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4.		22	4	10	8
5.	-	28	8	12	8
6.	-	26	10	12	4
7.	-	6	2	-	4
		108	**34**	**34**	**40**

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Движение в центральном поле

1. $U(r) = -\frac{\alpha}{r^n}$ n=- α=-1

$$dUdx(x,y) = \frac{d}{dx}U(x,y),\ dUdy(x,y) = \frac{d}{dx}U(x,y),$$

x=1, y=0, vx=0, vy=1,1, $X = \begin{pmatrix} x \\ y \\ vx \\ vy \end{pmatrix}$.

m=1.

$$D(t,X) = \begin{pmatrix} X_2 \\ X_3 \\ -\frac{1}{m}dUdx(X_0,X_1) \\ -\frac{1}{m}dUdy(X_0,X_1) \end{pmatrix}$$

rkfixed

.

2.

$$k = 0 \ldots N-1,\ r(k) = \begin{pmatrix} Z_{k,1} \\ Z_{k,2} \\ 0 \end{pmatrix},\ v(k) = \begin{pmatrix} Z_{k,3} \\ Z_{k,4} \\ 0 \end{pmatrix},\ p(k) = m \cdot v(k),\quad M(k) = r(k) \times p(k).$$

$M(k)_2 - M(0)_2$.

$$Ek(k) = \frac{m \cdot (|v(k)|)^2}{2},\ Ep(k) = U(r(k)_0, r(k)_1),\ E(k) = Ek(k) + Ep(k).$$

$E(k) - E(0)$.

3.

$E = \frac{m\dot{r}^2}{2} + \frac{M^2}{2mr^2} + U(r)$ $U_{eff}(r) = \frac{M^2}{2mr^2} + U(r)$

$r \geq r_{min}$

$r_{min} \leq r \leq r_{max}$

r

4. - min max.

$$\Delta\varphi = \int_{r_{min}}^{r_{max}} \frac{\frac{M}{r^2}dr}{\sqrt{2m(E-U) - \frac{M^2}{r^2}}}$$

$\frac{\Delta\varphi}{\pi}$.

5. $U(r) = -\frac{\alpha}{r^n} - \frac{\alpha_1}{r^{n_1}}$ n=-2, α=-1, n1 $_1$=0,115.

Брахистохрона

1. $\frac{d}{dx}\left(\frac{d}{dv}L(y,v)\right) - \frac{d}{dy}L(y,v) = 0$

$$F(y,v) = \frac{\frac{d}{dy}L(y,v) - v\left(\frac{d}{dv}\left(\frac{d}{dy}L(y,v)\right)\right)}{\frac{d^2}{dv^2}L(y,v)}$$

$$\frac{dv}{dx} = F(y,v)$$

2.

$$X(\varphi) = C\frac{\varphi - \sin\varphi}{2}, \ Y(\varphi) = C\frac{\cos\varphi - 1}{2}.$$

3. C

$$v0 = \frac{dy}{dx}$$

$A = \begin{pmatrix} y0 \\ v0 \end{pmatrix}$, $D(x,A) = \begin{pmatrix} A_1 \\ F(A_0, A_1) \end{pmatrix}$.

Bulstoer(A,x0,xk,n,D).

4.

tb $tb = \int_0^x L(y,v)dx$

$L[y(\varphi), v(\varphi)]\frac{d}{d\varphi}[x(\varphi)d\varphi]$

simplify

C=1.

5.

$y(x) = a_1x + a_2x^2 + a_3x^3$ a_3=- a_1 = - 2, - 2.5, -2.7,- a_2 (x1,y1).

tb

a_1 tb

tb.

Расчёт дифракционной картины

1.

