<1-1> (1.1.1)
¥frac{dx(x)}{dt}¥equiv v(t)

<1-2> (1.1.2)
s(t)=|v(t)|

<1-3> (1.1.3)
x(t)=¥int v(x)dt+C_1

<1-4> (1.1.4)
¥begin{equation*}
¥frac{dv(t)}{dt}¥equiv a(t)
¥end{equation*}

<1-5> (1.1.5)
v(t)=¥int a(t)dt+C_2

<2-1> (2.1.1)
¥vec{a}=¥frac{¥vec{F}}{m}

<2-2> (2.1.2)
¥vec{F}_{21}=-¥vec{F}_{12} ¥quad¥mbox{or}¥quad¥vec{F}_{21}+¥vec{F}_{12}=0

<2-3> (2.1.3)
m¥frac{d^2x(t)}{dt^2}=F

<2-4> (2.2.1)
m¥frac{d^2x(t)}{dt^2}=0

<2-5> (2.2.2)
m¥frac{dv(t)}{dt}=0

<2-6>
v(t)=C_2

<2-7> (2.2.3)
v(t)=v_0

<2-8>
x(t)=¥int v_2dt+C_1

<2-9> (2.2.4)
x(t)=v_0t+x_0

<2-10> (2.2.5)

m¥frac{d^2x(t)}{dt^2}=-mg

<2-11> (2.2.6)
v(t)=v_0-¥int gdt=v_0-gt

<2-12> (2.2.7)
¥begin{array}{ll}
x(t)&=¥displaystyle{x_0+¥int v(t)dt} ¥¥
&=¥displaystyle{x_0+¥int (v_0-gt)dt} ¥¥
&=¥displaystyle{v_0+v_0t-¥frac{1}{2}gt^2}
¥end{array}

<2-13> (2.2.8)
¥left¥{¥begin{array}{l}
¥displaystyle{v(t)= -gt} ¥¥ ¥¥
¥displaystyle{x(t)=h-¥frac{1}{2}gt^2}
¥end{array}¥right.

<2-14>
m_1¥frac{d^2x_1(t)}{dt^2}=F_{21}

<2-15>
m_2¥frac{d^2x_2(t)}{dt^2}=F_{12}

<2-16> (2.3.1)
F_{12}(x)=-F_{12}(x)

<2-17> (2.4.1)
m_1¥frac{d^2x_1(t)}{dt^2}+ m_2¥frac{d^2x_2(t)}{dt^2}
=¥frac{d^2[m_1x_1(t)+m_2x_2(t)]}{dt^2}=0

<2-18> (2.4.2)
X(t)=¥frac{ m_1x_1(t)+m_2x_2(t)}{m_1+m_2}

<2-19> (2.4.3)
Q=¥frac{ w_1Q_1+W_2Q_2}{w_1+w_2}

<2-20> (2.4.4)
M¥frac{ d^2X(t) }{dt^2}=0

<2-21> (2.4.5)
m¥frac{dv(t)}{dt}=F

<2-22> (2.4.6)
¥frac{d[mv(t)]}{dt}=F

<2-23> (2.4.7)
mv(t)¥equiv p(t)

<2-24> (2.4.8)
¥frac{dp(t)}{dt}=F

<2-25> (2.4.9)
¥left¥{ ¥begin{array}{l}
¥displaystyle{¥frac{dp_1(t)}{dt}=F_{21}} ¥¥ ¥¥
¥displaystyle{¥frac{dp_2(t)}{dt}=F_{12}}
¥end{array}¥right.,,

<2-26> (2.4.10)
V(t)=¥frac{dX(t)}{dt}

<2-27> (2.4.11)
M¥frac{dV(t)}{dt}=0

<2-28> (2.4.12)
¥frac{dP(t)}{dt}=0

<2-29>
¥begin{array}{ll}
V(t)&=¥displaystyle{¥frac{d¥left(¥displaystyle{¥frac{m_1x_1(t)+m_2x_2(t)}{m_1+m_2}}
¥right)}{dt}} ¥¥ ¥¥
&=¥displaystyle{¥frac{1}{M}¥frac{d¥left(m_1x_1¥right)}{dt}
+¥frac{1}{M}¥frac{d¥left(m_2x_2¥right)}{dt}} ¥¥ ¥¥
&=¥displaystyle{¥frac{p_1}{M}+¥frac{p_2}{M}}

<2-30> (2.4.13)
P=p_1+p_2

<2-31> (2.5.1)
m¥frac{d^2x}{dt^2}=m¥frac{dv}{dt}=F(x)

<2-32> (2.5.2)
¥frac{df(y(x))}{dx}=¥frac{df(y)}{dy}¥frac{dy(x)}{dx}

<2-33> (2.5.3)
T(v)=¥frac{m}{2}v^2

<2-34>
¥begin{array}{ll}
¥displaystyle{¥frac{dT}{dt}}&=¥displaystyle{¥frac{dT}{dv}¥frac{dv}{dt} }¥¥ ¥¥
&=¥displaystyle{¥frac{m}{2}¥frac{dv^2}{dv}¥frac{dv}{dt}}¥¥ ¥¥

&=¥displaystyle{¥frac{m}{2}(2v)¥frac{dv}{dt}} ¥¥ ¥¥
&=v¥displaystyle{¥left(m¥frac{dv}{dt}¥right)}
¥end{array}

<2-35>
¥frac{dT}{dt}=F(x)¥frac{dx}{dt}

<2-36>
¥int_{t_1}^{t_2}¥frac{dT}{dt}dt=¥int_{t_1}^{t_2}F(x)¥frac{dx}{dt}dt

<2-37>
¥begin{array}{rl}
¥displaystyle{¥int_{t_1}^{t_2}¥frac{dT}{dt}}dt&=¥displaystyle{¥int_{T_1}^{T_2}d} ¥¥ ¥¥
&=T_2-T_1
¥end{array}

<2-38>
¥int_{t_1}^{t_2}F(x)¥frac{dx}{dt}dt=¥int_{x_1}^{x_2}F(x)dx

<2-39> (2.5.4)
T_2-T_1=¥int_{x_1}^{x_2}F(x)dx

<2-40> (2.5.5)
¥int_{x_1}^{x_2}F(x)dx=-¥int_{x_2}^{x_1}F(x)dx

<2-41> (2.5.6)
F(x) =-¥frac{dV(x)}{dx}

<2-42> (2.5.7)
¥begin{array}{rl}
¥displaystyle{¥int_{x_1}^{x_2}F(x)dx}
&=-¥displaystyle{¥int_{x_1}^{x_2}¥frac{dV(x)}{dx}dx} ¥¥ ¥¥
&=V(x_1)-V(x_2)
¥end{array}

<2-43> (2.5.8)
T_1+V(x_1)=T_2+V(x_2)

<2-44>
¥int_{x_0}^{x}F(x)dx=V(x_0)-V(x)

<2-45> (2.5.9)
V(x)=V(x_0)+¥left[-¥int_{x_0}^{x}F(x)dx¥right]

<2-46>
¥begin{array}{l}
V(x_1)-V(x_2) ¥¥ ¥¥
¥quad=¥displaystyle{¥left[V(x_0)+¥left¥{-¥int_{x_0}^{x_1}F(x)dx¥right¥}¥right]-
¥left[V(x_0)+¥left¥{-¥int_{x_0}^{x_2}F(x)dx¥right¥}¥right]} ¥¥ ¥¥
¥quad=¥displaystyle{-¥int_{x_0}^{x_1}F(x)dx+¥int_{x_0}^{x_2}F(x)dx }¥¥ ¥¥
¥quad=¥displaystyle{+¥int_{x_1}^{x_0}F(x)dx+¥int_{x_0}^{x_2}F(x)dx }¥¥ ¥¥
¥quad=¥displaystyle{¥int_{x_1}^{x_2}F(x)dx}
¥end{array}

<2-47> (2.5.10)
V(x)=-¥int_{x_0}^{x}F(x)dx

<2-48> (2.5.11)
¥frac{m}{2}v^2+V(x)=E

<2-49> (2.6.1)
v^2=¥frac{2[E-V(x)]}{m}

<2-50> (2.6.2)
E-V(x)¥ge0

<2-51> (2.6.3)
¥mbox{When}¥quad a¥ge x¥ge b,¥quad v^2=¥frac{2[E-V(x)]}{m}¥ge

<2-52> (2.6.4)
v=¥frac{dx}{dt}=¥pm¥sqrt{¥frac{2}{m}}¥sqrt{E-V(x)}}

<2-53> (2.6.5)
¥begin{array}{rl}
¥displaystyle{¥int¥frac{1}{¥sqrt{E-V(x)}}}dx
&=¥displaystyle{¥sqrt{¥frac{2}{m}}¥int dt+C} ¥¥ ¥¥
&=¥displaystyle{¥sqrt{¥frac{2}{m}}t+C}
¥end{array}

<2-54> (2.6.6)
¥left¥{
¥begin{array}{l}
x(t)=x_0+v_0t ¥¥ ¥¥
v(t)=v_0
¥end{array}
¥right.

<2-55> (2.6.7)
¥frac{m}{2}v^2(t)=E

<2-56> (2.6.8)
E=¥frac{m}{2}v_0^2

<2-57> (2.6.9)
¥int¥frac{1}{¥sqrt{E}}dx=¥pm¥sqrt{¥frac{2}{m}}t+C

<2-58> (2.6.10)
¥sqrt{¥frac{2}{m}}¥frac{x}{v_0}=¥pm¥sqrt{¥frac{2}{m}}t+C

<2-59> (2.6.11)
C=¥sqrt{¥frac{2}{m}}¥frac{x_0}{v_0}

<2-60>
¥sqrt{¥frac{2}{m}}¥frac{x-x_0}{v_0}=¥pm¥sqrt{¥frac{2}{m}}t

<2-61>
x-x_0=¥pm¥sqrt{¥frac{2}{m}}t¥sqrt{¥frac{m}{2}}v_0=¥pm v_0t

<2-62> (2.6.12)
x=x_0¥pm v_0t

<2-63>
v(t)=¥frac{dx(t)}{dt}=¥pm v_0

<2-64> (2.6.13)
v(t)=v_0

<2-65> (2.6.14)
¥left¥{
¥begin{array}{l}
x(t)=x_0+v_0t ¥¥ ¥¥
v(t)=v_0
¥end{array}¥right.

