

MECA482 CSU Chico - Furuta Pendulum Model - Aaron Taylor Angel Sanchez Ingrid Tisell Michele Fragasso Joe Karam

This is the model from Wikipedia. The corresponding publication is "Cazzolato, B.S and Prime, Z (2011) "On the Dynamics of the Furuta Pendulum", Journal of Control Science and Engineering, Volume 2011 (2011), Article ID 528341, 8 pages." However the first model has been used to implement the feedback controller.

This model has been developed initially to be run in Simulink. However the model has been later simulated in CoppeliaSim.

```
> with(plots):
  with(CodeGeneration):
  with(VectorCalculus):
  with(LinearAlgebra):
> merge := proc(x,y)
  [op(x), op(y)]
end proc;

merge := proc(x,y) [op(x), op(y)] end proc (1.1)
```

```
> linearize := proc(eqs, lin_point)
local var, vardot, f, var_sub_eqs, var_sub, lin_point_sub, f_sub,
J, deltax, f_subx0, f_lin_sub, var_sub_eqs_inv, f_lin,
eqs_space_state;

var := [seq(lhs(lin_point[i]), i=1..numelems(lin_point))];
vardot := diff(var, t);
f := map(rhs, map(op, solve(eqs, vardot)));
var_sub_eqs := [seq(var[i]=cat(x, __, i), i = 1..numelems
(var))];
var_sub := [seq(rhs(var_sub_eqs[i]), i=1..numelems
(var_sub_eqs))];
lin_point_sub := subs(var_sub_eqs, lin_point);
f_sub := subs(var_sub_eqs, f);
J := Matrix(evalf(subs(lin_point_sub, Jacobian(f_sub,
var_sub))));
deltax := Transpose(Matrix([seq(var_sub[i] - rhs
(lin_point_sub[i]), i=1..numelems(var_sub))]);
f_subx0 := Transpose(Matrix(evalf(subs(lin_point_sub,
(f_sub))));
f_lin_sub := simplify(f_subx0 + J.deltax);
var_sub_eqs_inv := [seq(rhs(var_sub_eqs[i]) = lhs
(var_sub_eqs[i]), i = 1..numelems(var_sub))];
f_lin := subs(var_sub_eqs_inv, f_lin_sub);
eqs_space_state := [seq(vardot[i] = f_lin[i,1], i=1..
numelems(var))];

end proc;
```

```
linearize := proc(eqs, lin_point) (1.2)
local var, vardot, f, var_sub_eqs, var_sub, lin_point_sub, f_sub, J, deltax, f_subx0,
f_lin_sub, var_sub_eqs_inv, f_lin, eqs_space_state;
var := [seq(lhs(lin_point[i]), i = 1..numelems(lin_point))];
vardot := VectorCalculus:-diff(var, t);
```

```

f := map(rhs, map(op, solve(eqs, vardot)));
var_sub_eqs := [seq(var[i] = cat(x, __, i), i = 1 .. numelems(var))];
var_sub := [seq(rhs(var_sub_eqs[i]), i = 1 .. numelems(var_sub_eqs))];
lin_point_sub := subs(var_sub_eqs, lin_point);
f_sub := subs(var_sub_eqs, f);
J := Matrix(evalf(subs(lin_point_sub, VectorCalculus:-Jacobian(f_sub, var_sub))));
deltax := LinearAlgebra:-Transpose(Matrix([seq(VectorCalculus:-`+`(var_sub[i],
VectorCalculus:-`-`(rhs(lin_point_sub[i]))), i = 1 .. numelems(var_sub))]);
f_subx0 := LinearAlgebra:-Transpose(Matrix(evalf(subs(lin_point_sub, f_sub))));
f_lin_sub := simplify(VectorCalculus:-`+`(f_subx0, VectorCalculus:-`.`(J, deltax)));
var_sub_eqs_inv := [seq(rhs(var_sub_eqs[i]) = lhs(var_sub_eqs[i]), i = 1
.. numelems(var_sub))];
f_lin := subs(var_sub_eqs_inv, f_lin_sub);
eqs_space_state := [seq(vardot[i] = f_lin[i, 1], i = 1 .. numelems(var))]
end proc

```

Equations of Motion with and without parameters

```

> eq1 := diff(theta1(t), t, t)*(J_1zz+m_1*(l_1)^2+(m_2)*(
(L_1)^2+(J_2yy+m_2*(l_2)^2)*sin(theta2(t))^2+J_2xx*cos
(theta2(t))^2)+diff(theta2(t), t, t)*m_2*L_1*l_2*cos
(theta2(t))-m_2*L_1*l_2*sin(theta2(t))*diff(theta2(t), t)
^2+diff(theta1(t), t)*diff(theta2(t), t)*sin(2*theta2(t))*
(m_2*l_2^2+J_2yy-J_2xx) + b_1*diff(theta1(t), t) =
eta_g*k_g*eta_m*k_m*t*((V_m - k_g*k_m*diff(theta1(t), t)
)/r_m)

```

$$\begin{aligned}
 eq1 := & \left(\frac{d^2}{dt^2} \theta_1(t) \right) \left(m_2 L_1^2 + m_1 l_1^2 + J_{1zz} + (m_2 l_2^2 + J_{2yy}) \sin^2(\theta_2(t)) \right. \\
 & + J_{2xx} \cos^2(\theta_2(t)) + \left(\frac{d^2}{dt^2} \theta_2(t) \right) m_2 L_1 l_2 \cos(\theta_2(t)) \\
 & - m_2 L_1 l_2 \sin(\theta_2(t)) \left(\frac{d}{dt} \theta_2(t) \right)^2 + \left(\frac{d}{dt} \theta_1(t) \right) \left(\frac{d}{dt} \right. \\
 & \left. \theta_2(t) \right) \sin(2 \theta_2(t)) (m_2 l_2^2 - J_{2xx} + J_{2yy}) + b_1 \left(\frac{d}{dt} \theta_1(t) \right) \\
 & = \frac{\eta_g k_g \eta_m k_t \left(V_m - k_g k_m \left(\frac{d}{dt} \theta_1(t) \right) \right)}{r_m}
 \end{aligned} \tag{1.1.1}$$

```

> eq2 := diff(theta1(t), t, t)*m_2*L_1*l_2*cos(theta2(t))+
diff(theta2(t), t, t)*(m_2*l_2^2+J_2zz)+1/2*diff(theta1
(t), t)^2*sin(2*theta2(t))*(-m_2*l_2^2-J_2yy+J_2xx)+b_2*
diff(theta2(t), t)+g*m_2*l_2*sin(theta2(t)) = tau_2

```

$$eq2 := \left(\frac{d^2}{dt^2} \theta_1(t) \right) m_2 L_1 l_2 \cos(\theta_2(t)) + \left(\frac{d^2}{dt^2} \theta_2(t) \right) (m_2 l_2^2 + J_{2zz}) \tag{1.1.2}$$

$$+ \frac{\left(\frac{d}{dt} \theta(t)\right)^2 \sin(2 \theta(t)) (-m_2 l_2^2 + J_{2xx} - J_{2yy})}{2} + b_2 \left(\frac{d}{dt} \theta(t)\right) + g m_2 l_2 \sin(\theta(t)) = \tau_2$$

> data_mechanical := [J_1zz = 0.0023, m_1 = 0, l_1 = 0.215, m_2 = 0.2, L_1 = 0.215, J_2yy = 0.0023, l_2 = 0.1675, J_2xx = 0, J_2zz = 0.0023, b_1 = 0, Vm = 0, g=9.81, tau_2 = 0, b_2 = 0]

data_mechanical := [J_{1zz}=0.0023, m₁=0, l₁=0.215, m₂=0.2, L₁=0.215, J_{2yy}=0.0023, (1.1.3)

l₂=0.1675, J_{2xx}=0, J_{2zz}=0.0023, b₁=0, Vm=0, g=9.81, τ₂=0, b₂=0]

> data_electrical := [eta_g = 0.85, eta_m = 0.87, k_g = 70, k_m = 0.0076, k_t=0.0076, r_m=2.6, V_m = 10];

data_electrical := [η_g=0.85, η_m=0.87, k_g=70, k_m=0.0076, k_t=0.0076, r_m=2.6, V_m (1.1.4)

= 10]

> data := merge(data_mechanical, data_electrical);

data := [J_{1zz}=0.0023, m₁=0, l₁=0.215, m₂=0.2, L₁=0.215, J_{2yy}=0.0023, l₂=0.1675, (1.1.5)

J_{2xx}=0, J_{2zz}=0.0023, b₁=0, Vm=0, g=9.81, τ₂=0, b₂=0, η_g=0.85, η_m=0.87, k_g

= 70, k_m=0.0076, k_t=0.0076, r_m=2.6, V_m=10]

> eqs := [eq1, eq2];

$$eqs := \left[\left(\frac{d^2}{dt^2} \theta(t) \right) \left(m_2 L_1^2 + m_1 l_1^2 + J_{1zz} + (m_2 l_2^2 + J_{2yy}) \sin(\theta(t))^2 \right. \right. \quad (1.1.6)$$

$$\left. + J_{2xx} \cos(\theta(t))^2 \right) + \left(\frac{d^2}{dt^2} \theta(t) \right) m_2 L_1 l_2 \cos(\theta(t))$$

$$- m_2 L_1 l_2 \sin(\theta(t)) \left(\frac{d}{dt} \theta(t) \right)^2 + \left(\frac{d}{dt} \theta(t) \right) \left(\frac{d}{dt} \theta(t) \right) \sin(2 \theta(t)) (m_2 l_2^2 - J_{2xx} + J_{2yy}) + b_1 \left(\frac{d}{dt} \theta(t) \right)$$

$$= \frac{\eta_g k_g \eta_m k_t \left(V_m - k_g k_m \left(\frac{d}{dt} \theta(t) \right) \right)}{r_m}, \left(\frac{d^2}{dt^2} \theta(t) \right) m_2 L_1 l_2 \cos(\theta(t))$$

$$+ \left(\frac{d^2}{dt^2} \theta(t) \right) (m_2 l_2^2 + J_{2zz})$$

$$\left[\begin{aligned} & + \frac{\left(\frac{d}{dt} \theta_1(t) \right)^2 \sin(2 \theta_2(t)) (-m_2 l_2^2 + J_{2xx} - J_{2yy})}{2} + b_2 \left(\frac{d}{dt} \theta_2(t) \right) \\ & + g m_2 l_2 \sin(\theta_2(t)) = \tau_2 \end{aligned} \right]$$

► Simulation

► Reducing to first order system of ODEs and Exporting model to Matlab(to simulate it in Simulink)

▼ Reducing to state space model and exporting to Matlab

```
> eqs_first_order;
[ ( d/dt theta1dot(t) ) ( m2 L1^2 + m1 l1^2 + J1zz + ( m2 l2^2 + J2yy ) sin( theta2(t) )^2
+ J2xx cos( theta2(t) )^2 ) + ( d/dt theta2dot(t) ) m2 L1 l2 cos( theta2(t) )
- m2 L1 l2 sin( theta2(t) ) theta2dot(t)^2
+ theta1dot(t) theta2dot(t) sin( 2 theta2(t) ) ( m2 l2^2 - J2xx + J2yy ) + b1 theta1dot(t)
= ( ng kg nm kt ( Vm - kg km theta1dot(t) ) / rm , ( d/dt theta1dot(t) ) m2 L1 l2 cos( theta2(t) )
+ ( d/dt theta2dot(t) ) ( m2 l2^2 + J2zz )
+ ( theta1dot(t)^2 sin( 2 theta2(t) ) ( -m2 l2^2 + J2xx - J2yy ) ) / 2 + b2 theta2dot(t)
+ g m2 l2 sin( theta2(t) ) = tau2, d/dt theta1(t) = theta1dot(t), d/dt theta2(t) = theta2dot(t) ]
> lin_point := [theta1(t) = 2.99, theta2(t) = Pi, theta1dot(t) = 0, theta2dot(t) = 0];
lin_point := [ theta1(t) = 2.99, theta2(t) = pi, theta1dot(t) = 0, theta2dot(t) = 0 ] (1.4.2)
> eqs_space_state := linearize(eqs_first_order, lin_point);
> dof := [theta1(t), theta2(t), theta1dot(t), theta2dot(t)];
dof := [ theta1(t), theta2(t), theta1dot(t), theta2dot(t) ] (1.4.3)
> eqs_space_state2 := op(solve(eqs_space_state, var)):
A, RES := GenerateMatrix(map(rhs, eqs_space_state2), dof):
```

```
> B, RES := GenerateMatrix([seq(RES[i], i=1..4)], [V__m]):
```

