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Численное моделирование нестационарного одномерного течения газа с использованием неявной параллельной разностной схемой с центральными разностями (ρ, u)

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Москва, 2021

Оглавление

1. Введение

1.1. Постановка задачи

Рассмотрим систему уравнений, описывающую нестационарное одномерное движение вязкого баротропного газа:

$$\begin{cases} \frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} = \rho f_0 \\ \rho \frac{\partial u}{\partial t} + \rho u \frac{\partial u}{\partial x} + \frac{\partial p}{\partial x} = \mu \frac{\partial^2 u}{\partial x^2} + \rho \\ p = p(\rho) \end{cases} \tag{1}$$

Через μ обозначен коэффициент вязкости газа, который будем считать известной положительной константой. Известными также будем считать функцию давления газа p (в данной работе будем рассматривать $p(\rho) = C\rho$, где C - положительная константа) и вектор внешних сил f. f - функция переменных Эйлера: $(t, x) \in Q = \Omega_t \times \Omega_x = [0; T] \times [0; X]$.

Неизвестные функции: плотность ρ и скорость u также являются функциями переменных Эйлера.

Перепишем систему (1) в эквивалентный вид, при условии того, что ρ и u гладкие:

$$\begin{cases} \frac{\partial \rho}{\partial t} + \frac{1}{2} \left(u \frac{\partial \rho}{\partial x} + \frac{\partial \rho u}{\partial x} + \rho \frac{\partial u}{\partial x} \right) = 0 \\ \frac{\partial u}{\partial t} + \frac{1}{3} \left(u \frac{\partial u}{\partial x} + \frac{\partial u^2}{\partial x} \right) + \frac{1}{\rho} \frac{\partial p}{\partial x} = \frac{\mu}{\rho} \frac{\partial^2 u}{\partial x^2} + f \end{cases} \tag{2}$$

Система (1) дополнена граничными условиями:

$$\begin{aligned} (\rho, u)|_{t=0} &= (\rho_0, u_0), & x &\in [0; X] \\ u(t, 0) &= u(t, X) = 0, & t &\in [0; T] \end{aligned} \tag{3}$$

1.2. Основные обозначения

Введем на Ω_x и Ω_t сетки:

$$\omega_x = \{mh : m = 0, \ldots, M\}, h = \frac{X}{M}$$
$$\omega_t = \{n\tau : n = 0, \ldots, N\}, \tau = \frac{T}{N} \tag{4}$$

Для сокращения записи значение для произвольной функции f в узле (n, m) сетки $\omega_x x \omega_t$ обозначим за f_m^n. Введем следующие обозначения:

$$\hat{f} = f_m^{n+1}$$
$$f_t = \frac{f_m^{n+1} - f_m^n}{\tau}$$
$$f_x = \frac{f_{m+1}^n - f_m^n}{h}$$
$$f_{\bar{x}} = \frac{f_m^n - f_{m-1}^n}{h} \tag{5}$$
$$f_{\overset{\circ}{x}} = \frac{f_{m+1}^n - f_{m-1}^n}{2h}$$
$$f_{x\bar{x}} = \frac{f_{m-1}^n - 2f_m^n + f_{m+1}^n}{h^2}$$

2. Разностная схема

2.1. Описание схемы

Для поиска численного решения задачи (1) можно использовать разностную схему, в которой при апроксимации конвективных членов используются центральные разности, но апроксимация не всех производных вынесена на верхний временной слой.

$$
H_t + 0.5(V\hat{H}_{\mathring{x}} + (V\hat{H})_{\mathring{x}} + HV_{\mathring{x}}) = 0, w \in \omega_h
$$
$$
H_{t,0} + 0.5((V\hat{H})_{x,0} + H_0 V_{x,0}) - 0.5h((HV)_{x\bar{x},1} - 0.5(HV)_{x\bar{x},2} +
$$
$$
+ H_0(V_{x\bar{x},1} - 0.5V_{x\bar{x},2})) = 0, x \in \gamma_h^-
$$
$$
H_{t,M} + 0.5((V\hat{H})_{\bar{x},M} + H_M V_{\bar{x},M}) + 0.5h((HV)_{x\bar{x},M-1} - 0.5(HV)_{x\bar{x},M-2} +
$$
$$
+ H_M(V_{x\bar{x},M-1} - 0.5V_{x\bar{x},M-2})) = 0, x \in \gamma_h^+
$$
$$
V_t + \frac{1}{3}(V\hat{V}_{\mathring{x}} + (V\hat{V})_{\mathring{x}}) + \frac{p(H)_{\mathring{x}}}{H} = \tilde{\mu}\hat{V}_{x\bar{x}} - \left(\tilde{\mu} - \frac{\mu}{H}\right)V_{x\bar{x}} + f, x \in \omega_h
$$
$$
\tag{6}
$$

