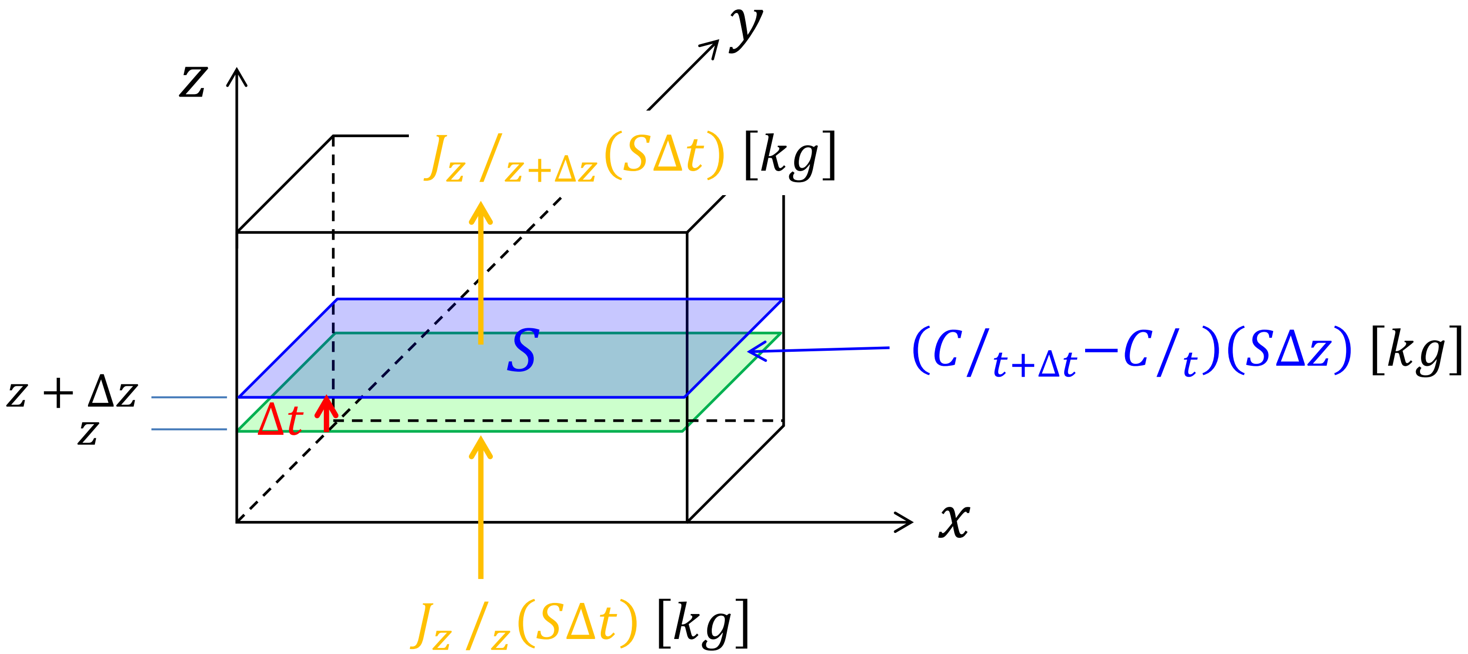


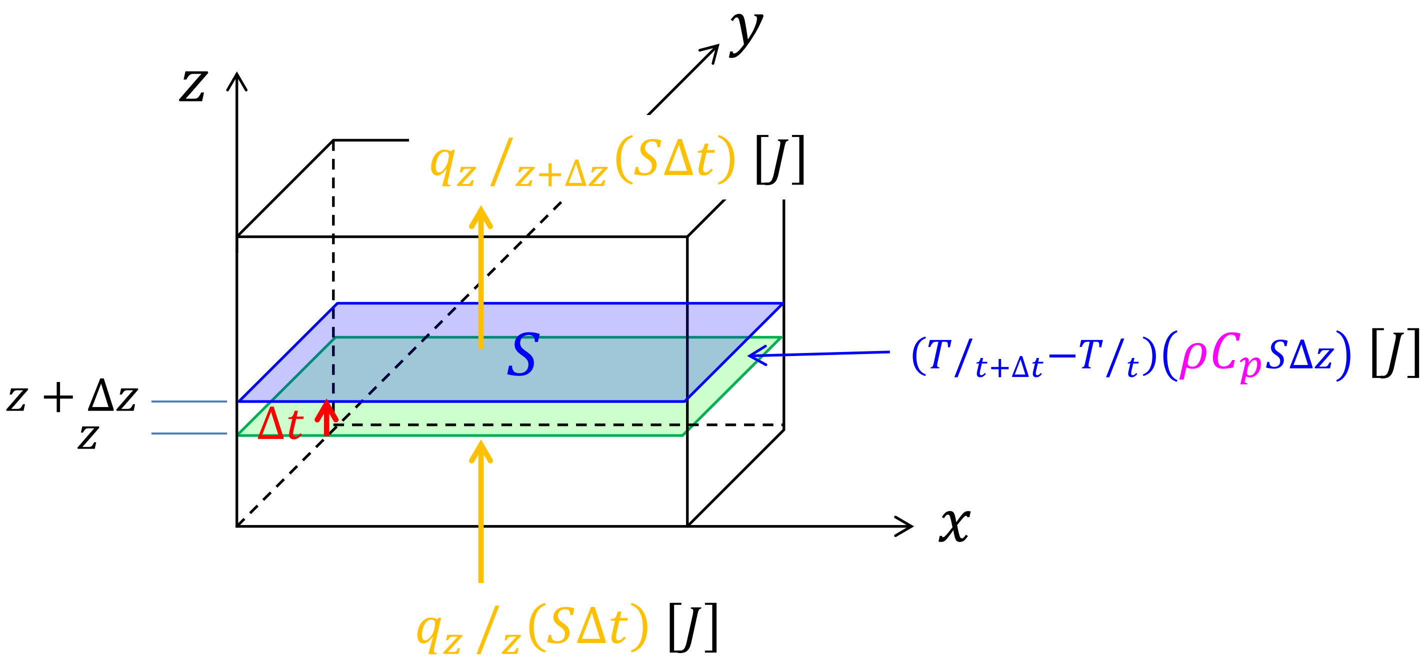
$$J_z/_z(S\Delta t) - (C/_{t+\Delta t}-C/_t)(S\Delta z) - 0 = J_z/_{z+\Delta z}(S\Delta t)$$

インプット　　溜まり　　消失　　アウトプット

$$-\frac{C/_{t+\Delta t}-C/_t}{\Delta t} = \frac{J_z/_{z+\Delta z}-J_z/_z}{\Delta z}$$

$$-\frac{\partial C}{\partial t} = \frac{\partial J_z}{\partial z}$$

$J_z = -D\frac{\partial C}{\partial z}$を代入して　$-\frac{\partial C}{\partial t} = \frac{\partial\left(-D\frac{\partial C}{\partial z}\right)}{\partial z}$　　$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}$