Space State Matrixes

```
> A := Matrix(A):
A_data := subs(data, A);
```

$$A_{data} := \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 59.98558162 & -16.13923708 & -0. \\ 0 & 96.15182815 & -14.69336136 & -0. \end{bmatrix} \quad (1.4.1.1)$$

```
> B := Matrix(B):
B_data := subs(data, B);
```

$$B_{data} := \begin{bmatrix} 0 \\ 0 \\ -30.33691204 \\ -27.61910058 \end{bmatrix} \quad (1.4.1.2)$$

```
> C = Matrix([[1, 0, 0, 0], [0, 1, 0, 0], [0, 0, 1, 0], [0, 0, 0, 1]]);
```

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1.4.1.3)$$

```
> Eigenvalues(A_data);
```

$$\begin{bmatrix} 0. I \\ -19.3199169910745 + 0. I \\ 7.69202312225786 + 0. I \\ -4.51134321118345 + 0. I \end{bmatrix} \quad (1.4.1.4)$$

Exporting to Matlab

Matrixes

```
> Matlab(A, resultname="A");
Matlab(A_data, resultname="dtheta1_dt");
A = [0 0 1 0; 0 0 0 1; 0 -0.3531740136e10 *
(0.8204135230e19 * V__m * eta__g * eta__m * k__g * k__t
* l__2 ^ 4 * m__2 ^ 3 * L__1 ^ 2 - 0.8204135230e19 *
V__m * eta__g * eta__m * k__g * k__t * l__2 ^ 4 * m__2
^ 2 * J__2xx + 0.8204135230e19 * V__m * eta__g * eta__m
* k__g * k__t * l__2 ^ 4 * m__2 ^ 2 * J__2yy +
0.1640827046e20 * V__m * eta__g * eta__m * k__g * k__t
* l__2 ^ 4 * m__2 ^ 2 * J__2zz + 0.8204135230e19 *
J__2zz ^ 2 * V__m * eta__g * eta__m * k__g * k__t *
l__2 ^ 2 * m__2 - 0.1000000000e29 * L__1 * l__2 ^ 2 *
m__2 ^ 2 * r__m * g * J__2zz * l__1 ^ 2 * m__1 +
0.4102067616e19 * L__1 * l__2 * m__2 * r__m * tau__2 *
J__2zz * l__1 ^ 2 * m__1 - 0.1640827046e20 * v__m *

```

$$\begin{aligned}
& \text{eta_g} * \text{eta_m} * \text{k_g} * \text{k_t} * \text{l_2}^2 * \text{m_2} * \\
& \text{J_2xx} * \text{J_2zz} + 0.1640827046\text{e}20 * \text{V_m} * \text{eta_g} * \\
& \text{eta_m} * \text{k_g} * \text{k_t} * \text{l_2}^2 * \text{m_2} * \text{J_2yy} * \\
& \text{J_2zz} + 0.8204135230\text{e}19 * \text{J_2zz} * \text{V_m} * \text{eta_g} * \\
& \text{eta_m} * \text{k_g} * \text{k_t} * \text{l_1}^2 * \text{l_2}^2 * \text{m_2}^2 - \\
& 0.1000000000\text{e}29 * \text{L_1} * \text{l_2}^4 * \text{m_2}^3 * \text{r_m} * \text{g} \\
& * \text{l_1}^2 * \text{m_2} - 0.1000000000\text{e}29 * \text{L_1} * \text{l_2}^2 * \\
& \text{m_2}^2 * \text{r_m} * \text{g} * \text{J_1zz} * \text{J_2zz} + 0.4102067616\text{e}19 \\
& * \text{L_1} * \text{l_2}^3 * \text{m_2}^2 * \text{r_m} * \text{tau_2} * \text{l_1}^2 * \\
& \text{m_2} + 0.4102067616\text{e}19 * \text{L_1} * \text{l_2} * \text{m_2}^2 * \text{r_m} * \\
& \text{tau_2} * \text{J_1zz} * \text{J_2zz} - 0.1000000000\text{e}29 * \text{L_1} * \text{g} * \\
& \text{l_2}^2 * \text{m_2}^2 * \text{r_m} * \text{J_2xx} * \text{J_2zz} + \\
& 0.1682695872\text{e}10 * \text{L_1} * \text{g} * \text{l_2}^2 * \text{m_2}^2 * \text{r_m} \\
& * \text{J_2yy} * \text{J_2zz} - 0.4102067614\text{e}19 * \text{L_1} * \text{l_2} * \\
& \text{m_2} * \text{r_m} * \text{tau_2} * \text{J_2xx} * \text{J_2zz} + \\
& 0.8204135230\text{e}19 * \text{L_1} * \text{l_2} * \text{m_2} * \text{r_m} * \text{tau_2} * \\
& \text{J_2yy} * \text{J_2zz} + 0.8204135230\text{e}19 * \text{V_m} * \text{eta_g} * \\
& \text{eta_m} * \text{k_g} * \text{k_t} * \text{l_2}^6 * \text{m_2}^3 - \\
& 0.8204135230\text{e}19 * \text{J_2zz}^2 * \text{V_m} * \text{eta_g} * \text{eta_m} * \\
& \text{k_g} * \text{k_t} * \text{J_2xx} + 0.8204135230\text{e}19 * \text{J_2zz}^2 * \\
& \text{V_m} * \text{eta_g} * \text{eta_m} * \text{k_g} * \text{k_t} * \text{J_2yy} - \\
& 0.1000000000\text{e}29 * \text{L_1} * \text{g} * \text{l_2}^4 * \text{m_2}^3 * \text{r_m} \\
& * \text{J_2xx} + 0.1682695872\text{e}10 * \text{L_1} * \text{g} * \text{l_2}^4 * \text{m_2}^2 \\
& ^3 * \text{r_m} * \text{J_2yy} + 0.1682695872\text{e}10 * \text{L_1} * \text{g} * \text{l_2}^2 \\
& ^4 * \text{m_2}^3 * \text{r_m} * \text{J_2zz} - 0.4102067614\text{e}19 * \text{L_1} \\
& * \text{l_2}^3 * \text{m_2}^2 * \text{r_m} * \text{tau_2} * \text{J_2xx} + \\
& 0.8204135230\text{e}19 * \text{L_1} * \text{l_2}^3 * \text{m_2}^2 * \text{r_m} * \\
& \text{tau_2} * \text{J_2yy} + 0.8204135230\text{e}19 * \text{L_1} * \text{l_2}^3 * \\
& \text{m_2}^2 * \text{r_m} * \text{tau_2} * \text{J_2zz} - 0.1000000000\text{e}29 * \\
& \text{L_1} * \text{l_2}^4 * \text{m_2}^3 * \text{r_m} * \text{g} * \text{J_1zz} - \\
& 0.1000000000\text{e}29 * \text{L_1}^3 * \text{l_2}^2 * \text{m_2}^3 * \text{r_m} \\
& * \text{g} * \text{J_2zz} + 0.4102067616\text{e}19 * \text{L_1} * \text{l_2}^3 * \text{m_2}^2 \\
& ^2 * \text{r_m} * \text{tau_2} * \text{J_1zz} + 0.4102067616\text{e}19 * \text{L_1}^3 \\
& * \text{l_2}^2 * \text{m_2}^2 * \text{r_m} * \text{tau_2} * \text{J_2zz} + \\
& 0.3365391745\text{e}10 * \text{L_1}^3 * \text{g} * \text{l_2}^4 * \text{m_2}^4 * \\
& \text{r_m} + 0.1682695872\text{e}10 * \text{L_1} * \text{g} * \text{l_2}^6 * \text{m_2}^4 \\
& * \text{r_m} + 0.8204135230\text{e}19 * \text{L_1}^3 * \text{l_2}^3 * \text{m_2}^2 \\
& ^3 * \text{r_m} * \text{tau_2} + 0.8204135230\text{e}19 * \text{L_1} * \text{l_2}^5 * \\
& \text{m_2}^3 * \text{r_m} * \text{tau_2}) / \text{r_m} / (0.3531740136\text{e}38 * \\
& \text{l_1}^4 * \text{l_2}^4 * \text{m_2}^1 * \text{m_2}^2 + \\
& 0.1188568910\text{e}20 * \text{l_1}^2 * \text{l_2}^6 * \text{m_2}^1 * \text{m_2}^3 \\
& + 0.1188568910\text{e}20 * \text{J_2zz} * \text{L_1}^2 * \text{l_2}^4 * \text{m_2}^2 \\
& ^3 + 0.7063480271\text{e}38 * \text{J_1zz} * \text{J_2xx} * \text{l_2}^4 * \\
& \text{m_2}^2 + 0.1188568910\text{e}20 * \text{J_1zz} * \text{J_2yy} * \text{l_2}^4 \\
& * \text{m_2}^2 + 0.2377137820\text{e}20 * \text{J_1zz} * \text{J_2zz} * \text{l_2}^4 \\
& * \text{m_2}^2 + 0.1188568910\text{e}20 * \text{J_2xx} * \text{J_2yy} * \text{l_2}^4 \\
& ^4 * \text{m_2}^2 + 0.2377137820\text{e}20 * \text{J_2xx} * \text{J_2zz} * \\
& \text{l_2}^4 * \text{m_2}^2 + 0.4\text{e}1 * \text{J_2yy} * \text{J_2zz} * \text{l_2}^4 \\
& * \text{m_2}^2 + 0.1188568910\text{e}20 * \text{J_2zz}^2 * \text{L_1}^2 \\
& * \text{l_2}^2 * \text{m_2}^2 + 0.7063480271\text{e}38 * \text{J_1zz}^2 * \\
& \text{J_2zz} * \text{l_2}^2 * \text{m_2}^2 + 0.7063480271\text{e}38 * \text{J_1zz} * \\
& \text{J_2zz}^2 * \text{L_1}^2 * \text{m_2}^2 + 0.7063480271\text{e}38 * \text{J_1zz} \\
& * \text{J_2zz}^2 * \text{L_1}^2 * \text{m_2}^2 + 0.1188568910\text{e}20 * \\
& \text{J_1zz} * \text{J_2zz}^2 * \text{l_2}^2 * \text{m_2}^2 + 0.7063480271\text{e}38 \\
& * \text{J_2xx}^2 * \text{J_2zz} * \text{l_2}^2 * \text{m_2}^2 + \\
& 0.7063480271\text{e}38 * \text{J_2xx} * \text{J_2zz}^2 * \text{L_1}^2 * \text{m_2}^2 \\
& + 0.7063480271\text{e}38 * \text{J_2xx} * \text{J_2zz}^2 * \text{l_1}^2 * \text{m_2}^2
\end{aligned}$$