2.2. Координатная запись

Распишем схему приведенных выше обозначениях, и выделим коэффиценты при H и V на $n+1$ временном слое: 1 уравнение:

$$
H_t + 0.5(V\hat{H}_{\mathring{x}} + (V\hat{H})_{\mathring{x}} + HV_{\mathring{x}}) = 0
$$

$$
\frac{H_m^{n+1} - H_m^n}{\tau} + \frac{V(\hat{H}_{m+1}^n - \hat{H}_{m-1}^n)}{4h} + \frac{(V\hat{H})_{m+1}^n - (V\hat{H})_{m-1}^n}{4h} + \frac{H(V_{m+1}^n - V_{m-1}^n)}{4h} = 0
$$
$$
H_{m-1}^{n+1}\left(-\frac{(V_m^n + V_{m-1}^n)}{4h}\right) + H_m^{n+1}\left(\frac{1}{\tau}\right) + H_{m+1}^{n+1}\left(\frac{V_m^n + V_{m+1}^n}{4h}\right) = H_m^n\left(\frac{1}{\tau} - \frac{(V_{m+1}^n - V_{m-1}^n)}{4h}\right)
$$

2 уравнение:
$$
H_{t,0} + 0.5((V\hat{H})_{x,0} + H_0 V_{x,0}) - 0.5h((HV)_{x\bar{x},1} - 0.5(HV)_{x\bar{x},2} +
$$

$$+ H_0(V_{x\bar{x},1} - 0.5 V_{x\bar{x},2})) = 0$$

$$\frac{H_0^{n+1} - H_0^n}{\tau} + 0.5 \left(\frac{V_1^n H_1^{n+1} - V_0^n H_0^{n+1}}{h} + H_0^n \left(\frac{V_1^n - V_0^n}{h} \right) \right) -$$
$$- \frac{h}{2} \left(\frac{H_0^n V_0^n - 2 H_1^n V_1^n + H_2^n V_2^n}{h^2} - \frac{1}{2} \left(\frac{H_1^n V_1^n - 2 H_2^n V_2^n + H_3^n V_3^n}{h^2} \right) \right) -$$
$$- \frac{h}{2} \left(H_0 \left(\frac{V_0^n - 2 V_1^n + V_2^n}{h^2} - \frac{1}{2} \left(\frac{V_1^n - 2 V_2^n + V_3^n}{h^2} \right) \right) \right) = 0$$

$$H_0^{n+1} \left(\frac{1}{\tau} - \frac{V_0^n}{2h} \right) + H_1^{n+1} \left(\frac{V_1^n}{2h} \right) = \frac{H_0^n}{\tau} - \frac{H_0^n (V_1^n - V_0^n)}{2h} +$$
$$+ \frac{h}{2} \left(\frac{H_0^n V_0^n - 2 H_1^n V_1^n + H_2^n V_2^n}{h^2} - \frac{1}{2} \left(\frac{H_1^n V_1^n - 2 H_2^n V_2^n + H_3^n V_3^n}{h^2} \right) \right) +$$
$$+ \frac{h}{2} \left(H_0 \left(\frac{V_0^n - 2 V_1^n + V_2^n}{h^2} - \frac{1}{2} \left(\frac{V_1^n - 2 V_2^n + V_3^n}{h^2} \right) \right) \right) = 0$$

3 уравнение:

$$H_{t,M} + 0.5((V\hat{H})_{\bar{x},M} + H_M V_{\bar{x},M}) + 0.5h((HV)_{x\bar{x},M-1} - 0.5(HV)_{x\bar{x},M-2} +$$
$$+ H_M(V_{x\bar{x},M-1} - 0.5 V_{x\bar{x},M-2})) = 0$$

$$\frac{H_M^{n+1} - H_M^n}{\tau} + 0.5 \left(\frac{V_M^n H_M^{n+1} - V_{M-1}^n H_{M-1}^{n+1}}{h} + H_M^n \left(\frac{V_M^n - V_{M-1}^n}{h} \right) \right) +$$
$$+ \frac{h}{2} \left(\frac{H_{M-2}^n V_{M-2}^n - 2 H_{M-1}^n V_{M-1}^n + H_M^n V_M^n}{h^2} - \frac{1}{2} \left(\frac{H_{M-3}^n V_{M-3}^n - 2 H_{M-2}^n V_{M-2}^n + H_{M-1}^n V_{M-1}^n}{h^2} \right) \right) +$$
$$+ \frac{h}{2} \left(H_M \left(\frac{V_{M-2}^n - 2 V_{M-1}^n + V_M^n}{h^2} - \frac{1}{2} \left(\frac{V_{M-3}^n - 2 V_{M-2}^n + V_{M-1}^n}{h^2} \right) \right) \right)$$

$$H_M^{n+1} \left(\frac{1}{\tau} + \frac{V_M^n}{2h} \right) + H_{M-1}^{n+1} \left(-\frac{V_{M-1}^n}{2h} \right) = \frac{H_M^n}{\tau} - \frac{H_M^n (V_M^n - V_{M-1}^n)}{2h} -$$
$$- \frac{h}{2} \left(\frac{H_{M-2}^n V_{M-2}^n - 2 H_{M-1}^n V_{M-1}^n + H_M^n V_M^n}{h^2} - \frac{1}{2} \left(\frac{H_{M-3}^n V_{M-3}^n - 2 H_{M-2}^n V_{M-2}^n + H_{M-1}^n V_{M-1}^n}{h^2} \right) \right) -$$
$$- \frac{h}{2} \left(H_M \left(\frac{V_{M-2}^n - 2 V_{M-1}^n + V_M^n}{h^2} - \frac{1}{2} \left(\frac{V_{M-3}^n - 2 V_{M-2}^n + V_{M-1}^n}{h^2} \right) \right) \right)$$