-9 0-9 -9

$|U(0,0,z,k)|^2$

$\frac{z}{\lambda}$

z $z_n = R \cdot zb \cdot \chi^n$, $n = 0 \dots N-1$, $N = 200$, $\boldsymbol{\chi} = \sqrt[N-1]{\boldsymbol{\gamma}}$,

$\gamma = 20, zb = \frac{zc}{\gamma}, zc = 3$

2. $|U(0,0,z,k)|^2$ $|V(0,0,z,k)|^2$

:

$$zU(n) = -\frac{1}{4}\frac{8z_0^2 - 4(2z_0 + n\lambda)\sqrt{z_0^2 + R^2} + 4z_0 n\lambda + n^2\lambda^2}{2z_0 - 2\sqrt{z_0^2 + R^2} + n\lambda}$$

$$zV(n) = \frac{1}{4}\frac{4R^2 - n^2\lambda^2}{n\lambda}$$

$nF = 1 \dots 30$

$\frac{zU(nF)}{\lambda}$ $\frac{zV(nF)}{\lambda}$

3. -9

x z

$H = 1{,}2R$

x $n\Delta H$ $n = 0 \dots N-1$, $N = 55$, $\Delta H = \frac{H}{N-1}$ z

$zU(n)$ $zV(n)$

4.

$n = 8.$

$$N = 100, \quad n = 0 \dots N-1, \quad dH = \frac{H}{N-1},$$

$DU_n = |U(n \cdot dH, 0, zU(8), k)|^2,$

$$DU2d(u,v) = \begin{pmatrix} \frac{u \cdot dH}{R}\cos v \\ \frac{u \cdot dH}{R}\sin v \\ DU_u \end{pmatrix},$$

$DK = CreateMesh(DU2d, 0, N-1, 0, 2\pi, 100, 200)$

DK z

z 4.

5. -9 $R = 15\lambda$,

$R = 25\lambda$ $R = 50\lambda$ z $zV(n)$

$R = 15\lambda$ R

,6. *Дифракция Фраунгофера*

1. $\frac{dIdo(\theta)}{I}$ θ θ

$-\pi$ π $\pi/1000$

y y $\frac{dIdo(\theta)}{I} + 10^{-4}$

$\frac{Ixy(x,y)}{I}$

$H = 8 \cdot 10^{-2}$ y y $-H$ H $H/100$.

y y $\frac{Ixy(x,y)}{I} + 10^{-7}$,

2. $2A = 0,1$.

i *j* N- N=350.

$$\boldsymbol{Gxy_{i,j} = \ln\left(\frac{Ixy\left(-A + i\frac{2A}{N-1}, -A + j\frac{2A}{N-1}\right)}{I} + 10^{-5}\right)}$$

$$G(x,\theta) = \begin{pmatrix} x \\ \theta \\ \ln\left(\frac{dIdo(\theta)}{I} + 10^{-1}\right) \end{pmatrix}$$

$xmesh = 2, ymesh = 200,$

$Cyl = CreateMesh(G, -1, 1, -\pi, \pi, xmesh, ymesh)$

3. $(ny, \sqrt{1 - ny^2})$:

$$Gn(x,ny) = \begin{pmatrix} x \\ \arcsin ny \\ \ln\left(\frac{dIdo(\arcsin ny)}{I} + 10^{-2}\right) \end{pmatrix}$$

$Cyln = CreateMesh(Gn, -1, 1, -1, 1, xmesh, ymesh)$

$r = 1,5 \cdot 10^{-6}, L = 0,2.$

$\frac{kr^2}{L} \ll 1.$

do:

$$dIdos(\theta) = if\left(\theta = 0, \frac{I(rk)^2}{4\pi}, I\frac{J1(rk\theta)^2}{\pi\theta^2}\right)$$

$$Is(\theta, R) = \frac{\pi r^2}{R^2} dIdos(\theta)$$

$$Isxy(x, y) = Is\left(\arcsin\frac{\sqrt{x^2 + y^2}}{\sqrt{L^2 + x^2 + y^2}}, \sqrt{L^2 + x^2 + y^2}\right)$$