$$\begin{aligned}
& m_1 + 0.1188568910e20 * J_{2xx} * J_{2zz}^2 * l_2^2 \\
& * m_2 + 0.2e1 * J_{2yy}^2 * J_{2zz} * l_2^2 * m_2 \\
& + 0.1188568910e20 * J_{2yy} * J_{2zz}^2 * L_1^2 * \\
& m_2 + 0.1188568910e20 * J_{2yy} * J_{2zz}^2 * l_1^2 \\
& * m_1 + 0.2e1 * J_{2yy} * J_{2zz}^2 * l_2^2 * m_2 \\
& + 0.1188568910e20 * J_{1zz} * l_2^6 * m_2^3 + \\
& 0.1188568910e20 * J_{2xx} * l_2^6 * m_2^3 + 0.2e1 \\
& * J_{2yy} * l_2^6 * m_2^3 + 0.2e1 * J_{2zz} * l_2^2 \\
& ^6 * m_2^3 + 0.3531740136e38 * J_{1zz}^2 * l_2^4 \\
& * m_2^2 + 0.3531740136e38 * J_{2xx}^2 * l_2^4 \\
& * m_2^2 + J_{2yy}^2 * l_2^4 * m_2^2 + \\
& 0.3531740136e38 * J_{2zz}^2 * L_1^4 * m_2^2 + \\
& 0.3531740136e38 * J_{2zz}^2 * l_1^4 * m_1^2 + \\
& J_{2zz}^2 * l_2^4 * m_2^2 + 0.7063480271e38 * \\
& J_{1zz} * J_{2xx} * J_{2zz}^2 + 0.1188568910e20 * J_{1zz} \\
& * J_{2yy} * J_{2zz}^2 + 0.7063480271e38 * J_{2zz} * L_1^2 \\
& * l_1^2 * m_2^2 + 0.1412696054e39 * J_{1zz} * J_{2zz} * l_1^2 * l_2^2 \\
& * m_1 * m_2 + 0.1412696054e39 * J_{2xx} * J_{2zz} * \\
& l_1^2 * l_2^2 * m_1 * m_2 + 0.2377137820e20 * \\
& J_{2yy} * J_{2zz} * l_1^2 * l_2^2 * m_1 * m_2 + \\
& 0.7063480271e38 * J_{1zz} * l_1^2 * l_2^4 * m_1 * \\
& m_2^2 + 0.7063480271e38 * J_{2xx} * l_1^2 * l_2^4 * \\
& m_1 * m_2^2 + 0.1188568910e20 * J_{2yy} * l_1^2 * \\
& l_2^4 * m_1 * m_2^2 + 0.7063480271e38 * \\
& J_{2zz} * l_1^4 * l_2^2 * m_1^2 * m_2^2 + \\
& 0.2377137820e20 * J_{2zz} * l_1^2 * l_2^4 * m_1 * \\
& m_2^2 + 0.7063480271e38 * J_{1zz} * J_{2zz} * L_1^2 \\
& * l_2^2 * m_2^2 + 0.7063480271e38 * J_{2xx} * \\
& J_{2zz} * L_1^2 * l_2^2 * m_2^2 + \\
& 0.1188568910e20 * J_{2yy} * J_{2zz} * L_1^2 * l_2^2 * \\
& m_2^2 + 0.7063480271e38 * J_{2zz}^2 * L_1^2 * \\
& l_1^2 * m_1 * m_2 + 0.1188568910e20 * J_{2zz}^2 * \\
& l_1^2 * l_2^2 * m_1 * m_2 + 0.1412696054e39 * \\
& J_{1zz} * J_{2xx} * J_{2zz} * l_2^2 * m_2^2 + \\
& 0.2377137820e20 * J_{1zz} * J_{2yy} * J_{2zz} * l_2^2 * \\
& m_2^2 + 0.2377137820e20 * J_{2xx} * J_{2yy} * J_{2zz} * \\
& l_2^2 * m_2^2 + l_2^8 * m_2^4 + 0.3531740136e38 \\
& * J_{1zz}^2 * J_{2zz}^2 + 0.3531740136e38 * J_{2xx}^2 \\
& * J_{2zz}^2 + J_{2yy}^2 * J_{2zz}^2) \\
& -0.3531740136e10 * (0.1682695873e10 * J_{2zz}^2 * r_m \\
& * J_{2yy} * b_1 + 0.1000000000e29 * J_{2zz}^2 * r_m * \\
& J_{1zz} * b_1 + 0.1000000000e29 * J_{2zz}^2 * r_m * \\
& J_{2xx} * b_1 + 0.1682695873e10 * m_2^3 * l_2^6 * \\
& b_1 * r_m + 0.1000000000e29 * m_2 * J_{2zz}^2 * L_1 \\
& ^2 * eta_g * eta_m * k_g^2 * k_m * k_t + \\
& 0.1000000000e29 * J_{2zz}^2 * eta_m * eta_g * k_t * \\
& k_g^2 * k_m * l_1^2 * m_1 + 0.3365391746e10 * \\
& m_2^2 * l_2^4 * J_{2zz} * eta_m * eta_g * k_g^2 * \\
& k_m * k_t + 0.1000000000e29 * m_2^2 * l_2^4 \\
& * eta_m * eta_g * k_t^2 * k_g^2 * J_{2xx} * k_m + \\
& 0.1682695873e10 * m_2^2 * l_2^4 * eta_m * eta_g \\
& * k_t^2 * k_g^2 * J_{2yy} * k_m + 0.1000000000e29 * \\
& m_2^2 * l_2^4 * eta_m * eta_g * k_t * k_g^2 \\
& * J_{1zz} * k_m + 0.1682695873e10 * m_2^2 * l_2^2 * \\
& J_{2zz}^2 * eta_m * eta_g * k_g^2 * k_m * k_t +
\end{aligned}$$

$0.1682695873e10 * m_2^3 * l_2^6 * \eta_m * \eta_g$
 $* k_g^2 * k_m * k_t + 0.2000000000e29 * m_2^2 * l_2^2 * J_{2zz} * r_m * b_1 * l_1^2 * m_1 +$
 $0.3365391746e10 * m_2^2 * l_2^4 * J_{2zz} * b_1 * r_m + 0.1682695873e10 * m_2^2 * l_2^4 * r_m * J_{2yy} * b_1 +$
 $0.1000000000e29 * m_2^2 * l_2^4 * r_m * J_{1zz} * b_1 + 0.1000000000e29 * m_2^2 * l_2^4 * r_m * J_{2xx} * b_1 +$
 $0.1000000000e29 * m_2^2 * J_{2zz}^2 * l_1^2 * b_1 * r_m + 0.1682695873e10 * m_2^2 * l_2^2 * J_{2zz}^2 * b_1 * r_m +$
 $0.1000000000e29 * J_{2zz}^2 * r_m * b_1 * l_1^2 * m_1 + 0.2000000000e29 * m_2 * l_2^2 * J_{2zz} * r_m * J_{2xx} * b_1 +$
 $0.3365391746e10 * m_2 * l_2^2 * J_{2zz} * r_m * J_{2yy} * b_1 + 0.2000000000e29 * m_2 * l_2^2 * J_{2zz} * r_m * J_{1zz} * b_1 +$
 $0.1000000000e29 * m_2 * l_2^2 * J_{2zz} * r_m * b_1 * l_1^2 * m_1 + 0.1000000000e29 * m_2^2 * l_2^4 * r_m * b_1 * l_1^2 * m_1 +$
 $0.1000000000e29 * m_2^2 * l_2^4 * \eta_m * \eta_g * k_t * k_g^2 * k_m * l_1^2 * m_1 + 0.3365391746e10 * m_2 * l_2^2 * J_{2zz} * \eta_m * \eta_g * k_t * k_g^2 * k_m +$
 $0.2000000000e29 * m_2 * l_2^2 * J_{2zz} * \eta_m * \eta_g * k_t * k_g^2 * k_m + 0.2000000000e29 * m_2 * l_2^2 * J_{2zz} * \eta_m * \eta_g * k_t * k_g^2 * k_m +$
 $0.1000000000e29 * m_2^2 * J_{2zz} * l_2^2 * \eta_m * \eta_g * L_1^2 * k_g^2 * k_m * k_t + 0.2000000000e29 * m_2 * l_2^2 * J_{2zz} * \eta_m * \eta_g * k_t * k_g^2 * k_m * l_1^2 * m_1 +$
 $0.1000000000e29 * J_{2zz}^2 * \eta_m * \eta_g * k_t * k_g^2 * k_m * l_1^2 * m_1 + 0.1682695873e10 * J_{2zz}^2 * \eta_m * \eta_g * k_t * k_g^2 * k_m +$
 $0.1000000000e29 * J_{2zz}^2 * \eta_m * \eta_g * k_t * k_g^2 * k_m + 0.1000000000e29 * J_{2zz}^2 * \eta_m * \eta_g * k_t * k_g^2 * k_m +$
 $k_g^2 * J_{1zz} * k_m) / r_m / (0.3531740136e38 * l_1^4 * l_2^4 * m_1^2 * m_2^2 + 0.1188568910e20 * l_1^2 * l_2^6 * m_1 * m_2^3 +$
 $0.1188568910e20 * J_{2zz} * L_1^2 * l_2^4 * m_2^2 + 0.7063480271e38 * J_{1zz} * J_{2xx} * l_2^4 * m_2^2 + 0.1188568910e20 * J_{1zz} * J_{2yy} * l_2^4 * m_2^2 +$
 $0.2377137820e20 * J_{1zz} * J_{2zz} * l_2^4 * m_2^2 + 0.1188568910e20 * J_{2xx} * J_{2yy} * l_2^4 * m_2^2 + 0.2377137820e20 * J_{2xx} * J_{2zz} * l_2^4 * m_2^2 +$
 $0.4e1 * J_{2yy} * J_{2zz} * l_2^4 * m_2^2 + 0.1188568910e20 * J_{2zz}^2 * L_1^2 * l_2^2 * J_{2zz} * l_2^2 * m_2^2 + 0.7063480271e38 * J_{1zz}^2 * J_{2zz}^2 * l_2^2 * m_2^2 +$
 $0.7063480271e38 * J_{2xx} * J_{2zz}^2 * l_2^2 * m_2^2 + 0.1188568910e20 * J_{2xx} * J_{2zz}^2 * l_2^2 * m_2^2 + 0.2e1 * J_{2yy}^2 * J_{2zz} * l_2^2 * m_2^2 +$
 $0.1188568910e20 * J_{2yy}^2 * J_{2zz}^2 * L_1^2 * l_2^2 * m_2^2 + 0.1188568910e20 * J_{2yy}^2 * J_{2zz}^2 * l_2^2 * m_2^2$