<2-66> (2.7.1)
m¥frac{d^2x}{dt^2}=¥left¥{
¥begin{array}{l}
-R(v), ¥quad ¥mbox{when $v¥ge0$ travelling to the right} ¥¥ ¥¥
+R(v), ¥quad ¥mbox{when $v¥le0$ travelling to the left}
¥end{array}
¥right.

<2-67> (2.7.2)
m¥frac{dv}{dt}=-R(v)

<2-68> (2.7.3)
¥begin{array}{rl}
m¥displaystyle{¥int¥frac{1}{R(v)}dv}&=-¥displaystyle{¥int dt+C} ¥¥ ¥¥
&=-t+C
¥end{array*}

<2-69> (2.7.4)
R(v)=¥left¥{
¥begin{array}{ll}
¥alpha v&¥mbox{(for small v}} ¥¥ ¥¥
¥beta v^2&¥mbox{(for large v)}
¥end{array}¥right.

<2-70>
¥left¥{
¥begin{array}{ll}
m¥displaystyle{¥int¥frac{1}{¥alpha v}dv}=¥displaystyle{¥frac{m}{¥alpha}¥ln v}
=-t+C & ¥mbox{(for small v)} ¥¥ ¥¥
m¥displaystyle{¥int¥frac{1}{¥beta v^2}dv}=-¥displaystyle{¥frac{m}{¥beta v}}=-t+C} &
¥mbox{(for large v)}
¥end{array}¥right.

<2-71>
C=¥left¥{
¥begin{array}{ll}
¥displaystyle{¥frac{m}{¥alpha}}¥ln v_0 & ¥mbox{(for small v.)} ¥¥ ¥¥
-¥displaystyle{¥frac{m}{¥beta v_0}} & ¥mbox{(for large v.)}
¥end{array}¥right.

<2-72> (2.7.5)
v(t)=¥left¥{
¥begin{array}{ll}
v_0 e^{-¥alpha t} & ¥mbox{(for small v.)} ¥¥ ¥¥
-¥displaystyle{¥frac{v_0}{1+(¥beta/m)v_0t}} & ¥mbox{(for large v.)}
¥end{array}¥right.

<2-73> (2.7.6)
x(t)=¥left¥{
¥begin{array}{ll}
v_0¥displaystyle{¥int
e^{-(¥alpha/m)t}dt}+C'=-¥displaystyle{¥frac{mv_0}{¥alpha}}e^{-(¥alpha/m)t}+C’
& ¥mbox{(for small v.)} ¥¥ ¥¥
v_0¥displaystyle{¥int¥frac{1}{1+(¥beta/m)v_0t}}+C’
=¥frac{¥beta}{m}¥ln¥left(1+¥frac{v_0¥beta}{m}t¥right)+C’ & ¥mbox{(for large v.)}

¥end{array}¥right.

<2-74> (2.7.7)
C'=¥left¥{
¥begin{array}{ll}
x_0+¥displaystyle{¥frac{mv_0}{¥alpha}} & ¥mbox{(for small v.)} ¥¥ ¥¥
x_0 & ¥mbox{(for large v.)}
¥end{array}¥right.

<2-75> (2.7.8)
x(t)=¥left¥{
¥begin{array}{ll}
x_0+¥displaystyle{¥frac{mv_0}{¥alpha}}¥left[1-e^{-(¥alpha/m)t} ¥right]
& ¥mbox{(for small v.)} ¥¥ ¥¥
x_0+¥displaystyle{¥frac{¥beta}{m}}¥ln¥left(1+¥frac{v_0¥beta}{m}t¥right)
& ¥mbox{(for large v.)}
¥end{array}¥right.

<2-76>
x(t)¥rightarrow¥left¥{
¥begin{array}{ll}
x_0+¥displaystyle{¥frac{mv_0}{¥alpha}}& ¥mbox{(for small v.)} ¥¥ ¥¥
¥infty & ¥mbox{(for large v.)}
¥end{array}¥right.

<3-1> (3.1.1)
E=¥frac{m}{2}v^2+V(x)

<3-2> (3.1.2)
F(x)=-¥frac{dV(x)}{dx}

<3-3> (3.1.3)
F(x)=-kx

<3-4> (3.1.4)
m¥frac{d^2x}{dt^2}=-kx

<3-5> (3.1.5)
¥frac{d^2x}{dt^2}=-¥omega^2x

<3-6> (3.1.6)
x(t)=A¥sin(¥omega t+B)

<3-7> (3.1.7)
¥frac{dx}{dt}=A¥omega¥cos(¥omega t+B)

<3-8> (3.1.8)
¥left¥{
¥begin{array}{l}
a=A ¥sin B ¥¥ ¥¥
0=A¥omega¥cos B
¥end{array}
¥right.

<3-9> (3.1.9)
A=a,¥quad B=¥frac{¥pi}{2}

<3-10> (3.1.10)
¥left¥{
¥begin{array}{l}
x(t)=a ¥sin¥left(¥omega t+¥displaystyle{¥frac{¥pi}{2}}¥right)=a¥cos(¥omega t) ¥¥ ¥¥
v(t)=a ¥omega¥cos¥left(¥omega
t+¥displaystyle{¥frac{¥pi}{2}}¥right)=-a¥omega¥sin(¥omega t)
¥end{array}
¥right.

<3-11> (3.1.11)
V(x)=-¥int F(x)dx

<3-12> (3.1.12)
V(x)=-¥int (-kx)dx=¥frac{1}{2}kx^2

<3-13> (3.1.13)
F(x_0)=-V^{(1)}(x_0)¥equiv V^¥prime(x_0)=0

<3-14> (3.1.14)
¥begin{array}{rl}
V(x)=& V(x_0)+¥displaystyle{¥frac{V^{(1)}(x_0)}{1!}}(x-x_0)+
¥displaystyle{¥frac{V^{(2)}(x_0)}{2!}}(x-x_0)^2 ¥¥ ¥¥
& +¥displaystyle{¥frac{V^{(3)}(x_0)}{3!}}(x-x_0)^3+¥cdots
¥end{array}

<3-15> (3.1.15)
V(x)=V(x_0)+ ¥frac{V^{(2)}(x_0)}{2!}(x-x_0)^2

<3-16> (3.1.16)
V^{(2)}(x_0)¥equiv k¥quad¥mbox{(k is aconstant.)}

<3-17> (3.1.17)
V(x)=V(0)+¥frac{1}{2}kx^2

<3-18> (3.2.1)
m¥frac{d^2x}{dt^2}=-kx-¥alpha¥frac{dx}{dt}

<3-19> (3.2.2)
¥left¥{
¥begin{array}{l}
¥sqrt{¥displaystyle{¥frac{k}{m}}}=¥omega ¥¥ ¥¥
¥displaystyle{¥frac{¥alpha}{m}}=2¥gamma
¥end{array}
¥right.

<3-20> (3.2.3)
¥frac{d^2x}{dt^2}+2¥gamma¥frac{dx}{dt}+¥omega^2x=0

<3-21> (3.2.4)
x(t)=C_1e^{¥left(-¥gamma+¥sqrt{¥gamma^2-¥omega^2}¥right)t}+
C_2e^{¥left(-¥gamma-¥sqrt{¥gamma^2-¥omega^2}¥right)t}

<3-22> (3.2.5)
¥begin{array}{ll}
¥displaystyle{¥frac{dx(t)}{dt}}= & ¥left(-¥gamma+¥sqrt{¥gamma^2-¥omega^2}¥right)C_1
e^{¥left(-¥gamma+¥sqrt{¥gamma^2-¥omega^2}¥right)t} ¥¥ ¥¥
& +¥left(-¥gamma-¥sqrt{¥gamma^2-¥omega^2}¥right)C_2
e^{¥left(-¥gamma-¥sqrt{¥gamma^2-¥omega^2}¥right)t}
¥end{array}

<3-23> (3.2.6)
¥left¥{
¥begin{array}{l}
C_1+C_2=a ¥¥ ¥¥
¥left(-¥gamma+¥sqrt{¥gamma^2-¥omega^2}¥right)C_1
+¥left(-¥gamma-¥sqrt{¥gamma^2-¥omega^2}¥right)C_2=0
¥end{array}¥right.

<3-24> (3.2.7)
¥left¥{
¥begin{array}{l}
C_1=¥displaystyle{¥frac{1}{2}}¥left(1-¥displaystyle{
¥frac{¥gamma}{¥sqrt{¥gamma^2-¥omega^2}}}¥right)a ¥¥ ¥¥
C_2=¥displaystyle{¥frac{1}{2}}¥left(1+¥displaystyle{
¥frac{¥gamma}{¥sqrt{¥gamma^2-¥omega^2}}}¥right)a
¥end{array}¥right.

