharti Koshi teoremasi orqali ifodalanadi. Differensial tenglamalar yechimini topish jarayoni uni integrallash deyiladi. Differensial tenglamani integrallashning umumiy usuli mavjud emas. Bundan tashqari juda ko'p differensial tenglamalarning yechimi elementar funksiyalarda ifodalanmaydi. Shu sababli differensial tenglamalarning ayrim xususiy hollari uchun ularni integrallash usulini ko'rsatish mumkin.

Bu yerda I tartibli differensial tenglamalar yordamida yechiladigan iqtisodiy mazmunli amaliy masalalardan bir nechta bilan tanishamiz.

Aholi soni haqidagi demografik masala. Ma'lum bir vaqt birligida mamlakatda dunyoga kelgan chaqaloqlar va vafot etgan odamlar soni shu mamlakat aholisining soniga proporsional (mos ravishda qandaydir k_1 va k_2 proporsionallik koeffitsientlari bilan) ekanligi statistik ma'lumotlar asosida aniqlangan. Shu mamlakat aholisining sonini t vaqt bo'yicha o'zgarishini ifodalovchi $y=y(t)$ funksiyanini topish talab etiladi.

Yechish: Bu mamlakat aholisining Δt vaqt oralig'idagi o'zgarishi Δy shu vaqt oralig'ida dunyoga kelgan chaqaloqlar va vafot etgan odamlar sonlarining ayirmasiga

tengdir. Masala shartiga asosan, Δt vaqt oralig'ida dunyoga kelgan chaqaloqlar soni $k_1\Delta t$, vafot etgan odamlar soni esa $k_2\Delta t$ bo'ladi. Bu yerdan quyidagi natijalarni olamiz:

$$\Delta y = k_1 y \Delta t - k_2 y \Delta t = (k_1 - k_2) y \Delta t = ky \Delta t \quad (k = k_1 - k_2) \Rightarrow$$

$$\Rightarrow \frac{\Delta y}{\Delta t} = ky \Rightarrow \lim_{\Delta t \rightarrow 0} \frac{\Delta y}{\Delta t} = \lim_{\Delta t \rightarrow 0} ky \Rightarrow y' = ky .$$

Shunday qilib, aholi soni I tartibli $y'=ky$ differensial tenglama bilan ifodalanuvchi qonuniyat asosida o'zgaradi. Bu o'zgaruvchilari ajraladigan differensial tenglama bo'lib, uni integrallab izlanayotgan $y=y(t)$ funksiyani topamiz:

$$y' = ky \Rightarrow \frac{dy}{dt} = ky \Rightarrow \frac{dy}{y} = k dt \Rightarrow \int \frac{dy}{y} = \int k dt \Rightarrow \ln y = kt + C \Rightarrow$$

$$y = e^{kt+C} = C_0 e^{kt} .$$

Bunda C_0 o'zgarimas son qiymati boshlang'ich shartdan topiladi. Agar t_0 vaqtda aholi soni y_0 ekanligi ma'lum bo'lsa, unda $C_0 = y_0 e^{-kt_0}$ kabi aniqlanishini ko'rsatish mumkin.

Mahsulot narxi haqidagi marketing masalasi. Bozorda t vaqt o'tishi bilan biror mahsulot narxi $p(t)$, unga talab $h(t)$ va taklif $s(t)$ funksiyalar bo'yicha o'zgarib boradi. Narx funksiyasi, talab va taklif funksiyalari orasidagi bog'lanishni topish talab etiladi.

Yechish: Bozor qonuniyatlariga ko'ra Δt vaqt oralig'ida narxning o'sishi Δp talabni taklifdan qanchalik darajada kattaligiga va shu vaqt oralig'iga to'g'ri proporsional bo'ladi. Agar proporsionallik koeffitsiyenti k bo'lsa, bu qonuniyatni matematik ko'rinishda ifodalab, undan quyidagi natijalarni olamiz:

$$\Delta p = k(h - s)\Delta t \Rightarrow \frac{\Delta p}{\Delta t} = k(h - s) \Rightarrow \lim_{\Delta t \rightarrow 0} \frac{\Delta p}{\Delta t} = \lim_{\Delta t \rightarrow 0} k(h - s) \Rightarrow p' = k(h - s) .$$

Bunda eng oxirgi tenglik $p=p(t)$ narx funksiyasiga nisbatan eng sodda differensial tenglama bo'lib, undan

$$p(t) = k \int [h(t) - s(t)] dt$$

formulani hosil qilamiz. Bu formula bilan ifodalanadigan iqtisodiy jarayon *Evans modeli* deb ataladi.