4. $\frac{dIdos(\theta)}{I}$ θ θ

$-\pi$ π $\pi/180$

y y $\frac{dIdos(\theta)}{I} + 10^{-5}$

$\frac{Isxy(x,y)}{I}$ $H = 0,6$

y y $-H/2$ $H/2$ $H/100$

y y $\frac{Isxy(x,y)}{I}$

5. $H = 0,6.$

i j N- N=250.

$$\ln\left(\frac{Isxy\left(-H + i\frac{2H}{N-1}, -H + j\frac{2H}{N-1}\right)}{I} + 10^{-13}\right) Gsxy_{i,j} = l$$

$$Gs(\theta, \varphi) = \begin{pmatrix} \theta \cdot \cos\varphi \\ \theta \cdot \sin\varphi \\ \ln\left(\frac{dIdos(\theta)}{I} + 10^{-3}\right) \end{pmatrix}$$

$xmesh = 200, ymesh = 200,$

$Cyls = CreateMesh(Gs, 0, 2\pi, 0, 2\pi, xmesh, ymesh)$

6.

$\left(nx, ny, \sqrt{1 - nx^2 - ny^2}\right)$:

$$dInxny(nx, ny) = dIdos\left(\arcsin\sqrt{nx^2 + ny^2}\right)$$

$$Gns(u, v) = \begin{pmatrix} \sin u \cdot \cos v \\ \sin u \cdot \sin v \\ \ln\left(\frac{dInxny(\sin u \cdot \cos v, \sin u \cdot \sin v)}{I} + 10^{-3}\right) \end{pmatrix}$$

$$Sn = CreateMesh\left(Gns, 0, \frac{\pi}{2}, 0, 2\pi, xmesh, ymesh\right)$$

Принцип наименьшего действия

______

f

p

____

1.

$my'' = -\frac{mg}{(1+y/R)^2}$

rkfixed

R ^{6}, g=9,81, tn=0, tk=2200, m=1, n=100, $X = \binom{R}{0}$,

$D(t,X) = \begin{pmatrix} X_1 \\ \dfrac{-g}{\left(1+\dfrac{X_0}{R}\right)^2} \end{pmatrix}$

2. y(t

lspline interp.

v(t y(t).

t_0 root).

3.

f - a_2 t^2 + a_3 t^3 - a_4 t^4 $_2$, a_3 $_4$

4.

$_3$ $_4$ $_2$ t_0.

vp(t).

5. $_3$ $_4$

a_3~10^{-4}, a_4~10^{-8})

t_0.

6.

L=T-U T U

$L = \frac{mv^2}{2} - mg\frac{Ry}{R+y}$

7.

$_0$

8.

$_3$ $_4$

p.

Свободные колебания

$F_x = -m\omega^2 x - 2\lambda m\dot{x} + max^2 - mbx^3.$

v0.

1.

a=0, b=5, v0=0,5.

tn=0, xn=0,

tk $\tau = \frac{2\pi}{\omega}$ n Rkadapt.

2.

$x = \frac{v_0 \sin \omega t}{\omega}$ $v = v_0 \cos \omega t$.

3.

4.

$\omega \cdot \max(x(t))$.

5.

$\alpha = \frac{2\pi\lambda}{\omega_1}$, $\omega_1 = \sqrt{\omega^2 - \lambda^2}$

6.

7.

8.

$a \neq 0$ $b \neq 0$

Вынужденные колебания

m x

$F = -m\omega^2 x - 2\lambda m\dot{x} + f \cos \gamma t$

.

v0.

1. =1, m f=1, v_0=1, x_0=0, t_0=0, t_k Rkadapt

n=500.

2.

$x = \frac{v_0 \sin \omega t}{\omega}$ $v = v_0 \cos \omega t$.

3.

4.

$2\pi/\gamma$

5.

6.

$$b(\gamma, \lambda) = \frac{f}{m\sqrt{(\omega^2 - \gamma^2)^2 + 4\lambda^2\gamma^2}}$$

b

$$\gamma_p = \sqrt{\omega^2 - 2\lambda^2}.$$

7.

$$I(\gamma,\lambda) = m\gamma^2\big(b(\gamma,\lambda)\big)^2$$

=0,001, 0,02, 0,025, 0,03.