<3-25> (3.2.8)

¥begin{array}{rl}
x(t)=¥displaystyle{¥frac{a}{2}}&
¥left[¥left(1-¥displaystyle{¥frac{¥gamma}{¥sqrt{¥gamma^2-¥omega^2}}}
e^{¥left(-¥gamma+¥sqrt{¥gamma^2-¥omega^2}¥right)t} ¥right)¥right.¥¥ ¥¥
& +¥left.¥left(1+¥displaystyle{¥frac{¥gamma}{¥sqrt{¥gamma^2-¥omega^2}}}
e^{¥left(-¥gamma-¥sqrt{¥gamma^2-¥omega^2}¥right)t}¥right)¥right]
¥end{array}

<3-26> (3.2.9)
¥begin{array}{rl}
x(t)=¥displaystyle{¥frac{a}{2}}&
¥left[¥left(1-¥displaystyle{¥frac{¥gamma}{¥sqrt{¥gamma^2-¥omega^2}}}
e^{¥left(-¥gamma+¥sqrt{¥gamma^2-¥omega^2}¥right)t} ¥right)¥right.¥¥ ¥¥
& +¥left.¥left(1+¥displaystyle{¥frac{¥gamma}{¥sqrt{¥gamma^2-¥omega^2}}}
e^{¥left(-¥gamma-¥sqrt{¥gamma^2-¥omega^2}¥right)t}¥right)¥right]
¥end{array}

<3-27> (3.2.10)
¥begin{array}{rl}
x(t)=¥displaystyle{¥frac{a}{2}}e^{-¥gamma t}&
¥left[¥left(1+¥displaystyle{¥frac{i¥gamma}{¥sqrt{¥omega^2-¥gamma^2}}}
e^{¥left(i¥sqrt{¥omega^2-¥gamma^2}¥right)t} ¥right)¥right.¥¥ ¥¥
& +¥left.¥left(1-¥displaystyle{¥frac{i¥gamma}{¥sqrt{¥omega^2-¥gamma^2}}}
e^{¥left(-i¥sqrt{¥omega^2-¥gamma^2}¥right)t}¥right)¥right]
¥end{array}

<3-28> (3.2.11)
¥begin{array}{rl}
e^{¥pm i¥sqrt{¥omega^2-¥gamma^2}t}= & ¥cos¥left(¥sqrt{¥omega^2-¥gamma^2}t¥right)
¥¥ ¥¥
& ¥quad ¥pm i¥sin¥left(¥sqrt{¥omega^2-¥gamma^2}t¥right)
¥end{array}

<3-29> (3.2.12)
¥begin{array}{rl}
x(t)= ae^{-¥gamma t}& ¥left[¥cos¥left(¥sqrt{¥omega^2-¥gamma^2}t¥right)
¥right. ¥¥ ¥¥
& ¥quad¥left.-¥displaystyle{¥frac{¥gamma}{¥sqrt{¥omega^2-¥gamma^2}}
¥sin¥left(¥sqrt{¥omega^2-¥gamma^2}t¥right)¥right]
¥end{array}

<3-30> (3.3.1)
m¥frac{d^2x}{dt^2}=-kx+F¥cos(¥Omega t)

<3-31> (3.3.2)

¥frac{d^2x}{dt^2}+¥omega^2x=f¥cos(¥Omega t)

<3-32> (3.3.3)
x(t)=C_1e^{i¥omega t}+C_2 e^{-i¥omega t}+
¥frac{f}{¥left|¥Omega^2-¥omega^2¥right|} ¥cos(¥Omega t)

<3-33> (3.3.4)
¥begin{array}{rl}
¥displaystyle{¥frac{dx}{dt}}=i¥omega & ¥left(C_1e^{i¥omega t}-C_2 e^{-i¥omega t}¥right)
¥¥ ¥¥
& -¥displaystyle{¥frac{f¥Omega}{¥left|¥Omega^2-¥omega^2¥right|} }¥sin(¥Omega t)
¥end{array}

<3-34> (3.3.5)
i¥omega¥left(C_1-C_2 ¥right)=0

<3-35> (3.3.6)
x(t)=2C_1¥cos(¥omega t)+¥frac{f}{¥left|¥Omega^2-¥omega^2¥right|} ¥cos(¥Omega t)

<3-36>
C_1=¥frac{1}{2}¥left(a-¥frac{f}{¥left|¥Omega^2-¥omega^2¥right|}¥right)

<3-37>
¥cos A-¥cos B=-2¥cos¥left(¥frac{A+B}{2}¥right) ¥sin¥left(¥frac{A-B}{2}¥right)

<3-38> (3.3.7)
¥begin{array}{rl}
x(t)= & a¥cos(¥omega t) ¥¥ ¥¥
& ¥quad-¥displaystyle{¥frac{2f}{¥left|¥Omega^2-¥omega^2¥right|
¥sin¥left[¥left(¥displaystyle¥frac{¥Omega+¥omega}{2}¥right)t¥right]
¥sin¥left[¥left(¥displaystyle¥frac{¥Omega-¥omega}{2}¥right)t¥right]}
¥end{array}

<3-39> (3.4.1)
m¥frac{d^2x}{dt^2}=-kx-¥alpha¥frac{dx}{dt}+F¥cos(¥Omega t)

<3-40> (3.4.2)
¥frac{d^2x}{dt^2}+¥gamma¥frac{dx}{dt}+¥omega^2x=f¥cos(¥Omega t)

<3-41> (3.4.3)
¥begin{array}{rl}
x(t)= & e^{-¥gamma t}¥left[C_1e^{¥sqrt{¥gamma^2-¥omega^2}t}+
C_2e^{-¥sqrt{¥gamma^2-¥omega^2}t}¥right] ¥¥ ¥¥
& ¥quad+f¥cos¥left(¥Omega t-¥phi¥right)
¥end{array}

<3-42> (3.4.4)
¥tan¥phi=¥displaystyle{¥frac{2¥gamma¥Omega}{¥omega^2-¥Omega^2}}

<3-43>
¥frac{m}{2}v^2+V(x)=¥frac{m}{2}a^2¥omega^2¥equiv E

<4-1> (4.1.1)
¥begin{equation*}
¥vec{r}=¥vec{i}x+¥vec{j}y
¥end{equation*}

<4-2> (4.1.2)
¥vec{r}=¥vec{i}x+¥vec{j}y+¥vec{k}z

<4-3> (4.1.3)
¥vec{r}=¥vec{i}x+¥vec{j}y

<4-4> (4.1.4)
¥left¥{
¥begin{array}{rl}
& x=r¥cos¥theta ¥¥ ¥¥
& y=r¥sin¥theta
¥end{array}
¥right.

<4-5> (4.1.5)
¥left¥{
¥begin{array}{l}
r=¥sqrt{x^2+y^2} ¥¥ ¥¥
¥theta=¥tan^{-1}¥left(¥displaystyle{¥frac{y}{x}}¥right)
¥end{array}
¥right.

<4-6> (4.1.6)
¥rho=r¥cos¥left(¥frac{¥pi}{2}-¥theta¥right)=r¥sin¥theta

<4-7> (4.1.7)
¥left¥{
¥begin{array}{l}
x=¥rho¥cos¥phi ¥¥ ¥¥
y=¥rho¥sin¥phi
¥end{array}
¥right.

<4-8> (4.1.8)
¥left¥{
¥begin{array}{l}
x=r¥sin¥theta¥cos¥phi ¥¥ ¥¥
y=r¥sin¥theta¥sin¥phi
¥end{array}
¥right.

<4-9> (4.1.9)
z=r¥cos¥theta

<4-10> (4.1.10)
¥left¥{
¥begin{array}{l}
x=r¥sin¥theta¥cos¥phi ¥¥ ¥¥
y=r¥sin¥theta¥sin¥phi ¥¥ ¥¥
z=r¥cos¥theta
¥end{array}
¥right.,¥quad
(-¥pi¥le¥theta<¥pi, 0¥le¥phi<2¥pi)

<4-11> (4.1.11)
¥left¥{
¥begin{array}{l}
r=¥sqrt{x^2+y^2+z^2} ¥¥ ¥¥
¥theta=¥tan^{-1}¥left(¥displaystyle{¥frac{x^2+y^2}{z}}¥right) ¥¥ ¥¥
¥phi=¥tan^{-1}¥left(¥displaystyle{¥frac{y}{x}}¥right)
¥end{array}
¥right.

<4-12>
¥vec{F}=¥vec{i}F_x+¥vec{j}F_y+¥vec{k}F_z

<4-13> (4.2.1)
¥left.
¥begin{array}{l}
¥displaystyle{m¥frac{d^2x(t)}{dt^2}=F_x} ¥¥ ¥¥
¥displaystyle{m¥frac{d^2y(t)}{dt^2}=F_y} ¥¥ ¥¥
¥displaystyle{m¥frac{d^2z(t)}{dt^2}=F_z}
¥end{array}¥right¥} ¥quad ¥rightarrow¥quad
¥displaystyle{m¥frac{d^2¥vec{r}(t)}{dt^2}=¥vec{F}}

<4-14> (4.2.2)
¥left¥{
¥begin{array}{l}

¥vec{r}(0)¥equiv¥vec{r}_0=¥vec{i}0+¥vec{j}h+¥vec{k}0 ¥¥ ¥¥
¥vec{v}(0)¥equiv¥vec{v}_0=¥vec{i}v_0¥cos¥theta+¥vec{j}v_0¥sin¥theta+¥vec{k}0
¥end{array}¥right.

<4-15>
¥vec{r}(t)=¥vec{i}x(t)+¥vec{j}y(t)+¥vec{k}z(t)

<4-16> (4.2.3)
m¥frac{d^2¥vec{r}(t)}{dt^2}=¥vec{F}

<4-17> (4.2.4)
¥vec{F}=-¥vec{j}mg

<4-18> (4.2.5)
¥left¥{
¥begin{array}{l}
m¥displaystyle{¥frac{d^2x(t)}{dt^2}}=0 ¥¥ ¥¥
m¥displaystyle{¥frac{d^2y(t)}{dt^2}}=-mg¥¥ ¥¥
m¥displaystyle{¥frac{d^2z(t)}{dt^2}}=0
¥end{array}¥right.