4 уравнение:

$$V_t + \frac{1}{3}(V\hat{V}_{\mathring{x}} + (V\hat{V})_{\mathring{x}}) + \frac{p(H)_{\mathring{x}}}{H} = \tilde{\mu} \hat{V}_{x\bar{x}} - \left(\tilde{\mu} - \frac{\mu}{H} \right) V_{x\bar{x}} + f$$

$$\frac{V_m^{n+1} - V_m^n}{\tau} + \frac{1}{3} \left(V_m^n \frac{V_{m+1}^{n+1} - V_{m-1}^{n+1}}{2h} + \frac{V_{m+1}^n V_{m+1}^{n+1} - V_{m-1}^n V_{m-1}^{n+1}}{2h} \right) +$$
$$+ \frac{p(H)_{m+1}^n - p(H)_{m-1}^n}{2h H_m^n} - \tilde{\mu} \frac{V_{m-1}^{n+1} - 2 V_m^{n+1} + V_{m+1}^{n+1}}{h^2} + \left(\tilde{\mu} - \frac{\mu}{H_m^n} \right) \frac{V_{m-1}^n - 2 V_m^n + V_{m+1}^n}{h^2} - f_m^n = 0$$

$$V_{m-1}^{n+1} \left(-\frac{V_m^n + V_{m-1}^n}{6h} - \frac{\tilde{\mu}}{h^2} \right) + V_m^{n+1} \left(\frac{1}{\tau} + \frac{2\tilde{\mu}}{h^2} \right) + V_{m+1}^{n-1} \left(\frac{V_m^n + V_{m+1}^n}{6h} - \frac{\tilde{\mu}}{h^2} \right) =$$

$$\frac{V_m^n}{\tau} - \frac{p(H)_{m+1}^n - p(H)_{m-1}^n}{2hH_m^n} - \left(\tilde{\mu} - \frac{\mu}{H_m^n} \right) \frac{V_{m-1}^n - 2V_m^n + V_{m+1}^n}{h^2} + f_m^n = 0$$

3. Отладочный тест

3.1. Постановка задачи

Рассмотрим $Q = [0;1]x[0;1]$

Зададим функции $\tilde{\rho}(t,x)$ и $\tilde{u}(t,x)$ так, чтобы они являлись гладким решением задачи (1).

$$\tilde{\rho}(t,x) = e^t(cos(3\pi x) + 1.5),$$
$$\tilde{u}(t,x) = cos(2\pi t)sin(4\pi x) \tag{7}$$

Теперь определим функции f_0 и f, так, чтобы они удовлетворяли уравнениям:

$$\frac{\partial\tilde{\rho}}{\partial t} + \frac{\partial\tilde{\rho}\tilde{u}}{\partial x} = f_0,$$
$$\tilde{\rho}\frac{\partial\tilde{u}}{\partial t} + \tilde{u}\tilde{\rho}\frac{\partial\tilde{u}}{\partial x} + \frac{\partial p}{\partial x} = \mu\frac{\partial^2\tilde{u}}{\partial x^2} + \tilde{\rho}f \tag{8}$$

$$\frac{\partial\tilde{\rho}}{\partial t} = e^t(cos(3\pi x) + 1.5),$$
$$\frac{\partial\tilde{\rho}\tilde{u}}{\partial t} = \pi e^t cos(2\pi t) * (4(cos(3\pi x) + 1.5)cos(4\pi x) - 3sin(3\pi x)sin(4\pi x)),$$
$$\frac{\partial\tilde{u}}{\partial t} = -2\pi$$
$$\tag{9}$$

3.2. Численные эксперименты

Обычная сетка

Table of times.

τ/h	1.000e-01
1.000e-01	3.880e-04

Table of norms for H. $\mu = 0.0010 \quad C = 100.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$1.584e+07$ $1.042e+07$ $4.357e+07$	$4.294e+10$ $6.986e+09$ $9.938e+11$	$1.686e+15$ $1.245e+14$ $2.376e+17$	$5.580e+15$ $2.138e+14$ $3.459e+18$
1.000e-02	$6.821e+35$ $3.634e+35$ $7.863e+36$	$9.897e+89$ $1.347e+89$ $2.183e+91$	$2.222e+145$ $1.379e+144$ $1.944e+147$	$4.430e+170$ $inf\ inf$
1.000e-03	$1.065e+236$ $inf\ inf$	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$
1.000e-04	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$