$$\begin{aligned}
& * m_1 + 0.2e1 * J_{2yy} * J_{2zz}^2 * l_2^2 * m_2 \\
& + 0.1188568910e20 * J_{1zz} * l_2^6 * m_2^3 + \\
& 0.1188568910e20 * J_{2xx} * l_2^6 * m_2^3 + 0.2e1 \\
& * J_{2yy} * l_2^6 * m_2^3 + 0.2e1 * J_{2zz} * l_2^4 \\
& * m_2^2 + 0.3531740136e38 * J_{1zz}^2 * l_2^4 * \\
& * m_2^2 + J_{2yy}^2 * l_2^4 * m_2^2 + \\
& 0.3531740136e38 * J_{2zz}^2 * l_1^4 * m_2^2 + \\
& 0.3531740136e38 * J_{2zz}^2 * l_1^4 * m_1^2 + \\
& J_{2zz}^2 * l_2^4 * m_2^2 + 0.7063480271e38 * \\
& J_{1zz} * J_{2xx} * J_{2zz}^2 + 0.1188568910e20 * J_{1zz} \\
& * J_{2yy} * J_{2zz}^2 + 0.1188568910e20 * J_{2xx} * \\
& J_{2yy} * J_{2zz}^2 + 0.7063480271e38 * J_{2zz} * l_1^2 \\
& * l_1^2 * l_2^2 * m_1 * m_2^2 + \\
& 0.1412696054e39 * J_{1zz} * J_{2zz} * l_1^2 * l_2^2 * \\
& * m_1 * m_2 + 0.1412696054e39 * J_{2xx} * J_{2zz} * \\
& l_1^2 * l_2^2 * m_1 * m_2 + 0.2377137820e20 * \\
& J_{2yy} * J_{2zz} * l_1^2 * l_2^2 * m_1 * m_2 + \\
& 0.7063480271e38 * J_{1zz} * l_1^2 * l_2^4 * m_1 * \\
& m_2^2 + 0.7063480271e38 * J_{2xx} * l_1^2 * l_2^4 * \\
& * m_1 * m_2^2 + 0.1188568910e20 * J_{2yy} * l_1^2 * \\
& * l_2^4 * m_1 * m_2^2 + 0.7063480271e38 * \\
& J_{2zz} * l_1^4 * l_2^2 * m_1^2 * m_2 + \\
& 0.2377137820e20 * J_{2zz} * l_1^2 * l_2^4 * m_1 * \\
& m_2^2 + 0.7063480271e38 * J_{1zz} * J_{2zz} * l_1^2 \\
& * l_2^2 * m_2^2 + 0.7063480271e38 * J_{2xx} * \\
& J_{2zz} * l_1^2 * l_2^2 * m_2^2 + \\
& 0.1188568910e20 * J_{2yy} * J_{2zz} * l_1^2 * l_2^2 * \\
& * m_2^2 + 0.7063480271e38 * J_{2zz}^2 * l_1^2 * \\
& l_1^2 * m_1 * m_2 + 0.1188568910e20 * J_{2zz}^2 * \\
& l_1^2 * l_2^2 * m_1 * m_2 + 0.1412696054e39 * \\
& J_{1zz} * J_{2xx} * J_{2zz} * l_2^2 * m_2 + \\
& 0.2377137820e20 * J_{1zz} * J_{2yy} * J_{2zz} * l_2^2 * \\
& m_2 + 0.2377137820e20 * J_{2xx} * J_{2yy} * J_{2zz} * \\
& l_2^2 * m_2 + l_2^8 * m_2^4 + 0.3531740136e38 \\
& * J_{1zz}^2 * J_{2zz}^2 + 0.3531740136e38 * J_{2xx}^2 \\
& * J_{2zz}^2 + J_{2yy}^2 * J_{2zz}^2) \\
& -0.3531740136e10 * (0.1000000000e29 * m_2 * l_1 * r_m \\
& * J_{2zz} * l_2 * b_2 * l_1^2 * m_1 + \\
& 0.1682695873e10 * m_2^2 * l_2^3 * l_1 * r_m * \\
& J_{2yy} * b_2 + 0.1000000000e29 * m_2^2 * l_2^3 * \\
& l_1 * r_m * b_2 * J_{1zz} + 0.1000000000e29 * m_2^2 * \\
& * l_1^3 * r_m * J_{2zz} * l_2 * b_2 + \\
& 0.1682695873e10 * m_2^2 * l_2^3 * l_1 * r_m * \\
& J_{2zz} * b_2 + 0.1000000000e29 * m_2^2 * l_2^3 * \\
& l_1 * r_m * J_{2xx} * b_2 + 0.1682695873e10 * m_2^2 * \\
& * l_1^3 * r_m * l_2^5 * b_2 + 0.1000000000e29 * \\
& m_2^2 * l_2^3 * l_1 * r_m * b_2 * l_1^2 * \\
& m_1 + 0.1000000000e29 * m_2 * l_1 * r_m * J_{2zz} * \\
& l_2 * b_2 * J_{1zz} + 0.1000000000e29 * m_2 * l_1 * \\
& r_m * J_{2zz} * l_2 * J_{2xx} * b_2 + 0.1682695873e10 \\
& * m_2 * l_1 * r_m * J_{2zz} * l_2 * J_{2yy} * b_2) / \\
& r_m / (0.3531740136e38 * l_1^4 * l_2^4 * m_1^2 * \\
& * m_2^2 + 0.1188568910e20 * l_1^2 * l_2^6 * \\
& m_1 * m_2^3 + 0.1188568910e20 * J_{2zz} * l_1^2 * \\
& l_2^4 * m_2^3 + 0.7063480271e38 * J_{1zz} * J_{2xx} \\
& * l_2^4 * m_2^2 + 0.1188568910e20 * J_{1zz} *
\end{aligned}$$

$$\begin{aligned} & J_2yy * 1_2^4 * m_2^2 + 0.2377137820e20 * J_1zz \\ & * J_2zz * 1_2^4 * m_2^2 + 0.1188568910e20 * \\ & J_2xx * J_2yy * 1_2^4 * m_2^2 + 0.2377137820e20 \\ & * J_2xx * J_2zz * 1_2^4 * m_2^2 + 0.4e1 * \\ & J_2yy * J_2zz * 1_2^4 * m_2^2 + 0.1188568910e20 \\ & * J_2zz^2 * L_1^2 * 1_2^2 * m_2^2 + \\ & 0.7063480271e38 * J_1zz^2 * J_2zz * 1_2^2 * m_2^2 \\ & + 0.7063480271e38 * J_1zz * J_2zz^2 * L_1^2 * \\ & m_2^2 + 0.7063480271e38 * J_1zz * J_2zz^2 * 1_1^2 \\ & * m_1 + 0.1188568910e20 * J_1zz * J_2zz^2 * 1_2^2 \\ & * m_2 + 0.7063480271e38 * J_2xx^2 * J_2zz * 1_2^2 \\ & * m_2 + 0.7063480271e38 * J_2xx * J_2zz^2 * \\ & L_1^2 * m_2 + 0.7063480271e38 * J_2xx * J_2zz^2 * \\ & 1_1^2 * m_1 + 0.1188568910e20 * J_2xx * J_2zz^2 * \\ & 1_2^2 * m_2 + 0.1188568910e20 * J_2yy^2 * J_2zz * \\ & 1_2^2 * m_2 + 0.1188568910e20 * J_2yy * J_2zz^2 * \\ & L_1^2 * m_2 + 0.1188568910e20 * J_2yy * J_2zz^2 * \\ & 1_1^2 * m_1 + 0.2e1 * J_2yy * J_2zz^2 * \\ & 1_2^2 * m_2 + 0.1188568910e20 * J_1zz * 1_2^6 * \\ & m_2^3 + 0.1188568910e20 * J_2xx * 1_2^6 * m_2^3 \\ & + 0.2e1 * J_2yy * 1_2^6 * m_2^3 + 0.2e1 * \\ & J_2zz * 1_2^6 * m_2^3 + 0.3531740136e38 * J_1zz^2 \\ & * 1_2^4 * m_2^2 + 0.3531740136e38 * J_2xx^2 \\ & * 1_2^4 * m_2^2 + J_2yy^2 * 1_2^4 * m_2^2 \\ & + 0.3531740136e38 * J_2zz^2 * L_1^4 * m_2^2 \\ & + 0.3531740136e38 * J_2zz^2 * 1_1^4 * m_1^2 + \\ & J_2zz^2 * 1_2^4 * m_2^2 + 0.7063480271e38 * \\ & J_1zz * J_2xx * J_2zz^2 + 0.1188568910e20 * J_1zz \\ & * J_2yy * J_2zz^2 + 0.1188568910e20 * J_2xx * \\ & J_2yy * J_2zz^2 + 0.7063480271e38 * J_2zz * L_1^2 \\ & * 1_1^2 * 1_2^2 * m_1 * m_2^2 + \\ & 0.1412696054e39 * J_1zz * J_2zz * 1_1^2 * 1_2^2 \\ & * m_1 * m_2 + 0.1412696054e39 * J_2xx * J_2zz * \\ & 1_1^2 * 1_2^2 * m_1 * m_2 + 0.2377137820e20 * \\ & J_2yy * J_2zz * 1_1^2 * 1_2^2 * m_1 * m_2 + \\ & 0.7063480271e38 * J_1zz * 1_1^2 * 1_2^4 * m_1 * \\ & m_2^2 + 0.7063480271e38 * J_2xx * 1_1^2 * 1_2^4 \\ & * m_1 * m_2^2 + 0.1188568910e20 * J_2yy * 1_1^2 \\ & * 1_2^4 * m_1 * m_2^2 + 0.7063480271e38 * \\ & J_2zz * 1_1^4 * 1_2^2 * m_1^2 * m_2 + \\ & 0.2377137820e20 * J_2zz * 1_1^2 * 1_2^4 * m_1 * \\ & m_2^2 + 0.7063480271e38 * J_1zz * J_2zz * L_1^2 \\ & * 1_2^2 * m_2^2 + 0.7063480271e38 * J_2xx * \\ & J_2zz * L_1^2 * 1_2^2 * m_2^2 + \\ & 0.1188568910e20 * J_2yy * J_2zz * L_1^2 * 1_2^2 \\ & * m_2^2 + 0.7063480271e38 * J_2zz^2 * L_1^2 * \\ & 1_1^2 * m_1 * m_2 + 0.1188568910e20 * J_2zz^2 * \\ & 1_1^2 * 1_2^2 * m_1 * m_2 + 0.1412696054e39 * \\ & J_1zz * J_2xx * J_2zz * 1_2^2 * m_2 + \\ & 0.2377137820e20 * J_1zz * J_2yy * J_2zz * 1_2^2 * \\ & m_2 + 0.2377137820e20 * J_2xx * J_2yy * J_2zz * \\ & 1_2^2 * m_2 + 1_2^8 * m_2^4 + 0.3531740136e38 \\ & * J_1zz^2 * J_2zz^2 + 0.3531740136e38 * J_2xx^2 \\ & * J_2zz^2 + J_2yy^2 * J_2zz^2); 0 \\ & -0.5000000000e-9 / r_m / (0.1000000000e57 * 1_1^4 * \\ & 1_2^4 * m_1^2 * m_2^2 + 0.3365391746e38 * 1_1^2 \\ & * 1_2^6 * m_1 * m_2^3 + 0.3365391746e38 * \end{aligned}$$

$J_{2zz} * L_1^2 * m_2^4 + 0.2000000000e57 * J_{1zz} * J_{2xx} * L_1^2 * m_2^4 + 0.3365391746e38 * J_{1zz} * J_{2yy} * L_1^2 * m_2^4 + 0.6730783492e38 * J_{1zz} * J_{2zz} * L_1^2 * m_2^4 + 0.3365391746e38 * J_{2xx} * J_{2yy} * L_1^2 * m_2^4 + 0.6730783492e38 * J_{2xx} * J_{2zz} * L_1^2 * m_2^4 + 0.1132586160e20 * J_{2yy} * J_{2zz} * L_1^2 * m_2^4 + 0.3365391746e38 * J_{2zz}^2 * L_1^2 * m_2^2 + 0.2000000000e57 * J_{1zz}^2 * J_{2zz} * L_1^2 * m_2^2 + 0.2000000000e57 * J_{1zz} * J_{2zz}^2 * L_1^2 * m_2^2 + 0.3365391746e38 * J_{1zz}^2 * m_1 + 0.3365391746e38 * J_{1zz} * J_{2zz}^2 * m_1 + 0.2000000000e57 * J_{2xx}^2 * J_{2zz} * L_1^2 * m_2 + 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * L_1^2 * m_2 + 0.3365391746e38 * J_{2xx} * J_{2zz}^2 * L_1^2 * m_1 + 0.5662930802e19 * J_{2yy}^2 * J_{2zz} * L_1^2 * m_2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * L_1^2 * m_2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * L_1^2 * m_1 + 0.5662930802e19 * J_{2yy} * J_{2zz}^2 * L_1^2 * m_2 + 0.3365391746e38 * J_{1zz} * L_1^2 * m_2^3 + 0.3365391746e38 * J_{2xx} * L_1^2 * m_2^3 + 0.5662930802e19 * J_{2yy} * L_1^2 * m_2^3 + 0.5662930802e19 * J_{2zz} * L_1^2 * m_2^3 + 0.1000000000e57 * J_{1zz}^2 * L_1^2 * m_2^2 + 0.1000000000e57 * J_{2xx}^2 * L_1^2 * m_2^2 + 0.2831465401e19 * J_{2yy}^2 * L_1^2 * m_2^2 + 0.1000000000e57 * J_{2zz}^2 * L_1^2 * m_2^2 + 0.1000000000e57 * J_{2zz}^2 * L_1^2 * m_1^2 + 0.2831465401e19 * J_{2zz}^2 * L_1^2 * m_2^2 + 0.2000000000e57 * J_{1zz} * J_{2xx} * J_{2zz}^2 + 0.3365391746e38 * J_{1zz} * J_{2yy} * J_{2zz}^2 + 0.3365391746e38 * J_{2xx} * J_{2yy} * J_{2zz}^2 + 0.2000000000e57 * J_{2zz} * L_1^2 * L_1^2 * m_1^2 * m_2^2 + 0.4000000000e57 * J_{1zz} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.4000000000e57 * J_{2xx} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.6730783492e38 * J_{2yy} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.2000000000e57 * J_{1zz} * L_1^2 * m_1^2 * m_2^2 + 0.2000000000e57 * J_{2xx} * L_1^2 * m_1^2 * m_2^2 + 0.6730783492e38 * J_{2yy} * L_1^2 * m_1^2 * m_2^2 + 0.3365391746e38 * J_{2yy} * L_1^2 * m_1^2 * m_2^2 + 0.2000000000e57 * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.6730783492e38 * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.2000000000e57 * J_{1zz} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.2000000000e57 * J_{2xx} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.3365391746e38 * J_{2yy} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.4000000000e57 * J_{1zz} * J_{2xx} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.6730783492e38 * J_{1zz} * J_{2yy} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.6730783492e38 * J_{2xx} * J_{2yy} * J_{2zz} * L_1^2 * m_1^2 * m_2^2 + 0.2831465401e19 * L_1^2 * m_2^4 + 0.1000000000e57 * J_{1zz}^2 * J_{2zz}^2 +$