<4-19> (4.2.6)
¥left¥{
¥begin{array}{l}
¥left¥{¥begin{array}{l}
x(t)=(v_0¥cos¥theta)t ¥¥ ¥¥
v_x(t)=v_0¥cos¥theta
¥end{array}¥right. ¥¥ ¥¥
¥left¥{¥begin{array}{l}
y(t)=h+(v_0¥sin¥theta)t-¥displaystyle{¥frac{1}{2}}gt^2 ¥¥ ¥¥
v_y(t)=v_0¥sins¥theta-gt
¥end{array}¥right. ¥¥ ¥¥
¥left¥{¥begin{array}{l}
z(t)=0 ¥¥ ¥¥ v_z(t)=0
¥end{array}¥right.
¥end{array}¥right.

<4-20> (4.2.7)
¥left¥{
¥begin{array}{l}
x(t)=(v_0¥cos¥theta)t ¥¥ ¥¥
y(t)=h+(v_0¥sin¥theta)t-¥displaystyle{¥frac{1}{2}}gt^2
¥end{array}¥right.

<4-21>
t=¥frac{v_0¥sin¥theta+¥sqrt{v_0^2¥sin^2¥theta+2gh}}{g}

<4.22> (4.2.8)
y=-¥frac{g}{2v_0^2¥cos^2¥theta}(x-X)^2+¥frac{v_0^2¥sin^2¥theta}{2g}

<4-23>
X=¥frac{v_0^2¥sin(2¥theta)}{2g}

<4-24>
y=¥frac{v_0^2¥sin^2¥theta}{2g}

<4-25>
¥left(¥frac{dr}{dt},¥frac{d¥theta}{dt}¥equiv¥omega¥right)

<4-26> (4.3.1)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{dx}{dt}=¥frac{dr}{dt}¥cos¥theta-r¥omega¥sin¥theta} ¥¥ ¥¥
¥displaystyle{¥frac{dy}{dt}=¥frac{dr}{dt}¥sin¥theta+r¥omega¥cos¥theta}
¥end{array}¥right.

<4-27>
¥frac{df(x(t))}{dt}=¥frac{df(x)}{dx}¥frac{dx(t)}{dt}

<4-28>
¥frac{dx}{dt}¥cos¥theta+¥frac{dy}{dt}¥sin¥theta=¥frac{dr}{dt}

<4-29>
-¥frac{dx}{dt}¥sin¥theta+¥frac{dy}{dt}¥cos¥theta=r¥omega

<4-30> (4.3.2)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{dr}{dt}=¥frac{dx}{dt}¥cos¥theta+¥frac{dy}{dt}¥sin¥theta} ¥¥ ¥¥
r¥displaystyle{¥frac{d¥theta}{dt}=-¥frac{dx}{dt}¥sin¥theta+¥frac{dy}{dt}¥cos¥theta}
¥end{array}¥right.

<4-31> (4.3.3)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{d^2x}{dt^2}=¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)¥cos¥theta
-¥left(r¥frac{d¥omega}{dt}+2¥frac{dr}{dt}¥omega¥right)¥sin¥theta} ¥¥ ¥¥
¥displaystyle{¥frac{d^2y}{dt^2}=¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)¥sin¥theta
+¥left(r¥frac{d¥omega}{dt}+2¥frac{dr}{dt}¥omega¥right)¥cos¥theta}

¥end{array}¥right.

<4-32>
¥frac{d^2x}{dt^2}¥cos¥theta+¥frac{d^2y}{dt^2}¥sin¥theta
=¥frac{d^2r}{dt^2}-r¥omega^2

<4-33>
-¥frac{d^2x}{dt^2}¥sin¥theta+¥frac{d^2y}{dt^2}¥cos¥theta
=r¥frac{d¥omega}{dt}+2¥frac{dr}{dt}¥omega

<4-34>
¥frac{d¥{f(t)g(t)¥}}{dt}=¥frac{df(t)}{dt}g(t)+f(t)¥frac{dg(t)}{dt}

<4-35>
¥frac{d(r^2¥omega)}{dt}=2r¥frac{dr}{dt}¥omega+r^2¥frac{d¥omega}{dt}

<4-36>
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{d^2r}{dt^2}-r¥omega^2=¥frac{d^2x}{dt^2}¥cos¥theta+¥frac{d^2y}{dt^2}
¥sin¥theta} ¥¥ ¥¥
¥displaystyle{¥frac{1}{r}¥frac{d(r^2¥omega)}{dt}=-¥frac{d^2x}{dt^2}¥sin¥theta+¥frac{d^2y}{
dt^2}¥cos¥theta}
¥end{array}¥right.

<4-37> (4.3.5)
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥frac{d^2x}{dt^2}=F_x} ¥¥ ¥¥
¥displaystyle{m¥frac{d^2y}{dt^2}=F_y}
¥end{array}¥right.

<4-38> (4.3.6)
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)
=F_x¥cos¥theta+F_y¥sin¥theta} ¥¥ ¥¥
¥displaystyle{m¥frac{1}{r}¥frac{d(r^2¥omega)}{dt}
=-F_x¥sin¥theta+F_y¥cos¥theta}
¥end{array}¥right.

<4-39> (4.3.7)
¥vec{F}=¥frac{¥vec{r}}{r}f.

<4-40> (4.3.8)
¥vec{F}=-¥frac{¥vec{r}}{r}F

<4-41>
¥frac{¥vec{r}}{r}=¥vec{i}¥cos¥theta+¥vec{j}¥sin¥theta

<4-42>
¥vec{F}=-¥vec{i}F¥cos¥theta-¥vec{j}F¥sin¥theta

<4-43> (4.3.9)
¥left¥{
¥begin{array}{l}
F_x=-F¥cos¥theta ¥¥ ¥¥
F_y=-F¥sin¥theta
¥end{array}¥right.

<4-44> (4.3.10)
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)=-F }¥¥ ¥¥
¥displaystyle{¥frac{m}{r}¥frac{d(r^2¥omega)}{dt}=0}
¥end{array}¥right.

<4-45> (4.3.11)
m¥frac{d^2r}{dt^2}=-F+¥frac{mC^2}{r^3}

<4-46> (4.3.12)
F=¥frac{mC^2}{¥ell ^3}

<4-47>
r^2¥omega=¥ell ^2¥omega=C

<4-48> (4.3.13)
¥omega=¥frac{C}{¥ell ^2}=¥mbox{constant}¥equiv¥omega_0

<4-49> (4.4.1)
¥vec{F}=¥vec{j}mg

<4-50> (4.4.2)
¥vec{S}=-¥frac{¥vec{r}}{r}S

<4-51> (4.4.3)
m¥frac{d^2¥vec{r}}{dt^2}=¥vec{F}+¥vec{S}

<4,52> (4.4.4)
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥frac{d^2x}{dt^2}=-¥frac{x}{r}S }¥¥ ¥¥
¥displaystyle{m¥frac{d^2y}{dt^2}=mg-¥frac{y}{r}S }¥¥ ¥¥
¥displaystyle{m¥frac{d^2z}{dt^2}=0
¥end{array}¥right.

<4.53> (4.4.5)
¥left¥{
¥begin{array}{l}
x=¥ell¥sin¥phi¥¥ ¥¥
y=¥ell¥cos¥phi
¥end{array}¥right.

<4-54> (4.4.6)
¥left¥{
¥begin{array}{l}
x=¥ell ¥phi¥¥ ¥¥
y=¥ell
¥end{array}¥right.

<4-55> (4.4.7)
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥frac{d^2x}{dt^2}=-¥frac{x}{¥ell}S }¥¥ ¥¥
0=mg-S
¥end{array}¥right.

<4-56>
¥frac{d^2x}{dt^2}=-¥frac{g}{¥ell}x

<4-57> (4.4.8)
¥omega=¥sqrt{¥frac{g}{¥ell}}

<4-58> (4.4.9)
¥frac{d^2x}{dt^2}=-¥omega^2x

<4-59> (4.4.10)
x(t)=A¥sin(¥omega t+B)

<4-60> (4.4.11)
x(t)=a¥cos(¥omega t)

<4-61> (4.4.12)
¥left¥{
¥begin{array}{l}
¥omega=¥displaystyle{¥sqrt{¥frac{g}{¥ell}}}¥¥ ¥¥
T=2¥pi ¥displaystyle{¥sqrt{¥frac{¥ell}{g}}}
¥end{array}¥right.

<4-62> (4.4.13)
m¥frac{d^2¥vec{r}}{dt^2}=-k¥vec{r}¥quad¥Rightarrow¥quad¥left¥{
¥begin{array}{l}
¥displaystyle{m¥frac{d^2x}{dt^2}=-kx} ¥¥ ¥¥
¥displaystyle{m¥frac{d^2y}{dt^2}=-ky}
¥end{array}¥right.

<4-63> (4.4.14)
¥left¥{
¥begin{array}{l}
x(t)=a_1¥sin(¥omega t+b_1) ¥¥ ¥¥
y(t)=a_2¥sin(¥omega t+b_2)
¥end{array}¥right.