Table of norms for H. $\mu = 0.0010 \quad C = 10.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$3.090e+04$ $1.439e+04$ $1.701e+05$	$5.084e+06$ $6.602e+05$ $1.094e+08$	$1.411e+08$ $3.608e+07$ $4.934e+10$	$1.190e+12$ $6.018e+10$ $8.088e+14$
1.000e-02	$3.100e+39$ $1.131e+39$ $5.512e+39$	$4.683e+59$ $1.051e+59$ $2.281e+61$	$6.063e+101$ $5.588e+100$ $8.053e+103$	$2.753e+131$ $5.800e+129$ $6.606e+133$
1.000e-03	$1.325e+156$ $inf\ inf$	$3.595e+221$ $inf\ inf$	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$
1.000e-04	$6.715e+251$ $inf\ inf$	$2.001e-02$ $2.598e-03$ $2.318e-01$	$nan\ -nan$ $-nan$	$nan\ -nan$ $-nan$

Table of norms for H. $\mu = 0.0010 \quad C = 1.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$2.194e+03$ $7.559e+02$ $1.314e+04$	$2.567e+05$ $5.256e+04$ $6.524e+06$	$5.734e+08$ $6.550e+07$ $1.019e+11$	$2.799e+10$ $4.202e+09$ $5.942e+13$
1.000e-02	$1.165e+12$ $3.177e+11$ $5.886e+12$	$1.128e+36$ $1.306e+35$ $2.488e+37$	$5.900e+72$ $1.977e+71$ $2.775e+74$	$1.222e+106$ $1.594e+104$ $2.327e+108$
1.000e-03	$1.443e+12$ $3.323e+11$ $7.625e+12$	$3.696e-01$ $7.799e-02$ $9.401e+00$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e-04	$7.930e+49$ $1.785e+49$ $2.725e+50$	$3.933e-02$ $8.747e-03$ $1.206e+00$	$1.288e-02$ $2.307e-03$ $2.971e-01$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 1.0000, \gamma = 1.4000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e-02	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e-03	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e-04	nan $-nan$ $-nan$	$1.498e-02$ $4.873e-03$ $5.353e-01$	$6.867e-04$ $2.722e-04$ $5.344e-03$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0100$ $C = 100.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$1.989e+10$ $8.497e+09$ $1.238e+11$	$2.114e+14$ $4.989e+13$ $7.172e+15$	$9.462e+16$ $2.524e+16$ $3.578e+19$	$4.493e+14$ $5.190e+12$ $7.350e+16$
1.000e-02	$3.002e+50$ $1.631e+50$ $3.624e+51$	$7.628e+80$ $1.226e+80$ $1.901e+82$	$1.631e+128$ $6.805e+126$ $9.452e+129$	$2.725e+161$ $inf\ inf$
1.000e-03	$4.218e+263$ $inf\ inf$	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$
1.000e-04	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 10.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$7.870e+04$ $2.214e+04$ $3.880e+05$	$9.771e+08$ $1.978e+08$ $2.729e+10$	$3.380e+08$ $2.259e+07$ $2.587e+10$	$4.476e+10$ $1.033e+09$ $1.625e+13$
1.000e-02	$6.930e+23$ $2.252e+23$ $5.646e+24$	$8.442e+55$ $9.029e+54$ $1.630e+57$	$8.059e+114$ $3.720e+113$ $4.093e+116$	$8.610e+135$ $4.699e+134$ $6.088e+138$
1.000e-03	$8.130e+75$ $2.057e+75$ $5.090e+76$	$2.026e+178$ $inf\ inf$	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$
1.000e-04	$4.052e+127$ $9.276e+126$ $1.498e+128$	$3.101e-03$ $1.748e-03$ $2.052e-02$	$nan\ \ -nan$ $-nan$	$nan\ \ -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 1.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$6.976e+01$ $3.338e+01$ $6.133e+02$	$2.669e+05$ $4.897e+04$ $5.277e+06$	$8.971e+06$ $5.527e+05$ $7.833e+08$	$6.809e+11$ $3.064e+10$ $4.370e+14$
1.000e-02	$2.971e+05$ $7.642e+04$ $1.904e+06$	$1.138e+36$ $1.241e+35$ $2.314e+37$	$1.229e+74$ $1.570e+73$ $2.206e+76$	$3.672e+113$ $4.071e+111$ $6.121e+115$