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0.100000000000e57 * J_2xx ^ 2 * J_2zz ^ 2 +
0.2831465401e19 * J_2yy ^ 2 * J_2zz ^ 2) *
(-0.5662930809e28 * g * l_2 ^ 7 * m_2 ^ 4 * r_m +
0.1640827046e57 * L_1 ^ 3 * V_m * eta_g * eta_m *
k_g * k_t * l_2 ^ 3 * m_2 ^ 3 + 0.8204135230e56 *
J_2zz * L_1 * V_m * eta_g * eta_m * k_g * k_t *
l_1 ^ 2 * l_2 * m_1 * m_2 + 0.1640827046e57 * L_1
^ 2 * l_1 ^ 2 * l_2 * m_1 * m_2 ^ 2 * r_m *
tau_2 - 0.3999999999e66 * J_1zz * J_2zz * L_1 ^ 2 *
g * l_2 * m_2 ^ 2 * r_m - 0.3999999999e66 * J_2xx *
J_2zz * L_1 ^ 2 * g * l_2 * m_2 ^ 2 * r_m -
0.6730783497e47 * J_2yy * J_2zz * L_1 ^ 2 * g * l_2
* m_2 ^ 2 * r_m - 0.3999999999e66 * J_1zz * J_2xx *
J_2zz * g * l_2 * m_2 * r_m - 0.6730783497e47 *
J_1zz * J_2yy * J_2zz * g * l_2 * m_2 * r_m -
0.6730783497e47 * J_2xx * J_2yy * J_2zz * g * l_2 *
m_2 * r_m - 0.2000000000e66 * L_1 ^ 2 * g * l_1 ^ 2
* l_2 ^ 3 * m_1 * m_2 ^ 3 * r_m - 0.3999999999e66 *
J_1zz * g * l_1 ^ 2 * l_2 ^ 3 * m_1 * m_2 ^ 2 *
r_m - 0.3999999999e66 * J_2xx * g * l_1 ^ 2 * l_2 ^
3 * m_1 * m_2 ^ 2 * r_m - 0.6730783497e47 * J_2yy *
g * l_1 ^ 2 * l_2 ^ 3 * m_1 * m_2 ^ 2 * r_m -
0.2000000000e66 * J_2zz * g * l_1 ^ 4 * l_2 * m_1 ^
2 * m_2 * r_m - 0.6730783497e47 * J_2zz * g * l_1 ^
2 * l_2 ^ 3 * m_1 * m_2 ^ 2 * r_m + 0.8204135230e56
* J_1zz * L_1 * V_m * eta_g * eta_m * k_g * k_t
* l_2 ^ 3 * m_2 ^ 2 - 0.8204135230e56 * J_2xx * L_1
* V_m * eta_g * eta_m * k_g * k_t * l_2 ^ 3 *
m_2 ^ 2 + 0.1640827046e57 * J_2yy * L_1 * V_m *
eta_g * eta_m * k_g * k_t * l_2 ^ 3 * m_2 ^ 2 +
0.8204135230e56 * J_2zz * L_1 ^ 3 * V_m * eta_g *
eta_m * k_g * k_t * l_2 * m_2 ^ 2 +
0.1640827046e57 * J_2zz * L_1 * V_m * eta_g *
eta_m * k_g * k_t * l_2 ^ 3 * m_2 ^ 2 -
0.5662930809e28 * J_2yy ^ 2 * J_2zz * g * l_2 * m_2
* r_m - 0.2000000000e66 * g * l_1 ^ 4 * l_2 ^ 3 *
m_1 ^ 2 * m_2 ^ 2 * r_m - 0.6730783497e47 * g * l_1
^ 2 * l_2 ^ 5 * m_1 * m_2 ^ 3 * r_m -
0.2000000000e66 * J_1zz * L_1 ^ 2 * g * l_2 ^ 3 *
m_2 ^ 3 * r_m - 0.2000000000e66 * J_2xx * L_1 ^ 2 *
g * l_2 ^ 3 * m_2 ^ 3 * r_m + 0.3365391744e47 *
J_2yy * L_1 ^ 2 * g * l_2 ^ 3 * m_2 ^ 3 * r_m -
0.2000000000e66 * J_2zz * L_1 ^ 4 * g * l_2 * m_2 ^
3 * r_m - 0.6730783497e47 * J_2zz * L_1 ^ 2 * g *
l_2 ^ 3 * m_2 ^ 3 * r_m - 0.3999999999e66 * J_1zz *
J_2xx * g * l_2 ^ 3 * m_2 ^ 2 * r_m -
0.6730783497e47 * J_1zz * J_2yy * g * l_2 ^ 3 * m_2
^ 2 * r_m - 0.6730783497e47 * J_1zz * J_2zz * g *
l_2 ^ 3 * m_2 ^ 2 * r_m + 0.1640827046e57 * J_1zz *
L_1 ^ 2 * l_2 ^ 2 * m_2 ^ 2 * r_m * tau_2 -
0.6730783497e47 * J_2xx * J_2yy * g * l_2 ^ 3 * m_2
^ 2 * r_m - 0.6730783497e47 * J_2xx * J_2zz * g *
l_2 ^ 3 * m_2 ^ 2 * r_m - 0.1132586162e29 * J_2yy *
J_2zz * g * l_2 ^ 3 * m_2 ^ 2 * r_m +
0.1640827046e57 * J_2yy * L_1 ^ 2 * l_2 ^ 2 * m_2 ^
2 * r_m * tau_2 - 0.2000000000e66 * J_1zz ^ 2 *
J_2zz * g * l_2 * m_2 * r_m - 0.2000000000e66 *

```

$$\begin{aligned}
& J_{2xx}^2 * J_{2zz} * g * l_2^2 * m_2^2 * r_m + \\
& 0.6730783489e47 * L_1^4 * g * l_2^3 * m_2^4 * \\
& r_m + 0.1640827046e57 * L_1^4 * l_2^2 * m_2^3 \\
& * r_m * \tau_2 + 0.1640827046e57 * L_1 * V_m * \\
& \eta_g * \eta_m * k_g * k_t * l_2^5 * m_2^3 - \\
& 0.3999999999e66 * J_{2zz} * L_1^2 * g * l_1^2 * \\
& l_2^2 * m_1 * m_2^2 * r_m - 0.3999999999e66 * \\
& J_{1zz} * J_{2zz} * g * l_1^2 * l_2^2 * m_1 * m_2^2 * \\
& r_m - 0.3999999999e66 * J_{2xx} * J_{2zz} * g * l_1^2 * \\
& l_2^2 * m_1 * m_2^2 * r_m - 0.6730783497e47 * J_{2yy} \\
& * J_{2zz} * g * l_1^2 * l_2^2 * m_1 * m_2^2 * r_m + \\
& 0.3365391744e47 * L_1^2 * g * l_2^5 * m_2^4 * \\
& r_m - 0.6730783497e47 * J_{1zz} * g * l_2^5 * m_2^4 * \\
& 3 * r_m - 0.6730783497e47 * J_{2xx} * g * l_2^5 * \\
& m_2^3 * r_m - 0.1132586162e29 * J_{2yy} * g * l_2^5 * \\
& 5 * m_2^3 * r_m - 0.5662930809e28 * J_{2zz} * g * \\
& l_2^5 * m_2^3 * r_m + 0.1640827046e57 * L_1^2 * \\
& l_2^4 * m_2^3 * r_m * \tau_2 - 0.2000000000e66 \\
& * J_{1zz}^2 * g * l_2^3 * m_2^2 * r_m - \\
& 0.2000000000e66 * J_{2xx}^2 * g * l_2^3 * m_2^2 * \\
& r_m - 0.5662930809e28 * J_{2yy}^2 * g * l_2^3 * \\
& m_2^2 * r_m + 0.8204135230e56 * L_1 * V_m * \\
& \eta_g * \eta_m * k_g * k_t * l_1^2 * l_2^3 * \\
& m_1 * m_2^2 + 0.8204135230e56 * J_{1zz} * J_{2zz} * \\
& L_1 * V_m * \eta_g * \eta_m * k_g * k_t * l_2^2 * \\
& m_2 - 0.8204135230e56 * J_{2xx} * J_{2zz} * L_1 * V_m * \\
& \eta_g * \eta_m * k_g * k_t * l_2^2 * m_2 + \\
& 0.1640827046e57 * J_{2yy} * J_{2zz} * L_1 * V_m * \\
& \eta_g * \eta_m * k_g * k_t * l_2^2 * m_2) \\
& -0.5000000000e-9 / r_m / (0.1000000000e57 * l_1^4 * \\
& l_2^4 * m_1^2 * m_2^2 + 0.3365391746e38 * l_1^4 \\
& ^2 * l_2^6 * m_1 * m_2^3 + 0.3365391746e38 * \\
& J_{2zz} * L_1^2 * l_2^4 * m_2^3 + \\
& 0.2000000000e57 * J_{1zz} * J_{2xx} * l_2^4 * m_2^2 \\
& + 0.3365391746e38 * J_{1zz} * J_{2yy} * l_2^4 * m_2^2 \\
& + 0.6730783492e38 * J_{1zz} * J_{2zz} * l_2^4 * m_2^2 \\
& ^2 + 0.3365391746e38 * J_{2xx} * J_{2yy} * l_2^4 * \\
& m_2^2 + 0.6730783492e38 * J_{2xx} * J_{2zz} * l_2^4 * \\
& * m_2^2 + 0.1132586160e20 * J_{2yy} * J_{2zz} * l_2^4 * \\
& 4 * m_2^2 + 0.3365391746e38 * J_{2zz}^2 * L_1^2 * \\
& l_2^2 * m_2^2 + 0.2000000000e57 * J_{1zz}^2 * \\
& J_{2zz} * l_2^2 * m_2^2 + 0.2000000000e57 * J_{1zz} * \\
& J_{2zz}^2 * L_1^2 * m_2^2 + 0.2000000000e57 * J_{1zz} \\
& * J_{2zz}^2 * l_1^2 * m_1 + 0.3365391746e38 * \\
& J_{1zz} * J_{2zz}^2 * l_2^2 * m_2 + 0.2000000000e57 \\
& * J_{2xx}^2 * J_{2zz} * l_2^2 * m_2 + \\
& 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * L_1^2 * m_2 \\
& + 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * l_1^2 * \\
& m_1 + 0.3365391746e38 * J_{2xx} * J_{2zz}^2 * l_2^2 * \\
& * m_2 + 0.5662930802e19 * J_{2yy}^2 * J_{2zz} * l_2^2 * \\
& 2 * m_2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * L_1 \\
& ^2 * m_2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * \\
& l_1^2 * m_1 + 0.5662930802e19 * J_{2yy} * J_{2zz}^2 \\
& * l_2^2 * m_2 + 0.3365391746e38 * J_{1zz} * l_2^6 * \\
& * m_2^3 + 0.3365391746e38 * J_{2xx} * l_2^6 * m_2^2 \\
& ^3 + 0.5662930802e19 * J_{2yy} * l_2^6 * m_2^2^3 + \\
& 0.5662930802e19 * J_{2zz} * l_2^6 * m_2^2^3 +
\end{aligned}$$

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0.10000000000e57 * J_1zz ^ 2 * l_2 ^ 4 * m_2 ^ 2 +
0.10000000000e57 * J_2xx ^ 2 * l_2 ^ 4 * m_2 ^ 2 +
0.2831465401e19 * J_2yy ^ 2 * l_2 ^ 4 * m_2 ^ 2 +
0.10000000000e57 * J_2zz ^ 2 * L_1 ^ 4 * m_2 ^ 2 +
0.10000000000e57 * J_2zz ^ 2 * l_1 ^ 4 * m_1 ^ 2 +
0.2831465401e19 * J_2zz ^ 2 * l_2 ^ 4 * m_2 ^ 2 +
0.20000000000e57 * J_1zz * J_2xx * J_2zz ^ 2 +
0.3365391746e38 * J_1zz * J_2yy * J_2zz ^ 2 +
0.3365391746e38 * J_2xx * J_2yy * J_2zz ^ 2 +
0.20000000000e57 * J_2zz * L_1 ^ 2 * l_1 ^ 2 * l_2 ^ 2 *
2 * m_1 * m_2 ^ 2 + 0.40000000000e57 * J_1zz * J_2zz
* l_1 ^ 2 * m_1 * m_2 ^ 2 + 0.40000000000e57 *
J_2xx * J_2zz * l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 ^ 2 +
0.6730783492e38 * J_2yy * J_2zz * l_1 ^ 2 * l_2 ^ 2
* m_1 * m_2 + 0.20000000000e57 * J_1zz * l_1 ^ 2 *
l_2 ^ 4 * m_1 * m_2 ^ 2 + 0.20000000000e57 * J_2xx *
l_1 ^ 2 * l_2 ^ 4 * m_1 * m_2 ^ 2 + 0.3365391746e38
* J_2yy * l_1 ^ 2 * l_2 ^ 4 * m_1 * m_2 ^ 2 +
0.20000000000e57 * J_2zz * l_1 ^ 4 * l_2 ^ 2 * m_1 ^
2 * m_2 + 0.6730783492e38 * J_2zz * l_1 ^ 2 * l_2 ^
4 * m_1 * m_2 ^ 2 + 0.20000000000e57 * J_1zz * J_2zz
* L_1 ^ 2 * l_2 ^ 2 * m_2 ^ 2 + 0.20000000000e57 *
J_2xx * J_2zz * L_1 ^ 2 * l_2 ^ 2 * m_2 ^ 2 +
0.3365391746e38 * J_2yy * J_2zz * L_1 ^ 2 * l_2 ^ 2
* m_2 ^ 2 + 0.20000000000e57 * J_2zz ^ 2 * L_1 ^ 2 *
l_1 ^ 2 * m_1 * m_2 + 0.3365391746e38 * J_2zz ^ 2 *
l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 + 0.40000000000e57 *
J_1zz * J_2xx * J_2zz * l_2 ^ 2 * m_2 +
0.6730783492e38 * J_1zz * J_2yy * J_2zz * l_2 ^ 2 *
m_2 + 0.6730783492e38 * J_2xx * J_2yy * J_2zz *
l_2 ^ 2 * m_2 + 0.2831465401e19 * l_2 ^ 8 * m_2 ^ 4
+ 0.10000000000e57 * J_1zz ^ 2 * J_2zz ^ 2 +
0.10000000000e57 * J_2xx ^ 2 * J_2zz ^ 2 +
0.2831465401e19 * J_2yy ^ 2 * J_2zz ^ 2) *
(0.20000000000e66 * L_1 * eta_g * eta_m * k_g ^ 2 *
k_m * k_t * l_1 ^ 2 * l_2 ^ 3 * m_1 * m_2 ^ 2 +
0.20000000000e66 * J_1zz * J_2zz * L_1 * eta_g *
eta_m * k_g ^ 2 * k_m * k_t * l_2 * m_2 +
0.20000000000e66 * J_2xx * J_2zz * L_1 * eta_g *
eta_m * k_g ^ 2 * k_m * k_t * l_2 * m_2 +
0.3365391746e47 * J_2yy * J_2zz * L_1 * eta_g *
eta_m * k_g ^ 2 * k_m * k_t * l_2 * m_2 +
0.3365391746e47 * L_1 * eta_g * eta_m * k_g ^ 2 *
k_m * k_t * l_2 ^ 5 * m_2 ^ 3 + 0.20000000000e66 *
J_2zz * L_1 * b_1 * l_1 ^ 2 * l_2 * m_1 * m_2 *
r_m + 0.3365391746e47 * L_1 * b_1 * l_2 ^ 5 * m_2
^ 3 * r_m + 0.20000000000e66 * J_2zz * L_1 * eta_g *
eta_m * k_g ^ 2 * k_m * k_t * l_1 ^ 2 * l_2 *
m_1 * m_2 + 0.20000000000e66 * L_1 * b_1 * l_1 ^ 2
* l_2 ^ 3 * m_1 * m_2 ^ 2 * r_m + 0.20000000000e66 *
J_1zz * J_2zz * L_1 * b_1 * l_2 * m_2 * r_m +
0.20000000000e66 * J_2xx * J_2zz * L_1 * b_1 * l_2
* m_2 * r_m + 0.3365391746e47 * J_2yy * J_2zz *
L_1 * b_1 * l_2 * m_2 * r_m + 0.20000000000e66 *
J_2zz * L_1 ^ 3 * b_1 * l_2 * m_2 ^ 2 * r_m +
0.3365391746e47 * J_2zz * L_1 * b_1 * l_2 ^ 3 * m_2
^ 2 * r_m + 0.20000000000e66 * J_1zz * L_1 * b_1 *