<4-64>
¥sin(A+B)=¥sin A¥cos B+¥cos A¥sin B

<4-65>
¥sin¥omega t=¥frac{1}{¥sin (b_2-b_1)}¥left(¥frac{x}{a_1}¥sin b_2
-¥frac{y}{a_2}¥sin b_1¥right)

<4-66>
¥cos¥omega t=¥frac{1}{¥sin (b_2-b_1)}¥left(-¥frac{x}{a_1}¥cos b_2
+¥frac{y}{a_2}¥cos b_1¥right)

<4-67>
¥cos(A+B)=¥cos A¥cos B-¥sin A¥sin B

<4-68> (4.4.15)
¥sin^2(b_2-b_1)=¥frac{x^2}{a_1^2}+¥frac{y^2}{a_2^2}
-2¥frac{x}{a_1}¥frac{y}{a_2}¥cos(b_2-b_1)

<4-69> (4.4.16)
1=¥frac{x^2}{a_1^2}+¥frac{y^2}{a_2^2}

<4-70> (4.5.1)
m¥frac{d^2¥vec{r}(t)}{dt^2}=¥vec{F}(x,y,z)

<4-71> (4.5.2)
m¥frac{d¥vec{v}}{dt}=¥vec{F}(x,y,z)

<4-72> (4.5.3)
m¥left(¥vec{v}¥cdot¥frac{d¥vec{v}}{dt}¥right)=¥vec{v}¥cdot¥vec{F}(x,y,z)

<4-73> (4.5.4)
¥vec{v}¥cdot¥vec{v}=v_x^2+ v_y^2+ v_z^2¥equiv v^2

<4-74> (4.5.5)
¥begin{array}{rl}
¥displaystyle{¥frac{d(v^2)}{dt}}
&=¥displaystyle{¥frac{d(v_x^2+ v_y^2+ v_z^2)}{dt}} ¥¥ ¥¥
&=2¥displaystyle{¥left(v_x¥frac{dv_x}{dt}+ v_y¥frac{dv_y}{dt}+
v_z¥frac{dv_z}{dt}¥right) }¥¥ ¥¥
&=2¥displaystyle{¥left(¥vec{v}¥cdot¥frac{d¥vec{v}}{dt¥right)}
¥end{array}¥right.

<4-75> (4.5.6)
¥frac{m}{2}¥frac{dv^2}{dt}=¥frac{d¥left(m¥vec{v}^2/2¥right)}{dt}}
=¥vec{v}¥cdot¥vec{F}(x,y,z)

<4-76> (4.5.7)
¥int_{t_1}^{t_2}¥frac{dT}{dt}dt=¥int_{t_1}^{t_2}¥left¥{¥vec{v}¥cdot¥vec{F}(x,y,z)¥right¥}dt

<4-77> (4.5.8)
¥int_{T_1}^{T_2}dT=T_2-T_1

<4-78> (4.5.9)
¥begin{array}{rl}
¥displaystyle{¥int_{t_1}^{t_2}¥vec{v}¥cdot¥vec{F}(x,y,z)dt}
&=¥displaystyle{¥int_{t_1}^{t_2}¥frac{dx}{dt}F_xdt+¥int_{t_1}^{t_2}¥frac{dy}{dt}F_ydt
+¥int_{t_1}^{t_2}¥frac{dz}{dt}F_zdt} ¥¥ ¥¥
&=¥displaystyle{¥int_{x_1}^{x_2}F_xdx+¥int_{y_1}^{y_2}F_ydy
+¥int_{z_1}^{z_2}F_zdz} ¥¥ ¥¥
&¥equiv¥displaystyle{¥int_{P_1}^{P_2}¥left(F_xdx+F_ydy+F_zdz¥right)}
¥end{array}

<4-79> (4.5.10)
T_2-T_1=¥int_{P_1}^{P_2}¥left(F_xdx+F_ydy+F_zdz¥right)

<4-80> (4.5.11)
¥left.¥begin{array}{l}
F_x¥equiv¥displaystyle{-¥frac{¥partial V(x,y,z)}{¥partial x} ¥¥ ¥¥
F_y¥equiv¥displaystyle{-¥frac{¥partial V(x,y,z)}{¥partial y} ¥¥ ¥¥

F_z¥equiv¥displaystyle{-¥frac{¥partial V(x,y,z)}{¥partial z}
¥end{array}¥right¥}¥quad¥rightarrow¥quad
¥vec{F}=-¥mbox{grad}V(x,y,z)

<4-81> (4.5.12)
¥int_{P_1}^{P_2}¥vec{F}¥cdot d¥vec{S}=-¥int_{P_1}^{P_2}¥mbox{grad}V(x,y,z)¥cdot d¥vec{S}

<4-82>
d¥vec{S}=¥vec{i}dx+¥vec{j}dy+¥vec{k}dz

<4-83> (4.5.13)
¥mbox{grad}V(x,y,z)¥cdot d¥vec{S}=¥frac{¥partial V}{¥partial x}dx
+¥frac{¥partial V}{¥partial y}dy+¥frac{¥partial V}{¥partial z}dz

<4-84> (4.5.14)
¥begin{array}{rl}
dV(x,y,z)&=V(x+dx,y+dy,z+dz)-V(x,y,z) ¥¥ ¥¥
&=¥displaystyle{¥frac{¥partial V}{¥partial x}dx
+¥frac{¥partial V}{¥partial y}dy+¥frac{¥partial V}{¥partial z}dz}
¥end{array}

<4-85> (4.5.15)
¥int_{P_1}^{P_2}¥vec{F}¥cdot d¥vec{S}
=-¥int_{P_1}^{P_2}dV=V_1-V_2

<4-86>
T_2-T_1=V_1-V_2

<4-87> (4.5.16)
T_1+V_1=T_2+V_2

<4-88> (4.6.1)
¥vec{L}(t)= ¥vec{r}(t)¥times¥vec{p}(t)

<4-89> (4.6.2)
¥left|¥vec{L}¥right|= ¥left|¥vec{r}¥right|¥left|¥vec{p}¥right|¥sin¥theta

<4-90> (4.6.3)
¥vec{r}(t)= ¥vec{i}x+ ¥vec{j}y+ ¥vec{k}z

<4-91> (4.6.4)
¥vec{F}(r)= ¥vec{e}_rf(r)

<4-92> (4.6.5)
¥vec{e}_r= ¥frac{1}{r}¥vec{r}=¥frac{¥vec{r}}{r}

<4-93>
¥left(¥vec{e}_r¥cdot¥vec{e}_r ¥right)

<4-94> (4.6.6)
¥left¥{¥begin{array}{l}
x=r¥sin¥theta¥cos¥phi ¥¥ ¥¥
y=r¥sin¥theta¥sin¥phi ¥¥ ¥¥
z=r¥cos¥theta
¥end{array}¥right.,¥quad¥left¥{¥begin{array}{l}
r=¥displaystyle{¥sqrt{x^2+y^2+z^2}} ¥¥ ¥¥
¥theta=¥displaystyle{¥tan^{-1}¥frac{¥sqrt{x^2+y^2}}{z}} ¥¥ ¥¥
¥phi=¥displaystyle{¥tan^{-1}¥frac{y}{x}}
¥end{array}¥right.

<4-95> (4.6.7)
¥vec{r}¥times¥vec{F}(r)=0

<4-96> (4.6.8)
m¥frac{d^2¥vec{r}}{dt^2}=¥vec{F}

<4-97> (4.6.9)
m¥frac{d¥vec{v}}{dt}=¥vec{F}

<4-98> (4.6.10)
m¥left(¥vec{r}¥times¥frac{d¥vec{v}}{dt}¥right)
= ¥vec{r}¥times ¥vec{F}=0

<4-99>
¥begin{array}{rl}
¥displaystyle{¥frac{d¥left(¥vec{r}¥times¥vec{v}¥right)}{dt}}
&=¥displaystyle{¥frac{d¥vec{r}}{dt}¥times¥vec{v}+{¥vec{r}¥times¥frac{d¥vec{v}}{dt}} ¥¥ ¥¥
&= ¥displaystyle{¥vec{v}¥times¥vec{v}+{¥vec{r}¥times¥frac{d¥vec{v}}{dt}} ¥¥ ¥¥
&=¥displaystyle{{¥vec{r}¥times¥frac{d¥vec{v}}{dt}}
¥end{array}

<4-100> (4.6.11)
¥begin{array}{rl}
¥displaystyle{m¥left(¥vec{r}¥times ¥frac{d¥vec{v}}{dt}¥right)}
&=¥displaystyle{¥frac{d¥left(¥vec{r}¥times¥vec{p}¥right)}{dt}} ¥¥ ¥¥
&= ¥displaystyle{ ¥frac{d¥vec{L}}{dt}} ¥¥ ¥¥
&=0
¥end{array}

<4-101> (4.6.12)
m¥frac{d^2¥vec{r}}{dt^2}=¥vec{F}¥quad¥rightarrow¥quad¥left¥{

¥begin{array}{l}
¥displaystyle{m¥frac{d^2x}{dt^2}}=F_x ¥¥ ¥¥
¥displaystyle{m¥frac{d^2y}{dt^2}}=F_y
¥end{array}

<4-102> (4.6.13)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{dx}{dt}=¥frac{dr}{dt}¥cos¥theta-r¥frac{d¥theta}{dt}¥sin¥theta ¥¥ ¥¥
¥displaystyle{¥frac{dy}{dt}=¥frac{dr}{dt}¥sin¥theta+r¥frac{d¥theta}{dt}¥cos¥theta
¥end{array}¥right.

<4-103> (4.6.14)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{d^2x}{dt^2}=¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)¥cos¥theta
-¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)¥sin¥theta ¥¥ ¥¥
¥displaystyle{¥frac{d^2y}{dt^2}=¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)¥sin¥theta
+¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)¥cos¥theta
¥end{array}¥right.

<4-104>
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)¥cos¥theta
-m¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)¥sin¥theta=F_x} ¥¥ ¥¥
¥displaystyle{m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)¥sin¥theta
+m¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)¥cos¥theta =F_y}
¥end{array}¥right.

<4-105> (4.6.15)
¥left¥{
¥begin{array}{l}
¥displaystyle{m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)
=F_x¥cos¥theta+F_y¥sin¥theta} ¥¥ ¥¥
¥displaystyle{m¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)
=-F_x¥sin¥theta+F_y¥cos¥theta }
¥end{array}¥right.

<4-106> (4.6.16)
¥left¥{
¥begin{array}{l}
¥displaystyle{F_x¥cos¥theta+F_y¥sin¥theta=F_r} ¥¥ ¥¥
¥displaystyle{-F_x¥sin¥theta+F_y¥cos¥theta=F_¥theta }
¥end{array}¥right.