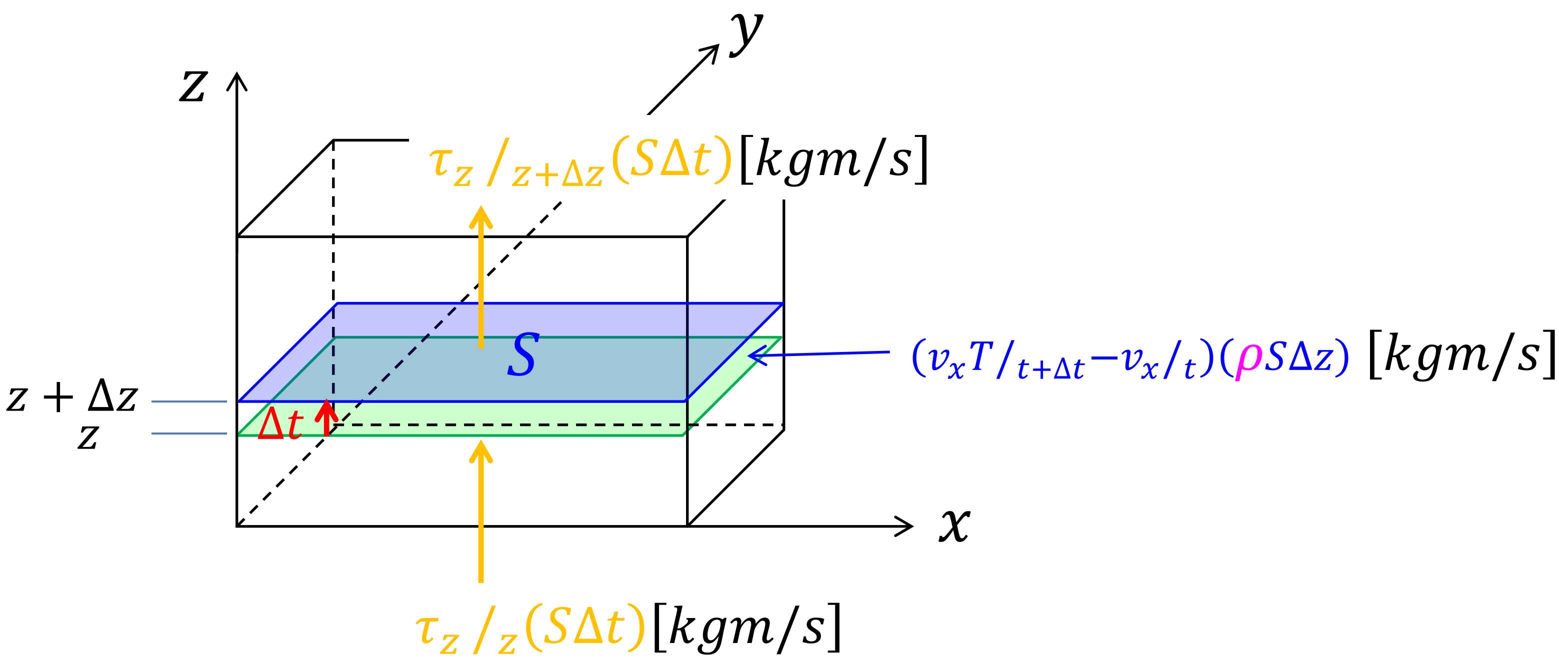
$$q_z/_z(S\Delta t) - (T/_{t+\Delta t}-T/_t)(\rho C_p S\Delta z) - 0 = q_z/_{z+\Delta z}(S\Delta t)$$

インプット　溜まり　消失　アウトプット

$$-\rho C_p \frac{T/_{t+\Delta t}-T/_t}{\Delta t} = \frac{q_z/_{z+\Delta z}-q_z/_z}{\Delta z}$$

$$-\rho C_p \frac{\partial T}{\partial t} = \frac{\partial q_z}{\partial z}$$

$q_z = -k\frac{\partial T}{\partial z}$を代入して　$-\rho C_p \frac{\partial T}{\partial t} = \frac{\partial\left(-k\frac{\partial T}{\partial z}\right)}{\partial z}$　$\frac{\partial T}{\partial t} = \left(\frac{k}{\rho C_p}\right)\frac{\partial^2 T}{\partial z^2}$



$$\tau_z/_z(S\Delta t) - (v_x/_{t+\Delta t} - v_x/_t)(\rho S\Delta z) - 0 = \tau_z/_{z+\Delta z}(S\Delta t)$$

インプット　　溜まり　　消失　　アウトプット

$$-\rho\frac{v_x/_{t+\Delta t} - v_x/_t}{\Delta t} = \frac{\tau_z/_{z+\Delta z} - \tau_z/_z}{\Delta z}$$

$$-\rho\frac{\partial v_x}{\partial t} = \frac{\partial \tau_z}{\partial z}$$

$\tau_z = -\mu\frac{\partial v_x}{\partial z}$を代入して　$-\rho\frac{\partial v_x}{\partial t} = \frac{\partial\left(-\mu\frac{\partial v_x}{\partial z}\right)}{\partial z}$　　$\frac{\partial v_x}{\partial t} = \left(\frac{\mu}{\rho}\right)\frac{\partial^2 v_x}{\partial z^2}$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}$$

$$\frac{\partial T}{\partial t} = \left(\frac{k}{\rho C_p}\right)\frac{\partial^2 T}{\partial z^2} \qquad \alpha = \frac{k}{\rho C_p}$$

$$\frac{\partial v_x}{\partial t} = \left(\frac{\mu}{\rho}\right)\frac{\partial^2 v_x}{\partial z^2} \qquad \nu = \frac{\mu}{\rho}$$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}$$

$$\frac{\partial T}{\partial t} = \alpha\frac{\partial^2 T}{\partial z^2}$$

$$\frac{\partial v_x}{\partial t} = \nu\frac{\partial^2 v_x}{\partial z^2}$$

$[m^2/s]$

$$\frac{\partial \blacksquare}{\partial t} = \nu\frac{\partial^2 \blacksquare}{\partial z^2}$$