I_m

i n, $\gamma_i = i\cdot\omega\cdot\frac{2}{n}, I1_i = I(\gamma_i,\lambda),$

$$I1m = \max(I1), \gamma p1_i = if(I1_i = I1m, \gamma_i, 0), \gamma p = \max(\gamma p1)$$

.

$$\gamma 1_i = if\left(I1_i \le \frac{I1m}{2} \wedge \gamma_i < \gamma p, \gamma_i, 0\right), \gamma 1 = \max(\gamma 1),$$

$$\gamma 2_i = if\left(I1_i \le \frac{I1m}{2} \wedge \gamma_i > \gamma p, \gamma_i, 2\right), \gamma 2 = \min(\gamma 2), \Gamma = 0{,}5(\gamma 2 - \gamma 1)$$

Изучение малых колебаний многомерного осциллятора

l,

c ***m***

h

S=2

m=0,1, ***l***=0,5, ***c***=10, ***h***=0,2***l***, ***g***=9,81.

$$L(v_1,v_2,x_1,x_2) = \frac{1}{2}ml^2(v_1^2+v_2^2) + mgl(\cos x_1 + \cos x_2) - \frac{1}{2}c(h\sin x_2 - h\sin x_1)^2$$

1.

$$L = \frac{1}{2}\sum_{i,j=1}^{s}\left(m_{i,j}\dot{x}_i\dot{x}_j - k_{i,j}x_i x_j\right)$$

x_i m_{ij}

k_{ij}

k

$$k_{ij} = -\frac{d}{dx_i}\frac{d}{dx_j}L$$

m

$$m_{ij} = \frac{d}{dv_i}\frac{d}{dv_j}L$$

2.

$$x_j = \sum_{\alpha=1}^{s} A_{j,\alpha} C_\alpha \exp i\omega_\alpha t = \sum_{\alpha=1}^{s} A_{j,\alpha} Q_\alpha$$

Q_α

.

$$\sum_{j=1}^{s} \left(k_{i,j} - \omega^2 m_{i,j}\right) A_i = 0$$

$A_{j,\alpha}$.

A

$D=m^{-1}k$.

$$\omega = \overrightarrow{\sqrt{eigenvals(D)}}, A = eigenvecs(D)$$

3. Q x

$$x_j = \sum_{\alpha=1}^{s} A_{j\alpha} Q_\alpha$$

$x=AQ$ $Q=Rx$ $R=A^{-1}$.

R $Q=Rx$

$q=A1^{-1}x$ $A1=A/A_{ss}$ R

$R1=R/R_{ss}$

$A1$ $R1$.

$q1_\alpha$

x_i x_α q_i:

$$q1_\alpha = \sum_{i=1}^{s} R1_{\alpha i} x_i$$

$$x_\alpha = \sum_{i=1}^{s} A1_{\alpha i} q_i$$

4. x_α q_α

5.

q1(t)=Q sin $_1$t+ $_1$

q2(t)=Q sin $_2$t+ $_2$ Q1=Q

x: $x1(t)=A_{11}q1(t)+A_{12}q2(t)$, $x2=A_{21}q1(t)+A_{22}q2(t)$

: y(t)=x2(t)-x1(t)

Тепловое излучение

f

$$R_{\nu d}(\nu,T) = \frac{8\pi\nu^2 kT}{c^3}$$

$$R_\nu(\nu,T) = \frac{8\pi h\nu^3}{c^3\left(\exp\left(\frac{h\nu}{kT}\right)-1\right)}$$

1. f f T = 450

2.

$$u(t) = \int_0^\infty R_\nu(\nu,T)d\nu$$

$$\int_0^\infty \frac{x^3}{e^x-1}dx$$

- $E(T) = \sigma T^4$ -

f $E(\nu,T) = \frac{c}{4}R_\nu(\nu,T)$.