<4-107> (4.6.17)
m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)=F_r

<4-108> (4.6.18)
m¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)=F_¥theta

<4-109> (4.6.19)
¥left¥{
¥begin{array}{l}
¥displaystyle{F_x=¥frac{x}{r}f(r)=f(r)¥cos¥theta} ¥¥ ¥¥
¥displaystyle{F_y=¥frac{y}{r}f(r)=f(r)¥sin¥theta}
¥end{array}¥right.

<4-110> (4.6.20)
¥left¥{
¥begin{array}{rl}
F_r&=F_x¥cos¥theta+F_y¥sin¥theta ¥¥ ¥¥
&=f(r)¥cos^2¥theta+f(r)¥sin^2¥theta ¥¥ ¥¥
&=f(r) ¥¥ ¥¥
F_¥theta&=-F_x¥sin¥theta+F_y¥cos¥theta ¥¥ ¥¥
&=-f(r)¥cos¥theta¥sin¥theta+f(r)¥sin¥theta¥cos¥theta ¥¥ ¥¥
&=0
¥end{array}¥right.

<4-111> (4.6.21)
m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)=f(r)

<4-112> (4.6.22)
m¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)=0

<4-113>
¥frac{d¥left(f(t)g(t)¥right)}{dt}=¥frac{df(t) }{dt}g(t)+f(t)¥frac{dg(t) }{dt}

<4-114>
¥begin{array}{rl}
¥displaystyle{¥frac{d(r^2¥omega)}{dt}}&=¥displaystyle{2r¥frac{dr}{dt}¥omega+r^2¥frac{d¥omega}{dt}} ¥¥ ¥¥
&=¥displaystyle{r¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)}
¥end{array}¥right.

<4-115> (4.6.23)
¥frac{m}{r}¥frac{d(r^2¥omega)}{dt}=0

<4-116> (4.6.24)
mr^2¥omega=h

<4-117>
¥vec{a}¥times¥vec{b}=¥vec{i} (a_yb_z-a_zb_y)
+¥vec{j} (a_zb_x-a_xb_z)+¥vec{k} (a_xb_y-a_yb_x)

<4-118> (4.6.25)
L_z=xp_y-yp_x=m¥left(x¥frac{dy}{dt}-y¥frac{dx}{dt}¥right)

<4-119> (4.6.26)
¥begin{array}{rl}
L_z&=¥displaystyle{mr¥cos¥theta¥left(¥frac{dr}{dt}¥sin¥theta+r¥omega¥cos¥theta¥right)
- mr¥sin¥theta¥left(¥frac{dr}{dt}¥cos¥theta-r¥omega¥sin¥theta¥right)} ¥¥ ¥¥
&=mr^2¥omega
¥end{array}

<4-120>
¥begin{array}{rl}
¥displaystyle{¥frac{dA}{dt}}
&=¥displaystyle{ ¥frac{d¥left(¥displaystyle{¥frac{r^2¥theta}{2}}¥right)}{dt}} ¥¥ ¥¥
&=¥displaystyle{¥frac{r^2}{2}¥frac{d¥theta}{dt}} ¥¥ ¥¥
&=¥displaystyle{¥frac{r^2}{2}¥omega}
¥end{array}

<4-121> (4.6.27)
L_z=2m¥frac{dA}{dt}

<4-122> (4.7.1)
¥vec{F}=¥frac{¥vec{r}}{r}¥frac{K}{r^2}

<4-123> (4.7.2)
¥left¥{¥begin{array}{l}
F_x=¥displaystyle{ K¥frac{¥cos¥theta}{r^2}} ¥¥ ¥¥
F_y=¥displaystyle{ K¥frac{¥sin¥theta}{r^2}} ¥¥ ¥¥
¥end{array}¥right.

<4-124> (4.7.3)
¥left¥{¥begin{array}{rl}
F_r&=F_x¥cos¥theta+F_y¥sin¥theta ¥¥ ¥¥
&=¥displaystyle{ K¥frac{¥cos^2¥theta}{r^2}+ K¥frac{¥sin^2¥theta}{r^2}} ¥¥ ¥¥
&=¥displaystyle{ ¥frac{K}{r^2}} ¥¥ ¥¥
F_¥theta&=- F_x¥sin¥theta+F_y¥cos¥theta ¥¥ ¥¥
&=¥displaystyle{-K¥frac{¥cos¥theta}{r^2}¥sin¥theta+ K¥frac{¥sin¥theta}{r^2}¥cos¥theta}
¥¥ ¥¥
&=0
¥end{array}¥right.

<4-125> (4.7.4)
m¥left(¥frac{d^2r}{dt^2}-r¥omega^2¥right)= ¥frac{K}{r^2}

<4-126> (4.7.5)
m¥left(2¥frac{dr}{dt}¥omega+r¥frac{d¥omega}{dt}¥right)=0

<4-127> (4.7.6)
m¥frac{dv}{dt}-¥frac{h^2}{mr^3}-¥frac{K}{r^2}=0

<4-128> (4.7.7)
m¥frac{dv}{dt}=¥frac{h^2}{mr^3}+¥frac{K}{r^2}

<4-129> (4.7.8)
mv¥frac{dv}{dt}-¥frac{h^2}{mr^3}v-¥frac{K}{r^2}v=0

<4-130>
¥frac{d¥left(¥displaystyle{¥frac{m}{2}}v^2¥right)}{dt}=mv¥frac{dv}{dt}

<4-131>
¥begin{array}{rl}
¥displaystyle{¥frac{d¥left(¥displaystyle{¥frac{h^2}{2mr^2}}¥right)}{dt}}
&=¥displaystyle{¥frac{d¥left(¥displaystyle{¥frac{h^2}{2mr^2}}¥right)}{dr}¥frac{dr}{dt}¥righ
t)}¥¥ ¥¥
&=-¥displaystyle{¥frac{h^2}{mr^3}}v
¥end{array}

<4-132>
¥begin{array}{rl}
¥displaystyle{¥frac{d¥left(¥displaystyle{-¥frac{K}{r}}¥right)}{dt}}
&=¥displaystyle{¥frac{d¥left(¥displaystyle{-¥frac{K}{r}}¥right)}{dr}
¥frac{dr}{dt}¥right)}¥¥ ¥¥
&=¥displaystyle{¥frac{K}{r^2}}v
¥end{array}

<4-133> (4.7.9)
¥frac{d}{dt}¥left(¥frac{m}{2}}v^2+¥frac{h^2}{2mr^2}}+¥frac{K}{r}¥right)=0

<4-134> (4.7.10)
¥frac{m}{2}v^2+¥frac{h^2}{2mr^2}}+¥frac{K}{r}=E

<4-135> (4.7.11)
¥frac{K}{r}=V(r)

<4-136>
¥nabla V(r)=¥vec{i}¥frac{¥partial V(r)}{¥partial x}

+¥vec{j}¥frac{¥partial V(r)}{¥partial y}
+¥vec{k}¥frac{¥partial V(r)}{¥partial z}

<4-137>
¥begin{array}{rl}
¥displaystyle{¥frac{¥partial V(r)}{¥partial x}}}
&=¥displaystyle{¥frac{dV(r)}{dr}}¥displaystyle{¥frac{¥partial r}{¥partial x}}}¥¥ ¥¥
&=¥displaystyle{-¥frac{K}{r^2}}¥displaystyle{-¥frac{2x}{2¥sqrt{x^2+y^2}}} ¥¥ ¥¥
&=¥displaystyle{-¥frac{K}{r^2}}¥displaystyle{¥frac{x}{r}}}
¥end{array}

<4-138>
¥frac{¥partial V(r)}{¥partial x}=-¥frac{K}{r^2}¥frac{x}{r}

<4-139>
¥nabla V(r)= -¥left(¥vec{i}¥frac{x}{r}+¥vec{j}¥frac{y}{r}¥right)¥frac{K}{r^2}

<4-140>
¥vec{e}_r=¥frac{¥vec{r}}{r}

<4-141> (4.7.12)
¥nabla V(r)= -¥vec{e}_r ¥frac{K}{r^2}

<4-142> (4.7.13)
¥vec{F}=-¥nabla V(r)

<4-143> (4.7.14)
v=¥pm¥frac{2}{m}¥sqrt{E-¥frac{h^2}{2mr^2}-¥frac{K}{r}

<4-144> (4.7.15)
E¥ge¥frac{h^2}{2mr^2}+¥frac{K}{r}

<4-145> (4.7.16)
Er^2-Kr-¥frac{h^2}{2m}¥ge0

<4-146>
r=¥frac{K}{2E}

<4-147>
¥frac{mK^2+h^2E}{2mE}

<4-148>
D=K^2-¥frac{2h^2E}{m}

<4-149> (4.7.17)
¥left¥{
¥begin{array}{l}
¥displaystyle{r_1=¥frac{1}{2E}¥left[K-¥sqrt{K^2-¥frac{2h^2E}{m}}¥right]} ¥¥ ¥¥
¥displaystyle{r_2=¥frac{1}{2E}¥left[K+¥sqrt{K^2-¥frac{2h^2E}{m}}¥right]}
¥end{array}¥right.

<4-150> (4.7.18)
¥frac{dr}{dt}=¥pm¥frac{2}{m}¥sqrt{E-¥frac{h^2}{2mr^2}-¥frac{K}{r}}

<4-151> (4.7.19)
mr^2¥omega=h

<4-152> (4.7.20)
r=¥frac{p}{1-e¥sin(¥theta-¥theta_0)},¥quad¥left¥{
¥begin{array}{l}
p=-¥displaystyle{¥frac{h^2}{mK}} ¥¥ ¥¥
e=¥displaystyle{¥sqrt{1+¥frac{2Eh^2}{mK^2}}}
¥end{array}¥right.