1.000e-03	$3.947e+08$ $9.196e+07$ $2.146e+09$	$6.048e-02$ $1.407e-02$ $8.331e-01$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$8.764e+08$ $2.025e+08$ $4.668e+09$	$1.676e-02$ $3.944e-03$ $1.796e-01$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 1.0000, \gamma = 1.4000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-02	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-03	$nan \quad -nan$ $-nan$	$5.963e-03$ $3.227e-03$ $4.939e-02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$nan \quad -nan$ $-nan$	$5.153e-03$ $3.079e-03$ $4.458e-02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000 \quad C = 100.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$1.092e+13$ $7.623e+12$ $1.475e+14$	$2.732e+09$ $7.216e+08$ $1.095e+11$	$4.137e+14$ $4.144e+13$ $5.844e+16$	$5.153e+18$ $1.860e+18$ $2.630e+22$
1.000e-02	$1.066e+42$ $6.768e+41$ $1.415e+43$	$1.149e+75$ $2.453e+74$ $4.384e+76$	$8.038e+113$ $2.088e+113$ $2.677e+116$	$1.023e+156$ $inf\ inf$
1.000e-03	$1.680e+182$ $inf\ inf$	$nan\quad -nan$ $-nan$	$nan\quad -nan$ $-nan$	$nan\quad -nan$ $-nan$
1.000e-04	$3.704e+139$ $8.718e+138$ $2.060e+140$	$3.805e-03$ $2.345e-03$ $2.391e-02$	$nan\quad -nan$ $-nan$	$nan\quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000 \quad C = 10.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$2.420e+07$ $8.931e+06$ $1.527e+08$	$4.162e+08$ $1.015e+08$ $1.506e+10$	$2.225e+11$ $5.549e+10$ $7.874e+13$	$1.171e+12$ $1.579e+10$ $2.237e+14$
1.000e-02	$5.714e+16$ $2.842e+16$ $5.635e+17$	$1.120e+61$ $1.687e+60$ $3.017e+62$	$4.242e+86$ $3.811e+85$ $7.186e+88$	$1.460e+132$ $1.854e+131$ $2.644e+135$
1.000e-03	$3.881e+00$ $1.149e+00$ $1.627e+01$	$4.363e+237$ $inf\ inf$	$nan\quad -nan$ $-nan$	$nan\quad -nan$ $-nan$
1.000e-04	$2.368e+00$ $8.436e-01$ $1.160e+01$	$4.524e-03$ $2.327e-03$ $2.437e-02$	$nan\quad -nan$ $-nan$	$nan\quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 1.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$3.067e+03$ $1.629e+03$ $9.858e+03$	$1.389e+03$ $3.821e+02$ $5.319e+04$	$4.085e+06$ $1.976e+05$ $2.779e+08$	$9.049e+06$ $1.494e+06$ $2.117e+10$
1.000e-02	$1.747e+07$ $4.378e+06$ $7.831e+07$	$2.420e+38$ $2.541e+37$ $3.981e+39$	$6.187e+80$ $3.617e+79$ $7.764e+82$	$2.201e+106$ $5.889e+104$ $9.151e+108$
1.000e-03	$4.465e+09$ $1.031e+09$ $2.376e+10$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$1.774e+09$ $4.033e+08$ $6.395e+09$	$1.484e-02$ $5.417e-03$ $1.140e-01$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 1.0000, \gamma = 1.4000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-02	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-03	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$nan \quad -nan$ $-nan$	$5.328e-03$ $2.564e-03$ $4.033e-02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 100.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	8.432e + 01 4.331e + 01 6.501e + 02	5.324e + 02 1.322e + 02 1.830e + 04	2.264e + 07 4.238e + 06 7.540e + 09	1.452e + 07 5.688e + 05 8.032e + 09
1.000e-02	6.617e + 01 3.743e + 01 5.206e + 02	5.845e + 02 1.259e + 02 2.333e + 04	1.664e + 05 1.282e + 04 1.642e + 07	1.117e + 04 7.549e + 02 1.440e + 07
1.000e-03	3.510e + 02 2.474e + 02 3.672e + 03	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*
1.000e-04	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*