$\sigma = 5{,}67051 \cdot 10^{-8}\,\frac{\text{Вт}}{\text{м}^2\text{К}^4}$.

3.

$\nu 1(T) = k_\nu T$

$$k_\nu = \frac{mean\left[\overrightarrow{(T\nu)}\right]}{mean\left[\overrightarrow{(t)^2}\right]}$$

$b_\nu = c/k_\nu$.

4.

$x = \frac{h\nu}{kT}$

$$3 - 3\exp(-x) - x = 0$$

$b_\nu = \frac{ch}{xk}$.

5.

$$R_\lambda(\lambda,T) = \frac{8\pi ch}{\lambda^5\left(\exp\left(\frac{hc}{k\lambda T}\right)-1\right)}$$

$$R_{\lambda d}(\lambda,T) = \frac{8\pi kT}{\lambda^4}$$

f T f T T =

6.

$$\lambda 1(T) = k_\lambda T$$

b

7.

$$x = \frac{hc}{\lambda kT}$$

$$5 - 5\exp(-x) - x = 0$$

$$b_\lambda = \frac{ch}{xk}$$

b , b

14. *Потенциальный барьер*

$$U(x) = \begin{cases} z_0^2, 0 \le x \le a \\ 0, x < 0, x > a \end{cases}$$

$$\Psi(x) = \begin{cases} A_1 e^{ik_1 x} + B_1 e^{-ik_1 x}, x < 0 \\ A_2 e^{ik_2 x} + B_2 e^{-ik_2 x}, 0 \le x \le a \\ A_3 e^{ik_1 x}, x > a \end{cases}$$

a u_0 E

$$k_1 = \sqrt{\frac{2mE}{\hbar^2}}, \quad k_2 = \sqrt{\frac{2m(E-u_0)}{\hbar^2}}$$

$\hbar = 1{,}054 \cdot 10^{-34}$ Дж

$$z_0 = \sqrt{\frac{ma^2u_0}{2\hbar^2}}, \qquad \varepsilon = \frac{E}{u_0}$$

1. $k_1 = 2\frac{z_0}{a}\sqrt{\varepsilon}$ $k_2 = 2\frac{z_0}{a}\sqrt{\varepsilon - 1}$

$$D = |A_3|^2/|A_1|^2$$

$$D(\varepsilon) = \frac{4\varepsilon(\varepsilon-1)}{\left(\sin\left(2z_0\sqrt{\varepsilon-1}\right)\right)^2 + 4\varepsilon(\varepsilon-1)}$$

D(0 k

a=1, z_0 0 k=5.

2. ,

3.

$$\varepsilon_j = 1 + \frac{1}{16}\pi^2\frac{j^2}{z_0^2}$$

z_0.

z_0 = 5, z_0 z_0 = 1,5.

D

4.

A a=1, z_0=5,

given

a

Ctrl

Minerr(A2,B1,B2,A3).

U(x z_0^2

-

5. 0 ,99.

6. 0

7. 0

8. 0

9. 1 2

$$a\sqrt{\frac{\varepsilon-1}{\varepsilon}}.$$

10.

D

15. *Движение частицы в потенциальной яме*

$$U(x) = \begin{cases} \infty, x < 0 \\ 0, 0 \le x \le a \\ U_0, x > a \end{cases}$$

E<U_0

$$k = \frac{\sqrt{2mE}}{\hbar}, \qquad \gamma = \frac{\sqrt{2m(U_0 - E)}}{\hbar},$$

$$\operatorname{tg} ka = -\frac{k}{\gamma} = \frac{-ka}{\sqrt{\frac{2mU_0a^2}{\hbar^2} - k^2a^2}} \qquad (1)$$

$$\psi(x) = \begin{cases} A \cdot \sin kx, 0 \le x \le a \\ A \cdot \sin kx \cdot \exp[(a - x)\gamma], x > a \end{cases}$$

$$\varepsilon = \frac{E}{E_0}$$

$$u = \frac{U_0}{E_0} \qquad z = \frac{x}{a} \qquad E_0 = \frac{\pi^2\hbar^2}{2ma^2}$$

$$k = \frac{\pi\sqrt{\varepsilon}}{a}, \gamma = \frac{\pi\sqrt{u-\varepsilon}}{a}.$$