<4-153> (4.8.1)
¥left¥{
¥begin{array}{l}
¥vec{F}_{21}=-¥displaystyle{¥frac{¥vec{r}_2-¥vec{r}_1}{¥left|¥vec{r}_2-¥vec{r}_1¥right|}
¥frac{GmM}{¥left|¥vec{r}_2-¥vec{r}_1¥right|^2}}¥¥ ¥¥
¥vec{F}_{12}=-¥displaystyle{¥frac{¥vec{r}_1-¥vec{r}_2}{¥left|¥vec{r}_1-¥vec{r}_2¥right|}
¥frac{GmM}{¥left|¥vec{r}_1-¥vec{r}_2¥right|^2}}
¥end{array}¥right.

<4-154> (4.8.2)
¥left¥{
¥begin{array}{l}
m¥displaystyle{¥frac{d^2¥vec{r}_2}{dt^2}}=¥vec{F}_{21} ¥¥ ¥¥
M¥displaystyle{¥frac{d^2¥vec{r}_1}{dt^2}}=¥vec{F}_{12}
¥end{array}¥right.

<4-155>
m¥frac{d^2¥vec{r}}{dt^2}=-¥vec{e}_r¥frac{GmM}{r^2}

<4-156> (4.8.3)
E=¥frac{m}{2}¥left(¥frac{dr}{dt}¥right)^2+¥frac{h^2}{2mr^2}-¥frac{GmM}{r}

<4-157> (4.8.4)
r=¥frac{p}{1+e¥cos¥theta},¥quad¥mbox{where}¥left¥{
¥begin{array}{l}

p=¥displaystyle{¥frac{h^2}{Gm^2M}} ¥¥ ¥¥
e=¥displaystyle{¥sqrt{1-¥frac{2|E|h^2}{G^2m^3M^2}}}
¥end{array}¥right.

<4-158> (4.8.5)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{p}{1-e^2}=¥frac{GmM}{2|E|}=a} ¥¥ ¥¥
¥displaystyle{¥frac{p}{¥sqrt{1-e^2} }=¥frac{h}{¥sqrt{m|E|}}=b} ¥¥ ¥¥
¥displaystyle{¥frac{ep}{e^2-1}=x_0}
¥end{array}¥right.

<4-159> (4.8.6)
¥frac{(x-x_0)^2}{a^2}+¥frac{y^2}{b^2}=1

<4-160> (4.8.7)
A=¥pi ab

<4-161>
¥frac{dA}{dt}=¥frac{1}{2}r^2¥frac{d¥theta}{dt}

<4-162>
mr^2¥frac{d¥theta}{dt}=h

<4-163>
¥frac{dA}{dt}=¥frac{h}{2m}

<4-164> (4.8.8)
T=¥frac{A}{(h/2m)}=¥frac{2¥pi mab}{h}

<4-165> (4.8.9)
b^2=¥frac{2h^2}{Gm^2M}a

<4-166> (4.8.10)
T^2=¥frac{8¥pi^2}{GM}a^3

<4-167> (4.9.1)
F=G¥frac{Mm}{R^2}

<4-168> (4.9.2)
¥left¥{
¥begin{array}{l}
G=6.67¥times10^{-11}¥left[¥mbox{m}^3¥mbox{s}^{-2}¥mbox{kg}^{-1}¥right] ¥¥ ¥¥
M=5.97¥times10^{24}¥left[¥mbox{kg}¥right] ¥¥ ¥¥
R=6.38¥times10^6¥left[¥mbox{m}¥right]

¥end{array}¥right.

<4-169> (4.9.3)
g=G¥frac{M}{R^2}=9.8¥left[¥mbox{m}/¥mbox{s}^{2}¥right]

<4-170> (4.9.4)
F=mg

<4-171>
¥pi¥times¥frac{5}{180}¥sim0.0873

<4-172>
¥pi¥times¥frac{10}{180}¥sim0.1745

<4-173>
¥sin5^¥circ¥sim0.0872

<4-174>
¥sin10^¥circ¥sim0.1736

<5-1> (5.1.1)
¥left¥{
¥begin{array}{l}
m_1¥displaystyle{¥frac{d^2¥vec{r}_1(t)}{dt^2}}
=¥vec{F}_{21}（｜¥vec{r}_2-¥vec{r}_1｜）¥¥ ¥¥
m_2¥displaystyle{¥frac{d^2¥vec{r}_2(t)}{dt^2}}
=¥vec{F}_{12}（｜¥vec{r}_1-¥vec{r}_2｜）
¥end{array}¥right.

<5-2>
｜¥vec{r}_1-¥vec{r}_2 ｜=｜¥vec{r}_2-¥vec{r}_1｜¥equiv r

<5-3> (5.1.2)
¥vec{F}_{21}（r）=-¥vec{F}_{12}（r）

<5-4> (5.1.3)
¥left¥{
¥begin{array}{l}
¥vec{p}_1(t)=m_1¥displaystyle{¥frac{d¥vec{r}_1(t)}{dt}}
¥equiv m_1¥vec{v}_1(t) ¥¥ ¥¥
¥vec{p}_2(t)=m_2¥displaystyle{¥frac{d¥vec{r}_2(t)}{dt}}
¥equiv m_2¥vec{v}_2(t)
¥end{array}¥right.

<5-5> (5.1.4)
¥left¥{
¥begin{array}{l}
¥displaystyle{¥frac{d¥vec{p}_1(t)}{dt}}= ¥vec{F}_{21}(r) ¥¥ ¥¥
¥displaystyle{¥frac{d¥vec{p}_2(t)}{dt}}= ¥vec{F}_{12}(r)
¥end{array}¥right.

<5-6> (5.1.5)
¥frac{d¥vec{p}_1(t)}{dt}+¥frac{d¥vec{p}_2(t)}{dt}=0

<5-7> (5.1.6)
¥vec{P}(t) =¥vec{p}_1(t) +¥vec{p}_2(t)

<5-8> (5.1.7)
¥frac{d¥vec{P}(t)}{dt}=0

<5-9> (5.1.8)
¥vec{P}(t) =¥vec{P}_0

<5-10> (5.1.9)
¥vec{R}(t)=¥frac{m_1¥vec{r}_1(t)+ m_2¥vec{r}_2(t)}{m_1+m_2}

<5-11>
¥begin{array}{rl}
¥displaystyle{¥frac{d¥vec{R}}{dt}}
&=¥displaystyle{¥frac{m_1}{m_1+m_2}¥frac{d¥vec{r}_1}{dt}
+¥frac{m_2}{m_1+m_2}¥frac{d¥vec{r}_2}{dt}} ¥¥ ¥¥
&=¥displaystyle{¥frac{1}{m_1+m_2}}¥left(¥vec{p}_1+¥vec{p}_2¥right) ¥¥ ¥¥
&=¥displaystyle{¥frac{1}{ m_1+m_2}}¥vec{P}
¥end{array}

<5-12> (5.1.10)
¥vec{P}(t)=(m_1+m_2)¥frac{d¥vec{R}(t)}{dt}

<5-13> (5.1.11)
¥begin{array}{l}
¥displaystyle{m_1¥frac{d^2¥vec{r}_1(t)}{dt^2}
=¥vec{F}_{21}(r_{21})+¥vec{F}_{31}(r_{31})+¥cdots+¥vec{F}_{N1}(r_{N1})} ¥¥ ¥¥
¥displaystyle{m_2¥frac{d^2¥vec{r}_2(t)}{dt^2}
=¥vec{F}_{12}(r_{12})+¥vec{F}_{32}(r_{32})+¥cdots+¥vec{F}_{N2}(r_{N2})} ¥¥ ¥¥
¥cdots¥cdots¥cdots¥cdots¥cdots ¥¥ ¥¥
¥displaystyle{m_N¥frac{d^2¥vec{r}_N(t)}{dt^2}
=¥vec{F}_{1N}(r_{1N})+¥vec{F}_{2N}(r_{2N})+¥cdots+¥vec{F}_{N-1,N}(r_{N-1,N})}
¥end{array}

<5-14> (5.1.12)
¥left¥{
¥begin{array}{l}
¥vec{p}_1(t) =m_1¥displaystyle{¥frac{d¥vec{r}_{1}(t)}{dt}}¥equiv m_1¥vec{v}_1(t) ¥¥ ¥¥
¥vec{p}_2(t) =m_2¥displaystyle{¥frac{d¥vec{r}_{2}(t) }{dt}}¥equiv m_2¥vec{v}_2(t) ¥¥ ¥¥
¥cdots¥cdots¥cdots¥cdots¥cdots ¥¥ ¥¥
¥vec{p}_N(t) =m_N¥displaystyle{¥frac{d¥vec{r}_{N}(t) }{dt}}¥equiv m_N¥vec{v}_N(t)
¥end{array}¥right.

<5-15> (5.1.13)
¥left¥{¥begin{array}{l}
¥displaystyle{¥frac{d¥vec{p}_1(t)}{dt}}=¥vec{F}_{21}(r_{21})+¥vec{F}_{31}(r_{31})+¥cdots
+¥vec{F}_{N1}(r_{N1}) ¥¥ ¥¥
¥displaystyle{¥frac{d¥vec{p}_2(t)}{dt}}=¥vec{F}_{12}(r_{12})+¥vec{F}_{32}(r_{32})+¥cdots
+¥vec{F}_{N2}(r_{N2}) ¥¥ ¥¥
¥cdots¥cdots¥cdots¥cdots¥cdots ¥¥ ¥¥
¥displaystyle{¥frac{d¥vec{p_N}(t)}{dt}}=¥vec{F}_{1N}(r_{1N})+¥vec{F}_{2N}(r_{2N})+¥cdots
+¥vec{F}_{N-1,N}(r_{N-1,N})
¥end{array}¥right.