放物線型

$\dfrac{\partial f}{\partial t} = 2$を積分すると$f(t) = 2t + C_1$

例えば、$t = 0$のとき$f(0) = 3$であれば ← 境界条件1つ

$C_1 = 3$となり、$f(t) = 2t + 3$

$\dfrac{\partial^2 f}{\partial z^2} = 2$を積分すると$f(z) = z^2 + C_1 z + C_2$

例えば、$z = 0$のとき$f(0) = 2$、

$z = 0$のとき$\dfrac{\partial f}{\partial z} = 4$であれば ← 境界条件2つ

$f(z) = z^2 + 4z + 2$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}$$

$t = 0 \quad C = 0$

$z = 0 \quad C = C_s$

$z = L \quad C = 0$

$z = L \quad J_z = 0$

$\downarrow$

$z = L \quad -D\dfrac{\partial C}{\partial z} = 0$

$\downarrow$

$z = L \quad \dfrac{\partial C}{\partial z} = 0$

$$\frac{\partial T}{\partial t} = \alpha\frac{\partial^2 T}{\partial z^2}$$

$t = 0 \quad T = T_0$

$z = 0 \quad T = T_s$

$z = L \quad T = T_0$

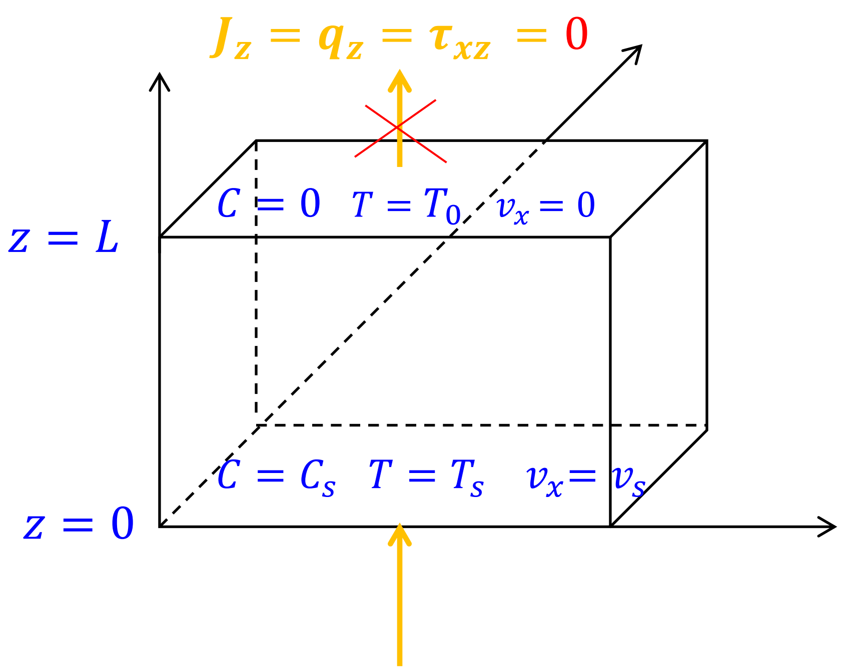
$z = L \quad q_z = 0$

$\downarrow$

$z = L \quad -k\dfrac{\partial T}{\partial z} = 0$

$\downarrow$

$z = L \quad \dfrac{\partial T}{\partial z} = 0$



$$\frac{\partial v_x}{\partial t} = \upsilon\frac{\partial^2 v_x}{\partial z^2}$$