Table of norms for H. $\mu = 0.0010$ $C = 10.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	1.819e + 01 9.487e + 00 1.608e + 02	2.903e + 02 4.585e + 01 6.678e + 03	3.428e + 03 4.193e + 02 5.587e + 05	1.526e + 05 3.533e + 03 5.238e + 07
1.000e-02	6.097e + 01 4.213e + 01 6.238e + 02	4.016e + 01 1.084e + 01 1.486e + 03	1.061e + 04 5.176e + 02 7.966e + 05	1.017e + 05 3.653e + 03 5.422e + 07
1.000e-03	1.360e + 02 9.542e + 01 1.420e + 03	5.326e + 01 3.245e + 01 4.176e + 03	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*
1.000e-04	1.606e + 02 1.123e + 02 1.669e + 03	4.320e − 03 2.316e − 03 4.976e − 02	*nan* *−nan* *−nan*	*nan* *−nan* *−nan*

Table of norms for H. $\mu = 0.0010$ $C = 1.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$8.932e+00$ $5.407e+00$ $9.547e+01$	$1.608e+02$ $1.700e+01$ $3.018e+03$	$2.663e+03$ $3.647e+02$ $5.621e+05$	$1.454e+05$ $4.429e+03$ $5.980e+07$
1.000e-02	$1.088e+01$ $6.594e+00$ $1.082e+02$	$3.517e+01$ $8.779e+00$ $1.286e+03$	$8.087e+02$ $5.047e+01$ $7.391e+04$	$8.901e+03$ $4.288e+02$ $5.982e+06$
1.000e-03	$9.763e+00$ $6.295e+00$ $7.680e+01$	$1.316e-01$ $1.880e-02$ $2.607e+00$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$9.356e+01$ $4.787e+01$ $8.203e+02$	$1.041e-02$ $2.809e-03$ $2.416e-01$	$2.286e-03$ $6.048e-04$ $7.014e-02$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 1.0000, \gamma = 1.4000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-02	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-03	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$nan \quad -nan$ $-nan$	$7.771e-03$ $2.834e-03$ $2.030e-01$	$2.133e-04$ $1.024e-04$ $1.966e-03$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100$ $C = 100.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$2.359e+02$ $9.856e+01$ $1.597e+03$	$7.350e+03$ $9.909e+02$ $1.700e+05$	$2.230e+05$ $2.776e+04$ $3.924e+07$	$7.184e+05$ $3.530e+04$ $4.809e+08$
1.000e-02	$8.435e+01$ $4.727e+01$ $7.491e+02$	$9.495e+02$ $1.490e+02$ $2.491e+04$	$1.015e+03$ $7.917e+01$ $1.050e+05$	$8.649e+04$ $4.680e+03$ $7.055e+07$
1.000e-03	$3.524e+02$ $2.480e+02$ $3.690e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 10.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$2.159e+01$ $9.587e+00$ $1.198e+02$	$2.471e+02$ $3.984e+01$ $4.609e+03$	$2.133e+05$ $8.964e+03$ $1.237e+07$	$9.071e+06$ $9.628e+04$ $1.372e+09$
1.000e-02	$3.757e+01$ $1.960e+01$ $2.769e+02$	$7.268e+03$ $7.591e+02$ $1.296e+05$	$4.183e+03$ $2.453e+02$ $3.613e+05$	$1.706e+04$ $5.245e+02$ $7.946e+06$
1.000e-03	$8.250e+01$ $5.484e+01$ $9.331e+02$	$5.382e+01$ $2.538e+01$ $3.733e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$6.557e+01$ $4.134e+01$ $6.523e+02$	$4.257e-03$ $2.137e-03$ $3.011e-02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100$ $C = 1.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$6.402e+00$	$1.104e+02$	$5.696e+07$	$2.708e+06$
	$3.503e+00$	$1.829e+01$	$2.433e+06$	$1.053e+05$
	$6.085e+01$	$2.648e+03$	$3.442e+09$	$1.502e+09$
1.000e-02	$1.294e+01$	$3.998e+01$	$3.786e+03$	$8.133e+03$
	$6.238e+00$	$7.511e+00$	$2.706e+02$	$3.903e+02$
	$1.109e+02$	$1.111e+03$	$4.263e+05$	$5.520e+06$
1.000e-03	$1.213e+01$	$1.218e-02$	nan $-nan$	nan $-nan$
	$7.867e+00$	$4.318e-03$	$-nan$	$-nan$
	$1.109e+02$	$1.627e-01$		
1.000e-04	$1.310e+01$	$5.115e-03$	nan $-nan$	nan $-nan$
	$8.536e+00$	$2.362e-03$	$-nan$	$-nan$
	$1.386e+02$	$4.356e-02$		

Table of norms for H. $\mu = 0.0100$ $C = 1.0000, \gamma = 1.4000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	nan $-nan$	nan $-nan$	nan $-nan$	nan $-nan$
	$-nan$	$-nan$	$-nan$	$-nan$
1.000e-02	nan $-nan$	nan $-nan$	nan $-nan$	nan $-nan$
	$-nan$	$-nan$	$-nan$	$-nan$
1.000e-03	nan $-nan$	$5.471e-03$	nan $-nan$	nan $-nan$
	$-nan$	$2.580e-03$	$-nan$	$-nan$
		$3.763e-02$		
1.000e-04	nan $-nan$	$4.051e-03$	nan $-nan$	nan $-nan$
	$-nan$	$2.245e-03$	$-nan$	$-nan$
		$3.294e-02$		

Table of norms for H. $\mu = 0.1000$ $C = 100.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$1.396e+02$	$6.052e+04$	$4.018e+03$	$3.551e+06$
	$7.026e+01$	$1.539e+04$	$3.036e+02$	$4.198e+04$
	$1.006e+03$	$2.373e+06$	$4.364e+05$	$5.933e+08$
1.000e-02	$7.060e+01$	$1.619e+03$	$4.477e+03$	$1.287e+05$
	$4.460e+01$	$2.911e+02$	$6.658e+02$	$4.590e+03$
	$6.486e+02$	$4.415e+04$	$9.019e+05$	$6.990e+07$
1.000e-03	$3.685e+02$	$nan \quad -nan$	$nan \quad -nan$	$nan \quad -nan$
	$2.594e+02$	$-nan$	$-nan$	$-nan$
	$3.850e+03$			
1.000e-04	$3.042e+02$	$3.322e-03$	$nan \quad -nan$	$nan \quad -nan$
	$2.134e+02$	$1.908e-03$	$-nan$	$-nan$
	$3.178e+03$	$2.599e-02$		

Table of norms for H. $\mu = 0.1000 \quad C = 10.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$3.027e+01$	$8.695e+02$	$1.604e+03$	$2.520e+08$
	$1.154e+01$	$2.896e+02$	$1.172e+02$	$7.357e+07$
	$1.596e+02$	$4.336e+04$	$1.649e+05$	$1.040e+12$
1.000e-02	$2.598e+01$	$4.592e+03$	$1.307e+03$	$6.571e+04$
	$1.827e+01$	$7.747e+02$	$1.133e+02$	$1.681e+03$
	$3.042e+02$	$1.012e+05$	$1.539e+05$	$2.406e+07$
1.000e-03	$2.346e+00$	$6.357e+01$	$nan \quad -nan$	$nan \quad -nan$
	$1.013e+00$	$3.150e+01$	$-nan$	$-nan$
	$8.381e+00$	$4.358e+03$		
1.000e-04	$2.641e+00$	$3.157e-03$	$nan \quad -nan$	$nan \quad -nan$
	$1.060e+00$	$1.803e-03$	$-nan$	$-nan$
	$9.490e+00$	$2.536e-02$		