Mahsulot ishlab chiqarish hajmi haqidagi iqtisodiy masala. Biror tarmoqda t vaqtda ishlab chiqarilgan mahsulot hajmini $y=y(t)$ funksiya bilan belgilaymiz. Ishlab chiqarilgan mahsulot bozorda o'zgarimas p narxda sotiladi deb olamiz. Ishlab chiqarishni kengaytirish uchun sarflanadigan investitsiya hajmi t vaqt bo'yicha $I=I(t)$ funksiya bilan aniqlansin. Ishlab chiqarishni tabiiy o'sish modelida mahsulot hajmini ifodalovchi $y=y(t)$ funksiyani topish talab etiladi.

Yechish: Ishlab chiqarishni tabiiy o'sish modelida quyidagi ikkita shart qo'yiladi:

a) mahsulot ishlab chiqarish tezligi, ya'ni ishlab chiqarish sur'ati, investitsiya hajmiga proporsional (proporsionallik koeffitsiyenti α):

$$y'(t) = \alpha I(t) ;$$

b) investitsiya hajmi olinayotgan $Y(t)$ foydaning ma'lum bir qismiga teng, ya'ni $I(t) = mY(t) = mpy(t)$.

Bunda m (investitsiyalash normasi) $0 < m < 1$ shartni qanoatlantiruvchi biror o'zgarmas son.

Bu shartlardan mahsulot hajmi $y=y(t)$ uchun

$$y' = \alpha m p y = k y \quad (k = \alpha m p)$$

differensial tenglamaga ega bo'lamiz. Bu tenglama oldin ko'rilgan demografik masalada paydo bo'lgan edi va unda umumiy yechim

$$y(t) = C e^{kt} = C e^{\alpha m p t}$$

ko'rinishda bo'lishi ko'rsatilgan edi. Agar $y(t_0) = y_0$ boshlang'ich shart berilgan bo'lsa, mahsulot ishlab chiqarish hajmi

$$y(t) = y_0 e^{\alpha m p (t-t_0)}$$

funksiya orqali aniqlanadi.

Yuqorida biz mahsulot narxi p o'zgarmas deb oldik. Amalda bu shart ma'lum bir qisqa vaqt davri uchun o'rinli bo'ladi. Shu sababli ko'pincha ishlab chiqarishni raqobatli bozor sharoitida o'sish modelidan foydalaniladi. Bu modelda mahsulot hajmi y o'sib borishi bilan uning narxi p kamayib boradi, ya'ni ma'lum bir $p=p(y)$ kamayuvchi funksiya bo'yicha o'zgarib boradi deb olinadi. Bu holda mahsulot hajmi funksiyasi $y=y(t)$

$$y' = \alpha m p(y)y$$

o'zgaruvchilari ajraladigan differensial tenglama orqali aniqlanadi. Bu tenglamaning umumiy yechimi

$$\int \frac{dy}{yp(y)} = \alpha m t + C$$

tenglikdan topiladi. Jumladan, $p(y) = b - ay$ bo'lgan holda $y=y(t)$ logistik funksiyadan iborat bo'ladi.

Masalan, $p(y) = 3 - y$, $\alpha = 1.5$, $m = 0.4$, $y(0) = 1.5$ bo'lganda

$$\begin{aligned} \int \frac{dy}{y(3-y)} = 0.6t + C &\Rightarrow -\frac{1}{3} \int \left[\frac{1}{y-3} - \frac{1}{y} \right] dy = 0.6t + C \Rightarrow \ln \left| \frac{y-3}{y} \right| = -1.8t + C_1 \Rightarrow \\ \Rightarrow \frac{y-3}{y} = e^{-1.8t+C_1} = C_2 e^{-1.8t} &\Rightarrow y = \frac{3}{1 - C_2 e^{-1.8t}} \end{aligned}$$

umumiy yechimni olamiz. $y(0) = 1.5$ boshlang'ich shartga asosan bu yerdagi o'zgarmas son qiymati $C_2 = -1$ ekanligini topamiz. Demak, berilgan shartlarda mahsulot hajmi

$$y(t) = \frac{3}{1 + e^{-2t}}$$

funksiya bilan topiladi.

I tartibli differensial tenglamalar yordamida radioaktiv moddaning parchalanishi, reaktiv harakat, kimyoviy reaksiyada modda miqdori, jismning sovishi, quymaning qizishi, ilmiy axborot oqimi, berilgan elastiklikka ega bo'lgan talab funksiyasini topish, talab va taklif funksiyasini narxning o'zgarish tezligiga bog'liq holda qarash kabi masalalar ham o'z yechimini topadi.

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