$t = 0 \quad v_x = 0$

$z = 0 \quad v_x = v_s$

$z = L \quad v_x = 0$

$z = L \quad \tau_{xz} = 0$

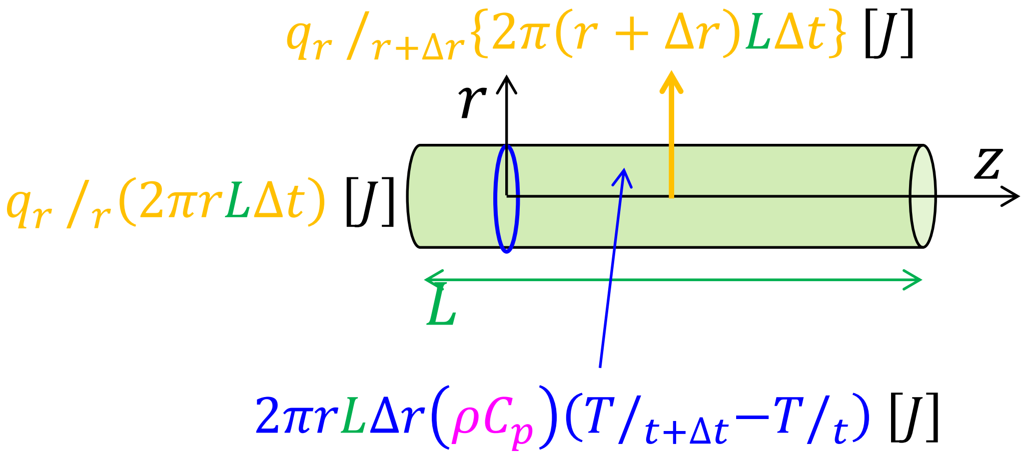
$\downarrow$

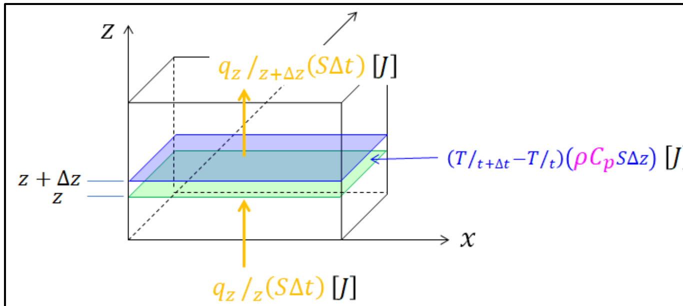
$z = L \quad -\mu\dfrac{\partial v_x}{\partial z} = 0$

$\downarrow$

$z = L \quad \dfrac{\partial v_x}{\partial z} = 0$

円筒状のきゅうりを冷蔵庫で冷やす





$$q_z/_z(S\Delta t) - (T/_{t+\Delta t}-T/_t)(\rho C_p S\Delta z) - 0 = q_z/_{z+\Delta z}(S\Delta t)$$

インプット　溜まり　消失　アウトプット

$$-\rho C_p \frac{T/_{t+\Delta t}-T/_t}{\Delta t} = \frac{q_z/_{z+\Delta z}-q_z/_z}{\Delta z}$$

$$-\rho C_p \frac{\partial T}{\partial t} = \frac{\partial q_z}{\partial z}$$

$q_z = -k\frac{\partial T}{\partial z}$を代入して $-\rho C_p \frac{\partial T}{\partial t} = \frac{\partial\left(-k\frac{\partial T}{\partial z}\right)}{\partial z}$ $\quad \frac{\partial T}{\partial t} = \left(\frac{k}{\rho C_p}\right)\frac{\partial^2 T}{\partial z^2}$

$$q_r/_r(2\pi rL\Delta t) - 2\pi rL\Delta r(\rho C_p)(T/_{t+\Delta t}-T/_t) - 0 = q_r/_{r+\Delta r}\{2\pi(r+\Delta r)L\Delta t\}$$

インプット　溜まり　消失　アウトプット

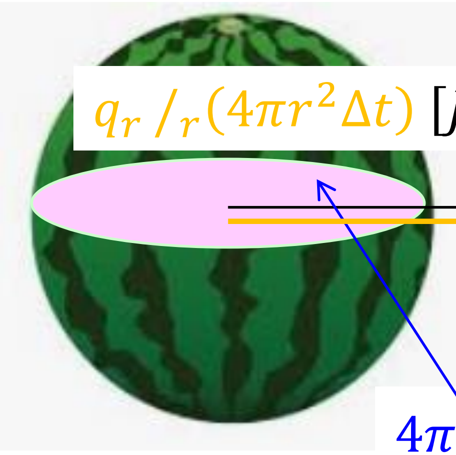
$$-\rho C_p \frac{T/_{t+\Delta t}-T/_t}{\Delta t} = \frac{q_r/_{r+\Delta r}-q_r/_r}{\Delta r} + \frac{1}{r}q_r/_{r+\Delta r}$$