Table of norms for H. $\mu = 0.1000 \quad C = 1.0000, \gamma = 1.0000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$9.659e + 00$ $5.958e + 00$ $5.483e + 01$	$5.237e + 02$ $1.162e + 02$ $1.816e + 04$	$1.452e + 05$ $5.142e + 03$ $6.937e + 06$	$6.679e + 10$ $1.526e + 09$ $2.159e + 13$
1.000e-02	$8.421e + 00$ $4.339e + 00$ $4.734e + 01$	$7.136e + 01$ $1.029e + 01$ $1.566e + 03$	$3.740e + 04$ $2.151e + 03$ $2.996e + 06$	$8.310e + 04$ $4.473e + 03$ $5.387e + 07$
1.000e-03	$1.806e + 01$ $8.472e + 00$ $1.203e + 02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$1.071e + 01$ $5.001e + 00$ $7.965e + 01$	$4.479e - 03$ $2.160e - 03$ $3.250e - 02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000 \quad C = 1.0000, \gamma = 1.4000$

τ/h	1.000e-01	1.000e-02	1.000e-03	1.000e-04
1.000e-01	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-02	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-03	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e-04	$nan \quad -nan$ $-nan$	$3.641e - 03$ $1.905e - 03$ $2.689e - 02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Вложенная сетка

Table of times.

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	3.400e-05	3.020e-03	3.339e+00	2.000e+02
1.000e+00	4.226e-03	6.185e-01	4.004e+01	1.825e+03
2.000e+00	4.568e-03	2.072e+00	1.426e+02	5.153e+03
3.000e+00	7.239e-03	7.557e+00	4.131e+02	9.639e+03