```

$$\begin{aligned}
& \frac{l_1^2}{L_1} * b_1 * m_1^2 + 0.2000000000e66 * J_{2xx} * \\
& 0.3365391746e47 * J_{2yy} * L_1 * b_1 * l_1^2 + 3 * m_1^2 \\
& + 2 * r_m + 0.3365391746e47 * J_{2zz} * L_1 * eta_g * \\
& eta_m * k_g^2 * k_m * k_t * l_1^2 + 3 * m_1^2 + 2 * \\
& 0.2000000000e66 * J_{1zz} * L_1 * eta_g * eta_m * \\
& k_g^2 * k_m * k_t * l_1^2 + 3 * m_1^2 + 2 * \\
& 0.2000000000e66 * J_{2xx} * L_1 * eta_g * eta_m * k_g \\
& + 2 * k_m * k_t * l_1^2 + 3 * m_1^2 + 2 * \\
& 0.3365391746e47 * J_{2yy} * L_1 * eta_g * eta_m * \\
& k_g^2 * k_m * k_t * l_1^2 + 3 * m_1^2 + 2 * \\
& 0.2000000000e66 * J_{2zz} * L_1^3 * eta_g * eta_m * \\
& k_g^2 * k_m * k_t * l_1^2 * m_1^2) \\
& -0.5000000000e-9 / r_m / (0.1000000000e57 * l_1^4 * \\
& l_1^2 + 4 * m_1^2 + 2 * m_1^2 + 2 * 0.3365391746e38 * l_1^4 * \\
& l_1^2 + 6 * m_1^2 + 3 * m_1^2 + 0.3365391746e38 * \\
& J_{2zz} * L_1^2 * l_1^2 + 4 * m_1^2 + 3 * \\
& 0.2000000000e57 * J_{1zz} * J_{2xx} * l_1^4 * m_1^2 + 2 \\
& + 0.3365391746e38 * J_{1zz} * J_{2yy} * l_1^4 * m_1^2 + 2 \\
& + 0.6730783492e38 * J_{1zz} * J_{2zz} * l_1^4 * m_1^2 \\
& + 2 * 0.3365391746e38 * J_{2xx} * J_{2yy} * l_1^4 * m_1^2 \\
& + 2 * 0.6730783492e38 * J_{2xx} * J_{2zz} * l_1^4 * m_1^2 \\
& + 2 * 0.1132586160e20 * J_{2yy} * J_{2zz} * l_1^4 * m_1^2 \\
& + 2 * 0.3365391746e38 * J_{2zz}^2 * L_1^2 \\
& * l_1^2 + 2 * m_1^2 + 0.2000000000e57 * J_{1zz}^2 * \\
& J_{2zz} * l_1^2 + 2 * m_1^2 + 0.2000000000e57 * J_{1zz} * \\
& J_{2zz}^2 * L_1^2 * m_1^2 + 0.2000000000e57 * J_{1zz} \\
& * J_{2zz}^2 * l_1^2 + 2 * m_1^2 + 0.3365391746e38 * \\
& J_{1zz} * J_{2zz}^2 * l_1^2 + 2 * m_1^2 + 0.2000000000e57 \\
& * J_{2xx}^2 * J_{2zz} * l_1^2 + 2 * m_1^2 + \\
& 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * L_1^2 * m_1^2 \\
& + 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * l_1^2 + 2 * m_1^2 \\
& m_1 + 0.3365391746e38 * J_{2xx} * J_{2zz}^2 * l_1^2 + 2 \\
& * m_1^2 + 0.5662930802e19 * J_{2yy}^2 * J_{2zz} * l_1^2 + 2 \\
& * m_1^2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * L_1^2 \\
& + 2 * m_1^2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * \\
& l_1^2 + 2 * m_1^2 + 0.5662930802e19 * J_{2yy} * J_{2zz}^2 \\
& * l_1^2 + 2 * m_1^2 + 0.3365391746e38 * J_{1zz} * l_1^2 + 6 \\
& * m_1^2 + 3 * 0.3365391746e38 * J_{2xx} * l_1^2 + 6 * m_1^2 \\
& + 3 * 0.5662930802e19 * J_{2yy} * l_1^2 + 6 * m_1^2 + 3 * \\
& 0.5662930802e19 * J_{2zz} * l_1^2 + 6 * m_1^2 + 3 * \\
& 0.1000000000e57 * J_{1zz}^2 * l_1^2 + 4 * m_1^2 + 2 * \\
& 0.1000000000e57 * J_{2xx}^2 * l_1^2 + 4 * m_1^2 + 2 * \\
& 0.2831465401e19 * J_{2yy}^2 * l_1^2 + 4 * m_1^2 + 2 * \\
& 0.1000000000e57 * J_{2zz}^2 * L_1^4 * m_1^2 + 2 * \\
& 0.1000000000e57 * J_{2zz}^2 * l_1^4 * m_1^2 + 2 * \\
& 0.2831465401e19 * J_{2zz}^2 * l_1^2 + 4 * m_1^2 + 2 * \\
& 0.2000000000e57 * J_{1zz} * J_{2xx} * J_{2zz}^2 + \\
& 0.3365391746e38 * J_{1zz} * J_{2yy} * J_{2zz}^2 + \\
& 0.3365391746e38 * J_{2xx} * J_{2yy} * J_{2zz}^2 + \\
& 0.2000000000e57 * J_{2zz} * L_1^2 * l_1^2 + 2 * l_1^2 + 2 * \\
& 2 * m_1 * m_1^2 + 2 * 0.4000000000e57 * J_{1zz} * J_{2zz} \\
& * l_1^2 + 2 * l_1^2 + 2 * m_1 * m_1^2 + 0.4000000000e57 * \\
& J_{2xx} * J_{2zz} * l_1^2 + 2 * l_1^2 + 2 * m_1 * m_1^2 + \\
& 0.6730783492e38 * J_{2yy} * J_{2zz} * l_1^2 + 2 * l_1^2 + 2 \\
& * m_1 * m_1^2 + 0.2000000000e57 * J_{1zz} * l_1^2 + 2 * \\
& l_1^2 + 4 * m_1 * m_1^2 + 2 * 0.2000000000e57 * J_{2xx} *
\end{aligned}$$