$$-\rho C_p \frac{\partial T}{\partial t} = \frac{\partial q_r}{\partial r} + \frac{1}{r}q_r$$

rの増加に伴う
補正として$\frac{1}{r}$を掛ける

$q_r = -k\frac{\partial T}{\partial r}$を代入して $-\rho C_p \frac{\partial T}{\partial t} = \frac{\partial\left(-k\frac{\partial T}{\partial r}\right)}{\partial r} + \boxed{\frac{1}{r}\left(-k\frac{\partial T}{\partial r}\right)}$ $\quad \frac{\partial T}{\partial t} = \alpha\left(\frac{\partial^2 T}{\partial r^2} + \boxed{\frac{1}{r}\frac{\partial T}{\partial r}}\right)$

球状のスイカを冷蔵庫で冷やす



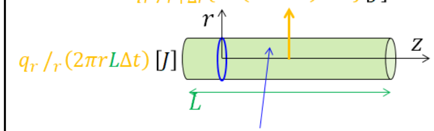
$q_r/_r(4\pi r^2\Delta t)\ [J]$

r

$q_r/_{r+\Delta r}\{4\pi(r+\Delta r)^2\Delta t\}\ [J]$

$4\pi r^2\Delta r(\rho C_p)(T/_{t+\Delta t}-T/_t)\ [J]$

円筒状のきゅうりを冷蔵庫で冷やす



$$q_r/_r(2\pi rL\Delta t)-2\pi rL\Delta r(\rho C_p)(T/_{t+\Delta t}-T/_t)-0=q_r/_{r+\Delta r}\{2\pi(r+\Delta r)L\Delta t\}$$

インプット　溜まり　消失　アウトプット

$$-\rho C_p\frac{T/_{t+\Delta t}-T/_t}{\Delta t}=\frac{q_r/_{r+\Delta r}-q_r/_r}{\Delta r}+\frac{1}{r}q_r/_{r+\Delta r}$$

$$-\rho C_p\frac{\partial T}{\partial t}=\frac{\partial q_r}{\partial r}+\frac{1}{r}q_r$$

$q_r=-k\frac{\partial T}{\partial r}$を代入して $-\rho C_p\frac{\partial T}{\partial t}=\frac{\partial\left(-k\frac{\partial T}{\partial r}\right)}{\partial r}+\boxed{\frac{1}{r}\left(-k\frac{\partial T}{\partial r}\right)}$ $\frac{\partial T}{\partial t}=\alpha\left(\frac{\partial^2 T}{\partial r^2}+\boxed{\frac{1}{r}\frac{\partial T}{\partial r}}\right)$

$$q_r/_r(4\pi r^2\Delta t)-4\pi r^2\Delta r(\rho C_p)(T/_{t+\Delta t}-T/_t)-0=q_r/_{r+\Delta r}\{4\pi(r+\Delta r)^2\Delta t\}$$

インプット　溜まり　消失　アウトプット

$$-\rho C_p\frac{T/_{t+\Delta t}-T/_t}{\Delta t}=\frac{q_r/_{r+\Delta r}-q_r/_r}{\Delta r}+\left(\frac{2}{r}+\boxed{\frac{\Delta r}{r^2}}\right)q_r/_{r+\Delta r}$$

0

$$-\rho C_p\frac{\partial T}{\partial t}=\frac{\partial q_r}{\partial r}+\frac{2}{r}q_r$$

円筒よりさらに拡がり大

$q_r=-k\frac{\partial T}{\partial r}$を代入して $-\rho C_p\frac{\partial T}{\partial t}=\frac{\partial\left(-k\frac{\partial T}{\partial r}\right)}{\partial r}+\frac{\boxed{2}}{r}\left(-k\frac{\partial T}{\partial r}\right)$ $\frac{\partial T}{\partial t}=\alpha\left(\frac{\partial^2 T}{\partial r^2}+\frac{\boxed{2}}{r}\frac{\partial T}{\partial r}\right)$