1. k

$$\operatorname{tg}(\pi\sqrt{\varepsilon}) = \frac{-\sqrt{\varepsilon}}{\sqrt{u - \varepsilon}} \qquad (2)$$

2.

$$f(y) = \frac{-y}{\sqrt{u \cdot \pi^2 - y^2}}, \qquad g(y) = \operatorname{tg} y,$$

$y = \pi\sqrt{\varepsilon}.$ y u.

u

yn.

$$\varepsilon(y) = y^2/\pi^2$$

(yn).

3. -

4. n

1=(n+0,5)[2] given u

Minerr(1).

y

5. U(z

U(z)/u /u z -

$$U(z) = \begin{cases} 0, 0 \le z \le 1 \\ 200, z < 0 \\ u, z > 1 \end{cases}$$

6.

a.

b.

c. [2] -

7.

$$\psi(z) = \begin{cases} A \cdot \sin(\pi\sqrt{\varepsilon}z), 0 \le z \le 1 \\ A \cdot \sin(\pi\sqrt{\varepsilon}) \exp[(1 - z)\pi\sqrt{u - \varepsilon}], z > 1 \end{cases}$$

z.

$$w(z) = \psi(z)^2$$

$$A = \left(1 + \frac{1}{\sqrt{u+\varepsilon}}\right)^{-\frac{1}{2}}$$

w(z U(z)/u z -

u

a. n

b.

c. u

n?

d.

n

$_0$).

$$\psi(z) = \begin{cases} A \cdot \sin\left(\pi\sqrt{\varepsilon} z\right), 0 \le z \le 1 \\ A1 \cdot \cos\left(\varphi + z\pi\sqrt{\varepsilon - u}\right), z > 1 \end{cases}$$

A

$$A1 \cdot \cos\left(\varphi + \pi\sqrt{\varepsilon - u}\right) = A \cdot \sin\left(\pi\sqrt{\varepsilon}\right)$$
$$-A1 \cdot \sin\left(\varphi + \pi\sqrt{\varepsilon - u}\right) \cdot \pi\sqrt{\varepsilon - u} = A \cdot \cos\left(\pi\sqrt{\varepsilon}\right) \cdot \pi\sqrt{\varepsilon}$$

8. w(z U(z)/u z -

$$D = 1 - A^2$$

,**17.** ***Пространственная структура атома***

-

$$\Psi(r, \varphi, \theta) = R(r)Y(\varphi, \theta)$$

$$R(z) = N \exp\left(-\frac{z}{2} z^l L(z)\right)$$

N $z = 2\rho n, \rho = r/r_0,$

r_0 l

$L(z)$

$$Y(\varphi, \theta) = N\, P_l^m(\cos\theta) \exp im\varphi$$

N l

l

-

l. $\exp im\varphi$ $Y(\varphi,\theta)$

$$w(\varphi,\theta) = |Y(\varphi,\theta)|^2 = N^2\left(P_l^m(\cos\theta)\right)^2$$

P_l^m $\cos\theta$.

---

1. l = 0, 1, 2, 3, 4; m = 0, 1, ..., l).

$$P(z) = \frac{1}{2^l l!}(1-z^2)^{\frac{m}{2}}\frac{d^{l+m}}{dz^{l+m}}(z^2-1)^l$$

l

$$\theta(z) = \arcsin z\,, \qquad w(z) = \frac{2l+1}{4\pi}\frac{(l-m)!}{(l+m)!}P(z)^2$$

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Указание к выполнению:

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Критерии оценивания

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Критерии оценивания

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