$$\begin{aligned}
& 1 _1^2 * 1 _2^4 * m _1 * m _2^2 + 0.3365391746e38 \\
& * J _2yy * 1 _1^2 * 1 _2^4 * m _1 * m _2^2 + \\
& 0.2000000000e57 * J _2zz * 1 _1^4 * 1 _2^2 * m _1^4 \\
& 2 * m _2 + 0.6730783492e38 * J _2zz * 1 _1^2 * 1 _2^2 \\
& 4 * m _1 * m _2^2 + 0.2000000000e57 * J _1zz * J _2zz \\
& * L _1^2 * 1 _2^2 * m _2^2 + 0.2000000000e57 * \\
& J _2xx * J _2zz * L _1^2 * 1 _2^2 * m _2^2 + \\
& 0.3365391746e38 * J _2yy * J _2zz * L _1^2 * 1 _2^2 \\
& * m _2^2 + 0.2000000000e57 * J _2zz^2 * L _1^2 * \\
& 1 _1^2 * m _1 * m _2 + 0.3365391746e38 * J _2zz^2 * \\
& 1 _1^2 * 1 _2^2 * m _1 * m _2 + 0.4000000000e57 * \\
& J _1zz * J _2xx * J _2zz * 1 _2^2 * m _2 + \\
& 0.6730783492e38 * J _1zz * J _2yy * J _2zz * 1 _2^2 * \\
& m _2 + 0.6730783492e38 * J _2xx * J _2yy * J _2zz * 1 _2^2 \\
& ^2 * m _2 + 0.2831465401e19 * 1 _2^8 * m _2^4 + \\
& 0.1000000000e57 * J _1zz^2 * J _2zz^2 + \\
& 0.1000000000e57 * J _2xx^2 * J _2zz^2 + \\
& 0.2831465401e19 * J _2yy^2 * J _2zz^2) * \\
& (0.5662930802e28 * b _2 * 1 _2^6 * m _2^3 * r _m + \\
& 0.2000000000e66 * J _1zz^2 * J _2zz * b _2 * r _m + \\
& 0.2000000000e66 * J _2xx^2 * J _2zz * b _2 * r _m + \\
& 0.5662930802e28 * J _2yy^2 * J _2zz * b _2 * r _m + \\
& 0.6730783492e47 * J _1zz * J _2yy * J _2zz * b _2 * \\
& r _m + 0.6730783492e47 * L _1^2 * b _2 * 1 _2^4 * \\
& m _2^3 * r _m + 0.6730783492e47 * J _1zz * b _2 * \\
& 1 _2^4 * m _2^2 * r _m + 0.6730783492e47 * J _2xx * \\
& b _2 * 1 _2^4 * m _2^2 * r _m + 0.1132586160e29 * \\
& J _2yy * b _2 * 1 _2^4 * m _2^2 * r _m + \\
& 0.2000000000e66 * J _2zz * L _1^4 * b _2 * m _2^2 * \\
& r _m + 0.2000000000e66 * J _2zz * b _2 * 1 _1^4 * \\
& m _1^2 * r _m + 0.5662930802e28 * J _2zz * b _2 * \\
& 1 _2^4 * m _2^2 * r _m + 0.2000000000e66 * J _1zz^2 * \\
& 2 * b _2 * 1 _2^2 * m _2^2 * r _m + 0.2000000000e66 * \\
& J _2xx^2 * b _2 * 1 _2^2 * m _2^2 * r _m + \\
& 0.5662930802e28 * J _2yy^2 * b _2 * 1 _2^2 * m _2^2 * \\
& r _m + 0.4000000000e66 * J _1zz * J _2xx * J _2zz * \\
& b _2 * r _m + 0.2000000000e66 * b _2 * 1 _1^4 * 1 _2^2 * \\
& 2 * m _1^2 * m _2^2 * r _m + 0.6730783492e47 * b _2 * \\
& 1 _1^2 * 1 _2^4 * m _1^2 * m _2^2 * r _m + \\
& 0.2000000000e66 * J _1zz * L _1^2 * b _2 * 1 _2^2 * \\
& m _2^2 * r _m + 0.2000000000e66 * J _2xx * L _1^2 * \\
& b _2 * 1 _2^2 * m _2^2 * r _m + 0.3365391746e47 * \\
& J _2yy * L _1^2 * b _2 * 1 _2^2 * m _2^2 * r _m + \\
& 0.6730783492e47 * J _2zz * L _1^2 * b _2 * 1 _2^2 * \\
& m _2^2 * r _m + 0.4000000000e66 * J _1zz * J _2xx * \\
& b _2 * 1 _2^2 * m _2^2 * r _m + 0.6730783492e47 * \\
& J _1zz * J _2yy * b _2 * 1 _2^2 * m _2^2 * r _m + \\
& 0.4000000000e66 * J _1zz * J _2zz * L _1^2 * b _2 * \\
& m _2 * r _m + 0.4000000000e66 * J _1zz * J _2zz * b _2 * \\
& * 1 _1^2 * m _1 * r _m + 0.6730783492e47 * J _1zz * \\
& J _2zz * b _2 * 1 _2^2 * m _2 * r _m + 0.6730783492e47 \\
& * J _2xx * J _2yy * b _2 * 1 _2^2 * m _2 * r _m + \\
& 0.4000000000e66 * J _2xx * J _2zz * L _1^2 * b _2 * \\
& m _2 * r _m + 0.4000000000e66 * J _2xx * J _2zz * b _2 * \\
& * 1 _1^2 * m _1 * r _m + 0.6730783492e47 * J _2xx * \\
& J _2zz * b _2 * 1 _2^2 * m _2 * r _m + 0.6730783492e47
\end{aligned}$$


```

* J_2yy * J_2zz * L_1 ^ 2 * b_2 * m_2 * r_m +
0.6730783492e47 * J_2yy * J_2zz * b_2 * l_1 ^ 2 *
m_1 * r_m + 0.1132586160e29 * J_2yy * J_2zz * b_2
* l_2 ^ 2 * m_2 * r_m + 0.2000000000e66 * L_1 ^ 2 *
b_2 * l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 * r_m +
0.4000000000e66 * J_1zz * b_2 * l_1 ^ 2 * l_2 ^ 2 *
m_1 * m_2 * r_m + 0.4000000000e66 * J_2xx * b_2 *
l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 * r_m +
0.6730783492e47 * J_2yy * b_2 * l_1 ^ 2 * l_2 ^ 2 *
m_1 * m_2 * r_m + 0.4000000000e66 * J_2zz * L_1 ^ 2
* b_2 * l_1 ^ 2 * m_1 * m_2 * r_m +
0.6730783492e47 * J_2zz * b_2 * l_1 ^ 2 * l_2 ^ 2 *
m_1 * m_2 * r_m);];
dthetal_dt = [0 0 1 0; 0 0 0 1; 0 0.5998558162e2
-0.1613923708e2 0; 0 0.9615182815e2 -0.1469336136e2 0;]
;
> Matlab(B, resultname="B");
Matlab(B_data, resultname="B");
B = [0; 0; 0.3531740136e10 * (-0.2000000000e29 * eta_g
* eta_m * k_g * k_t * l_2 ^ 2 * m_2 * J_2zz *
l_1 ^ 2 * m_1 - 0.2577405097e20 * eta_g * eta_m *
k_g * k_t * l_2 ^ 4 * m_2 ^ 3 * L_1 ^ 2 -
0.9999999974e28 * eta_g * eta_m * k_g * k_t * l_2 ^
4 * m_2 ^ 2 * J_2xx - 0.2577405097e20 * eta_g *
eta_m * k_g * k_t * l_2 ^ 4 * m_2 ^ 2 * J_2yy -
0.5154810194e20 * eta_g * eta_m * k_g * k_t * l_2
^ 4 * m_2 ^ 2 * J_2zz - 0.2577405097e20 * J_2zz ^ 2
* eta_g * eta_m * k_g * k_t * l_2 ^ 2 * m_2 -
0.1000000000e29 * eta_g * eta_m * k_g * k_t * l_2
^ 4 * m_2 ^ 2 * J_1zz - 0.1000000000e29 * J_2zz ^ 2
* eta_g * eta_m * k_g * k_t * L_1 ^ 2 * m_2 -
0.1000000000e29 * J_2zz ^ 2 * eta_g * eta_m * k_g *
k_t * l_1 ^ 2 * m_1 - 0.1000000000e29 * eta_g *
eta_m * k_g * k_t * l_2 ^ 4 * m_2 ^ 2 * l_1 ^ 2 *
m_1 - 0.2000000000e29 * eta_g * eta_m * k_g * k_t
* l_2 ^ 2 * m_2 * J_1zz * J_2zz - 0.1999999995e29 *
eta_g * eta_m * k_g * k_t * l_2 ^ 2 * m_2 * J_2xx
* J_2zz - 0.5154810194e20 * eta_g * eta_m * k_g *
k_t * l_2 ^ 2 * m_2 * J_2yy * J_2zz -
0.1000000003e29 * J_2zz * eta_g * eta_m * k_g *
k_t * L_1 ^ 2 * l_2 ^ 2 * m_2 ^ 2 - 0.1000000000e29
* J_2zz ^ 2 * eta_g * eta_m * k_g * k_t * J_1zz -
0.2577405097e20 * eta_g * eta_m * k_g * k_t * l_2
^ 6 * m_2 ^ 3 - 0.9999999974e28 * J_2zz ^ 2 * eta_g
* eta_m * k_g * k_t * J_2xx - 0.2577405097e20 *
J_2zz ^ 2 * eta_g * eta_m * k_g * k_t * J_2yy) /
r_m / (0.3531740136e38 * l_1 ^ 4 * l_2 ^ 4 * m_1 ^
2 * m_2 ^ 2 + 0.1188568910e20 * l_1 ^ 2 * l_2 ^ 6 *
m_1 * m_2 ^ 3 + 0.1188568910e20 * J_2zz * L_1 ^ 2 *
l_2 ^ 4 * m_2 ^ 3 + 0.7063480271e38 * J_1zz * J_2xx
* l_2 ^ 4 * m_2 ^ 2 + 0.1188568910e20 * J_1zz *
J_2yy * l_2 ^ 4 * m_2 ^ 2 + 0.2377137820e20 * J_1zz
* J_2zz * l_2 ^ 4 * m_2 ^ 2 + 0.1188568910e20 *
J_2xx * J_2yy * l_2 ^ 4 * m_2 ^ 2 + 0.2377137820e20
* J_2xx * J_2zz * l_2 ^ 4 * m_2 ^ 2 + 0.4e1 *
J_2yy * J_2zz * l_2 ^ 4 * m_2 ^ 2 + 0.1188568910e20