Table of norms for H. $\mu = 0.0010$ $C = 100.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$1.584e + 07$ $1.042e + 07$ $4.357e + 07$	$9.897e + 89$ $1.347e + 89$ $2.183e + 91$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$2.334e + 37$ $2.735e + 36$ $2.391e + 38$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$1.024e + 66$ $1.516e + 65$ $9.185e + 66$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$7.152e+148$ $3.998e+147$ $1.282e+150$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 10.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$3.090e+04$ $1.439e+04$ $1.701e+05$	$4.683e+59$ $1.051e+59$ $2.281e+61$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$1.022e+22$ $1.286e+21$ $6.174e+22$	$6.541e+247$ $inf\ inf$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$1.401e+52$ $1.108e+51$ $1.794e+53$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$3.310e+106$ $1.851e+105$ $6.003e+107$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 1.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$2.194e+03$ $7.559e+02$ $1.314e+04$	$1.128e+36$ $1.306e+35$ $2.488e+37$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$1.561e+15$ $1.755e+14$ $9.187e+15$	$5.727e+141$ $2.247e+140$ $8.271e+142$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$2.437e+27$ $1.927e+26$ $3.058e+28$	$1.315e+259$ $inf\ inf$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$1.795e+46$ $1.004e+45$ $2.215e+47$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 1.0000, \gamma = 1.4000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0100$ $C = 100.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$1.989e+10$ $8.497e+09$ $1.238e+11$	$7.628e+80$ $1.226e+80$ $1.901e+82$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$6.687e+34$ $7.942e+33$ $7.276e+35$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$5.651e+66$ $9.826e+65$ $3.858e+67$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$1.141e+141$ $6.398e+139$ $1.510e+142$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0100$ $C = 10.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$7.870e + 04$ $2.214e + 04$ $3.880e + 05$	$8.442e + 55$ $9.029e + 54$ $1.630e + 57$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$6.980e + 24$ $7.809e + 23$ $6.386e + 25$	$6.061e+254$ $inf\ inf$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$2.057e + 48$ $1.663e + 47$ $1.740e + 49$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$1.772e+106$ $1.218e+105$ $3.221e+107$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 1.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$6.976e + 01$ $3.338e + 01$ $6.133e + 02$	$1.138e + 36$ $1.241e + 35$ $2.314e + 37$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$2.047e + 09$ $2.297e + 08$ $1.740e + 10$	$1.040e+154$ $3.849e+152$ inf	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$1.520e + 18$ $1.829e + 17$ $1.101e + 19$	$2.689e+271$ $inf\ inf$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$3.045e + 39$ $1.702e + 38$ $3.889e + 40$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 1.0000, \gamma = 1.4000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000 \quad C = 100.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$1.092e + 13$ $7.623e + 12$ $1.475e + 14$	$1.149e + 75$ $2.453e + 74$ $4.384e + 76$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$7.270e + 42$ $1.814e + 42$ $5.340e + 43$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$3.587e + 72$ $2.837e + 71$ $4.604e + 73$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$4.236e+133$ $2.417e+132$ $6.930e+134$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000 \quad C = 10.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$2.420e+07$ $8.931e+06$ $1.527e+08$	$1.120e+61$ $1.687e+60$ $3.017e+62$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$6.616e+19$ $7.411e+18$ $4.214e+20$	$1.271e+242$ $inf\ inf$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$6.405e+40$ $5.063e+39$ $8.109e+41$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$2.817e+98$ $1.575e+97$ $5.056e+99$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 1.0000$, $\gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$3.067e+03$ $1.629e+03$ $9.858e+03$	$2.420e+38$ $2.541e+37$ $3.981e+39$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$2.753e+10$ $3.124e+09$ $2.774e+11$	$3.137e+137$ $1.109e+136$ $6.280e+138$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$1.437e+28$ $1.136e+27$ $1.285e+29$	$1.140e+263$ $inf\ inf$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$4.858e+53$ $2.716e+52$ $6.083e+54$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 1.0000, \gamma = 1.4000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 100.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$8.432e+01$ $4.331e+01$ $6.501e+02$	$5.845e+02$ $1.259e+02$ $2.333e+04$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$3.979e+02$ $7.814e+01$ $4.092e+03$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$2.326e+02$ $4.185e+01$ $3.829e+03$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$1.137e+03$ $1.010e+02$ $1.688e+04$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.0010$ $C = 10.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$1.819e+01$ $9.487e+00$ $1.608e+02$	$4.016e+01$ $1.084e+01$ $1.486e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$3.509e+01$ $8.056e+00$ $4.023e+02$	$7.851e+02$ $4.521e+01$ $2.854e+04$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$6.363e+02$ $7.266e+01$ $8.018e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$1.456e+02$ $1.403e+01$ $3.668e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0010 \quad C = 1.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$8.932e+00$ $5.407e+00$ $9.547e+01$	$3.517e+01$ $8.779e+00$ $1.286e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$6.414e+00$ $1.548e+00$ $1.019e+02$	$1.870e+02$ $1.009e+01$ $6.358e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$1.052e+01$ $1.766e+00$ $1.631e+02$	$5.731e+01$ $3.071e+00$ $3.337e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$8.281e+00$ $9.728e-01$ $2.262e+02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0010 \quad C = 1.0000, \gamma = 1.4000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 100.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$2.359e + 02$ $9.856e + 01$ $1.597e + 03$	$9.495e + 02$ $1.490e + 02$ $2.491e + 04$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$2.384e + 02$ $5.459e + 01$ $2.117e + 03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$1.888e + 02$ $3.119e + 01$ $3.336e + 03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$1.754e + 02$ $1.682e + 01$ $3.154e + 03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 10.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$2.159e+01$ $9.587e+00$ $1.198e+02$	$7.268e+03$ $7.591e+02$ $1.296e+05$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$5.197e+01$ $1.101e+01$ $5.498e+02$	$2.487e+02$ $2.032e+01$ $1.169e+04$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$1.030e+03$ $1.164e+02$ $1.413e+04$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$4.946e+02$ $3.929e+01$ $8.817e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100 \quad C = 1.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$6.402e+00$ $3.503e+00$ $6.085e+01$	$3.998e+01$ $7.511e+00$ $1.111e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$9.578e+00$ $2.515e+00$ $7.842e+01$	$9.894e+01$ $5.452e+00$ $3.238e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$5.369e+00$ $1.188e+00$ $1.546e+02$	$6.682e+01$ $2.910e+00$ $3.097e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$6.554e+00$ $9.122e-01$ $1.997e+02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.0100$ $C = 1.0000, \gamma = 1.4000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 100.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$1.396e + 02$ $7.026e + 01$ $1.006e + 03$	$1.619e + 03$ $2.911e + 02$ $4.415e + 04$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	$1.841e + 02$ $4.169e + 01$ $1.250e + 03$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	$2.107e + 03$ $2.653e + 02$ $2.421e + 04$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	$1.384e + 03$ $1.147e + 02$ $2.963e + 04$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 10.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$3.027e+01$ $1.154e+01$ $1.596e+02$	$4.592e+03$ $7.747e+02$ $1.012e+05$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$2.809e+01$ $6.465e+00$ $3.917e+02$	$1.349e+02$ $1.377e+01$ $6.291e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$3.030e+01$ $5.472e+00$ $5.579e+02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$4.498e+01$ $5.776e+00$ $9.202e+02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000 \quad C = 1.0000, \gamma = 1.0000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	$9.659e+00$ $5.958e+00$ $5.483e+01$	$7.136e+01$ $1.029e+01$ $1.566e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
1.000e+00	$1.944e+01$ $3.860e+00$ $2.054e+02$	$1.896e+02$ $1.037e+01$ $6.803e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
2.000e+00	$8.974e+00$ $1.688e+00$ $1.806e+02$	$5.351e+01$ $2.782e+00$ $3.019e+03$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$
3.000e+00	$8.595e+00$ $1.217e+00$ $2.800e+02$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$	$nan \quad -nan$ $-nan$

Table of norms for H. $\mu = 0.1000$ $C = 1.0000, \gamma = 1.4000$

$k/\tau = h$	1.000e-01	1.000e-02	1.000e-03	1.000e-04
0.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
1.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
2.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$
3.000e+00	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$	nan $-nan$ $-nan$

3.3. Выводы

Список литературы