```

```

* J_2zz ^ 2 * L_1 ^ 2 * l_2 ^ 2 * m_2 ^ 2 +
0.7063480271e38 * J_1zz ^ 2 * J_2zz * l_2 ^ 2 * m_2
+ 0.7063480271e38 * J_1zz * J_2zz ^ 2 * L_1 ^ 2 * m_2
* m_2 + 0.7063480271e38 * J_1zz * J_2zz ^ 2 * l_1 ^ 2
* m_1 + 0.1188568910e20 * J_1zz * J_2zz ^ 2 * l_2 ^
2 * m_2 + 0.7063480271e38 * J_2xx ^ 2 * J_2zz * l_2
^ 2 * m_2 + 0.7063480271e38 * J_2xx * J_2zz ^ 2 *
L_1 ^ 2 * m_2 + 0.7063480271e38 * J_2xx * J_2zz ^ 2
* l_1 ^ 2 * m_1 + 0.1188568910e20 * J_2xx * J_2zz ^
2 * l_2 ^ 2 * m_2 + 0.2e1 * J_2yy ^ 2 * J_2zz * l_2
^ 2 * m_2 + 0.1188568910e20 * J_2yy * J_2zz ^ 2 *
L_1 ^ 2 * m_2 + 0.1188568910e20 * J_2yy * J_2zz ^ 2
* l_1 ^ 2 * m_1 + 0.2e1 * J_2yy * J_2zz ^ 2 * l_2
^ 2 * m_2 + 0.1188568910e20 * J_1zz * l_2 ^ 6 * m_2
^ 3 + 0.1188568910e20 * J_2xx * l_2 ^ 6 * m_2 ^ 3 +
0.2e1 * J_2yy * l_2 ^ 6 * m_2 ^ 3 + 0.2e1 * J_2zz *
l_2 ^ 6 * m_2 ^ 3 + 0.3531740136e38 * J_1zz ^ 2 *
l_2 ^ 4 * m_2 ^ 2 + 0.3531740136e38 * J_2xx ^ 2 *
l_2 ^ 4 * m_2 ^ 2 + J_2yy ^ 2 * l_2 ^ 4 * m_2 ^ 2
+ 0.3531740136e38 * J_2zz ^ 2 * L_1 ^ 4 * m_2 ^ 2 +
0.3531740136e38 * J_2zz ^ 2 * l_1 ^ 4 * m_1 ^ 2 +
J_2zz ^ 2 * l_2 ^ 4 * m_2 ^ 2 + 0.7063480271e38 *
J_1zz * J_2xx * J_2zz ^ 2 + 0.1188568910e20 * J_1zz
* J_2yy * J_2zz ^ 2 + 0.1188568910e20 * J_2xx *
J_2yy * J_2zz ^ 2 + 0.7063480271e38 * J_2zz * L_1 ^
2 * l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 ^ 2 +
0.1412696054e39 * J_1zz * J_2zz * l_1 ^ 2 * l_2 ^ 2
* m_1 * m_2 + 0.1412696054e39 * J_2xx * J_2zz *
l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 + 0.2377137820e20 *
J_2yy * J_2zz * l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 +
0.7063480271e38 * J_1zz * l_1 ^ 2 * l_2 ^ 4 * m_1 *
m_2 ^ 2 + 0.7063480271e38 * J_2xx * l_1 ^ 2 * l_2 ^
4 * m_1 * m_2 ^ 2 + 0.1188568910e20 * J_2yy * l_1 ^
2 * l_2 ^ 4 * m_1 * m_2 ^ 2 + 0.7063480271e38 *
J_2zz * l_1 ^ 4 * l_2 ^ 2 * m_1 ^ 2 * m_2 +
0.2377137820e20 * J_2zz * l_1 ^ 2 * l_2 ^ 4 * m_1 *
m_2 ^ 2 + 0.7063480271e38 * J_1zz * J_2zz * L_1 ^ 2
* l_2 ^ 2 * m_2 ^ 2 + 0.7063480271e38 * J_2xx *
J_2zz * L_1 ^ 2 * l_2 ^ 2 * m_2 ^ 2 +
0.1188568910e20 * J_2yy * J_2zz * L_1 ^ 2 * l_2 ^ 2
* m_2 ^ 2 + 0.7063480271e38 * J_2zz ^ 2 * L_1 ^ 2 *
l_1 ^ 2 * m_1 * m_2 + 0.1188568910e20 * J_2zz ^ 2 *
l_1 ^ 2 * l_2 ^ 2 * m_1 * m_2 + 0.1412696054e39 *
J_1zz * J_2xx * J_2zz * l_2 ^ 2 * m_2 +
0.2377137820e20 * J_1zz * J_2yy * J_2zz * l_2 ^ 2 *
m_2 + 0.2377137820e20 * J_2xx * J_2yy * J_2zz *
l_2 ^ 2 * m_2 + l_2 ^ 8 * m_2 ^ 4 + 0.3531740136e38
* J_1zz ^ 2 * J_2zz ^ 2 + 0.3531740136e38 * J_2xx ^
2 * J_2zz ^ 2 + J_2yy ^ 2 * J_2zz ^ 2);
0.5000000000e-9 / r_m / (0.1000000000e57 * l_1 ^ 4 *
l_2 ^ 4 * m_1 ^ 2 * m_2 ^ 2 + 0.3365391746e38 * l_1
^ 2 * l_2 ^ 6 * m_1 * m_2 ^ 3 + 0.3365391746e38 *
J_2zz * L_1 ^ 2 * l_2 ^ 4 * m_2 ^ 3 +
0.2000000000e57 * J_1zz * J_2xx * l_2 ^ 4 * m_2 ^ 2
+ 0.3365391746e38 * J_1zz * J_2yy * l_2 ^ 4 * m_2 ^
2 + 0.6730783492e38 * J_1zz * J_2zz * l_2 ^ 4 * m_2
^ 2 + 0.3365391746e38 * J_2xx * J_2yy * l_2 ^ 4 *

```

$$\begin{aligned}
& m_2^2 + 0.6730783492e38 * J_{2xx} * J_{2zz} * l_2^2 + 4 \\
& * m_2^2 + 0.1132586160e20 * J_{2yy} * J_{2zz} * l_2^2 + 4 \\
& * m_2^2 + 0.3365391746e38 * J_{2zz}^2 * l_1^2 + 2 \\
& * l_2^2 * m_2^2 + 0.2000000000e57 * J_{1zz}^2 * J_{2zz} * l_2^2 + m_2^2 + 0.2000000000e57 * J_{1zz} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.2000000000e57 * J_{1zz} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.3365391746e38 * J_{1zz} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.2000000000e57 * J_{2xx}^2 * J_{2zz} * l_2^2 + m_2^2 + 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.2000000000e57 * J_{2xx} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.3365391746e38 * J_{2xx} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.5662930802e19 * J_{2yy}^2 * J_{2zz} * l_2^2 + 2 * m_2^2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.3365391746e38 * J_{2yy} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.5662930802e19 * J_{2yy} * J_{2zz}^2 * l_1^2 + 2 * m_2^2 + 0.3365391746e38 * J_{1zz} * l_2^2 + 6 * m_2^2 + 3 + 0.5662930802e19 * J_{2yy} * l_2^2 + 6 * m_2^2 + 3 + 0.5662930802e19 * J_{2zz} * l_2^2 + 6 * m_2^2 + 3 + 0.1000000000e57 * J_{1zz}^2 * l_2^2 + 4 * m_2^2 + 2 + 0.1000000000e57 * J_{2xx}^2 * l_2^2 + 4 * m_2^2 + 2 + 0.2831465401e19 * J_{2yy}^2 * l_2^2 + 4 * m_2^2 + 2 + 0.1000000000e57 * J_{2zz}^2 * l_1^2 + 4 * m_2^2 + 2 + 0.1000000000e57 * J_{2zz}^2 * l_1^2 + 4 * m_2^2 + 2 + 0.2831465401e19 * J_{2zz}^2 * l_1^2 + 4 * m_2^2 + 2 + 0.2000000000e57 * J_{1zz} * J_{2xx} * J_{2zz}^2 + 0.3365391746e38 * J_{1zz} * J_{2yy} * J_{2zz}^2 + 0.3365391746e38 * J_{2xx} * J_{2yy} * J_{2zz}^2 + 0.2000000000e57 * J_{2zz} * l_1^2 + 2 * l_1^2 + 2 * l_2^2 + 2 * m_1 * m_2 + 0.4000000000e57 * J_{1zz} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.4000000000e57 * J_{2xx} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.6730783492e38 * J_{2yy} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.2000000000e57 * J_{1zz} * l_1^2 + 2 * l_2^2 + 4 * m_1 * m_2 + 0.2000000000e57 * J_{2xx} * l_1^2 + 2 * m_1 * m_2 + 0.3365391746e38 * J_{2yy} * l_1^2 + 2 * m_1 * m_2 + 0.2000000000e57 * J_{2zz} * l_1^2 + 4 * m_1 * m_2 + 0.2000000000e57 * J_{2zz} * l_1^2 + 4 * m_1 * m_2 + 0.6730783492e38 * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.2000000000e57 * J_{1zz} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.2000000000e57 * J_{2xx} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.3365391746e38 * J_{2yy} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.2000000000e57 * J_{2zz} * J_{2zz} * l_1^2 + 2 * m_1 * m_2 + 0.6730783492e38 * J_{1zz} * J_{2yy} * J_{2zz} * l_2^2 + 2 * m_2 + 0.6730783492e38 * J_{2xx} * J_{2yy} * J_{2zz} * l_2^2 + 2 * m_2 + 0.2831465401e19 * l_2^2 + 8 * m_2^2 + 4 + 0.1000000000e57 * J_{1zz}^2 * J_{2zz}^2 + 0.1000000000e57 * J_{2xx}^2 * J_{2zz}^2 + 0.2831465401e19 * J_{2yy}^2 * J_{2zz}^2 + (-0.5154810193e57 * l_1^3 * eta_g * eta_m * k_g * k_t * l_2^3 * m_2^3 - 0.2000000003e66 * J_{2zz} * l_1 * eta_g * eta_m * k_g * k_t * l_1^2 * l_2^2
\end{aligned}$$

```

* m__1 * m__2 - 0.20000000003e66 * J__1zz * L__1 * eta__g
* eta__m * k__g * k__t * l__2 ^ 3 * m__2 ^ 2 -
0.1999999997e66 * J__2xx * L__1 * eta__g * eta__m *
k__g * k__t * l__2 ^ 3 * m__2 ^ 2 - 0.5154810194e57 *
J__2yy * L__1 * eta__g * eta__m * k__g * k__t * l__2 ^
3 * m__2 ^ 2 - 0.20000000003e66 * J__2zz * L__1 ^ 3 *
eta__g * eta__m * k__g * k__t * l__2 * m__2 ^ 2 -
0.5154810194e57 * J__2zz * L__1 * eta__g * eta__m *
k__g * k__t * l__2 ^ 3 * m__2 ^ 2 - 0.5154810194e57 *
L__1 * eta__g * eta__m * k__g * k__t * l__2 ^ 5 * m__2
^ 3 - 0.20000000003e66 * L__1 * eta__g * eta__m * k__g *
k__t * l__1 ^ 2 * l__2 ^ 3 * m__1 * m__2 ^ 2 -
0.20000000003e66 * J__1zz * J__2zz * L__1 * eta__g *
eta__m * k__g * k__t * l__2 * m__2 - 0.1999999997e66 *
J__2xx * J__2zz * L__1 * eta__g * eta__m * k__g * k__t
* l__2 * m__2 - 0.5154810194e57 * J__2yy * J__2zz *
L__1 * eta__g * eta__m * k__g * k__t * l__2 * m__2);];
B = [0; 0; -0.3033691204e2; -0.2761910058e2;];

```

Data

```

> Matlab(data_electrical, resultname="data_e");
eta__g = 0.85e0;
eta__m = 0.87e0;
k__g = 70;
k__m = 0.76e-2;
k__t = 0.76e-2;
r__m = 0.26e1;
V__m = 10;

> Matlab(data_mechanical, resultname="data_m");
J__1zz = 0.23e-2;
m__1 = 0;
l__1 = 0.215e0;
m__2 = 0.2e0;
L__1 = 0.215e0;
J__2yy = 0.23e-2;
l__2 = 0.1675e0;
J__2xx = 0;
J__2zz = 0.23e-2;
b__1 = 0;
Vm = 0;
g = 0.981e1;
tau__2 = 0;
b__2 = 0;

```