<5-16> (5.1.14)
¥vec{F}_{ij}(r_{ij})=-¥vec{F}_{ji}(r_{ji})=-¥vec{F}_{ji}(r_{ij})

<5-17> (5.1.15)
¥frac{d¥vec{P}(t)}{dt}=0

<5-18> (5.1.16)
¥vec{P}(t)=¥vec{p}_1(t)+ ¥vec{p}_2(t)+¥cdots+¥vec{p}_N(t)

<5-19> (5.1.17)
¥vec{R}(t)=¥frac{m_1¥vec{r}_1(t)+m_2¥vec{r}_2(t)+¥cdots+m_N¥vec{r}_N(t)}
{m_1+ m_2+¥cdots+ m_N}

<5-20> (5.1.18)
¥vec{P}(t)= (m_1+ m_2+¥cdots+ m_N)¥frac{d¥vec{R}(t) }{dt}

<5-21> (5.2.1)
¥vec{r}_1(t)-¥vec{r}_2(t)¥equiv¥vec{r}(t)

<5-22> (5.2.2)
¥left¥{
¥begin{array}{l}
m_1¥displaystyle{¥frac{d^2¥vec{r}_{1}(t)}{dt}}=¥vec{F}_{21}(r) ¥¥ ¥¥
m_2¥displaystyle{¥frac{d^2¥vec{r}_{2}(t)}{dt}}=¥vec{F}_{12}(r)
¥end{array}¥right.

<5-23>
¥vec{F}_{21}(r) ¥equiv ¥vec{F} (r)

<5-24>
m_1m_2¥frac{d^2¥vec{r}(t)}{dt^2}}=(m_1+m_2)¥vec{F} (r)

<5-25> (5.2.3)
¥mu=¥frac{m_1m_2}{m_1+m_2}

<5-26> (5.2.4)
¥mu¥frac{d^2¥vec{r}(t)}{dt^2}}=¥vec{F} (r)

<5-27> (5.2.5)
M¥frac{d^2¥vec{R}}{dt^2}}=0

<5-28>
¥left¥{
¥begin{array}{l}
m_1¥displaystyle{¥frac{d^2¥vec{r}_{1}(t)}{dt^2}}
=¥vec{F}_{21}(¥left|¥vec{r}_1-¥vec{r}_2¥right|) ¥¥ ¥¥
m_2¥displaystyle{¥frac{d^2¥vec{r}_{2}(t)}{dt^2}}
=¥vec{F}_{12}(¥left|¥vec{r}_2-¥vec{r}_1¥right|)
¥end{array}¥right.

<5-29>
¥left¥{
¥begin{array}{l}
M¥displaystyle{¥frac{d^2¥vec{R}(t)}{dt^2}}=0 ¥¥ ¥¥
¥mu¥displaystyle{¥frac{d^2¥vec{r}(t)}{dt^2}}=¥vec{F} (r)
¥end{array}¥right.

<5-30> (5.2.6)
¥left¥{
¥begin{array}{l}
¥vec{R}(t)=¥displaystyle{¥frac{m_1¥vec{r}_1(t)+ m_2¥vec{r}_2(t)}{ m_1+ m_2}} ¥¥ ¥¥
¥vec{r}(t)=¥vec{r}_1(t)-¥vec{r}_2 (t)
¥end{array}¥right.

<5-31>
¥vec{F}(r)¥equiv¥vec{F}_{21} (|¥vec{r}_1-¥vec{r}_2|)
=- ¥vec{F}_{12} (|¥vec{r}_2-¥vec{r}_1|)

<5-32> (5.2.7)
¥left¥{¥begin{array}{l}
¥displaystyle{¥vec{r}_1=¥vec{R}+¥frac{m_2}{M}¥vec{r}} ¥¥ ¥¥

¥displaystyle{¥vec{r}_2=¥vec{R}-¥frac{m_1}{M}¥vec{r}}
¥end{array}¥right.

<5-33> (5.2.8)
¥begin{array}{rl}
¥displaystyle{¥frac{m_1¥vec{v}_1^2}{2}}+¥displaystyle{¥frac{m_2¥vec{v}_2^2}{2}}
&=¥displaystyle{¥frac{m_1}{2}¥left(¥frac{d¥vec{R}}{dt}
+¥frac{¥vec{m_2}}{M}¥frac{d¥vec{r}}{dt}¥right)^2}
+¥frac{m_2}{2}¥left(¥frac{d¥vec{R}}{dt}
-¥frac{¥vec{m_1}}{M}¥frac{d¥vec{r}}{dt}¥right)^2} ¥¥ ¥¥
&=¥displaystyle{¥frac{M}{2}¥left(¥frac{d¥vec{R}}{dt}¥right)^2
+¥frac{¥mu}{2}¥left(¥frac{d¥vec{r}}{dt}¥right)^2}
¥end{array}

<5-34> (5.3.1)
¥begin{array}{rl}
¥displaystyle{m¥frac{d^2x_A}{dt^2}}
&=F_A+f_A ¥¥ ¥¥
&=-kx_A+k(x_B-x_A) ¥¥ ¥¥
&=-2kx_A+kx_B
¥end{array}

<5-35> (5.3.2)
¥begin{array}{rl}
¥displaystyle{m¥frac{d^2x_B}{dt^2}}
&=F_B+f_B ¥¥ ¥¥
&=-kx_B-k(x_B-x_A) ¥¥ ¥¥
&=kx_A-2kx_B
¥end{array}

<5-36>
¥frac{(¥ell+x_A)+(2¥ell+x_B)}{2}=¥frac{x_A+x_B}{2}+¥frac{3}{2}¥ell

<5-37>
(2¥ell+x_B)-(¥ell+x_A)=x_B-x_A+¥ell

<5-38> (5.3.3)
¥left¥{¥begin{array}{rl}
X&=¥displaystyle{¥frac{(x_A+¥ell)+(x_B+2¥ell)}{2}}-¥frac{3¥ell}{2}¥¥ ¥¥
&=¥displaystyle{¥frac{x_A+x_B}{2}} ¥¥ ¥¥
x&=¥displaystyle{(x_B-x_A+¥ell)-¥ell} ¥¥ ¥¥
&=¥displaystyle{x_B-x_A}
¥end{array}¥right.

<5-39> (5.3.4)
M¥frac{d^2X}{dt^2}=-2kX

<5-40> (5.3.5)
¥mu¥frac{d^2x}{dt^2}=-¥frac{3k}{2}x

<5-41> (5.3.6)
X(t)=A¥sin(¥Omega t+B)

<5-42>
¥Omega=¥sqrt¥frac{2k}{M}}

<5-43> (5.3.7)
x(t)=a¥sin(¥omega t+b)

<5-44>
¥omega=¥sqrt{¥frac{3k}{2¥mu}}

<5-45> (5.3.8)
¥left¥{¥begin{array}{l}
x_A=X-¥displaystyle{¥frac{x}{2}}¥¥ ¥¥
x_B=X+¥displaystyle{¥frac{x}{2}}
¥end{array}¥right.

<5-46> (5.3.9)
¥left¥{¥begin{array}{l}
¥displaystyle{x_A=A¥sin(¥Omega t+B)-¥frac{a}{2}¥sin(¥omega t+b)}¥¥ ¥¥
¥displaystyle{x_B= A¥sin(¥Omega t+B)+¥frac{a}{2}¥sin(¥omega t+b)}
¥end{array}¥right.

<5-47> (5.4.1)
¥left¥{¥begin{array}{l}
¥vec{r}=¥vec{r}_1-¥vec{r}_2¥¥ ¥¥
¥displaystyle{¥vec{R}= ¥frac{m_1¥vec{r}_1+m_2¥vec{r}_1}{m_1+m_2}}
¥end{array}¥right.

<5-48> (5.4.2)
¥left¥{¥begin{array}{l}
¥vec{v}=¥vec{v}_1-¥vec{v}_2¥¥ ¥¥
¥displaystyle{¥vec{V}= ¥frac{m_1¥vec{v}_1+m_2¥vec{v}_1}{M}}
¥end{array}¥right.

<5-49> (5.4.3)
¥left¥{¥begin{array}{l}
¥displaystyle{¥vec{v}_1=¥vec{V}+¥frac{m_2}{M}¥vec{v}}¥¥ ¥¥

¥displaystyle{¥vec{v}_2=¥vec{V}-¥frac{m_1}{M}¥vec{v}}
¥end{array}¥right.

<5-50> (5.4.4)
¥begin{array}{rl}
K&=¥displaystyle{¥frac{m_1}{2}¥vec{v}_1^2+¥frac{m_2}{2}¥vec{v}_2^2} ¥¥ ¥¥
&=¥displaystyle{¥frac{m_1}{2}¥left(¥vec{V}+¥frac{m_2¥vec{v}}{M}¥right)^2+
¥frac{m_2}{2}¥left(¥vec{V}-¥frac{m_1¥vec{v}}{M}¥right)^2} ¥¥ ¥¥
&=¥displaystyle{¥frac{M}{2}¥vec{V}^2+¥frac{m_1m_2}{2(m_1+m_2)}¥vec{v}^2} ¥¥ ¥¥
&=¥displaystyle{¥frac{M}{2}¥vec{V}^2+¥frac{¥mu}{2}¥vec{v}^2}
¥end{array}

<5-51> (5.4.5)
¥left¥{¥begin{array}{l}
¥vec{v}^¥prime=¥vec{v}_1^¥prime -¥vec{v}_2 ^¥prime ¥¥ ¥¥
¥displaystyle{¥vec{V}^¥prime =¥frac{m_1¥vec{v}_1^¥prime +m_2¥vec{v}_1^¥prime }{M}}
¥end{array}¥right.

<5-52> (5.4.6)
¥left¥{¥begin{array}{l}
¥displaystyle{¥vec{v}_1^¥prime=¥vec{V}^¥prime+¥frac{m_2}{M}¥vec{v}^¥prime} ¥¥ ¥¥
¥displaystyle{¥vec{v}_2^¥prime=¥vec{V}^¥prime-¥frac{m_1}{M}¥vec{v}^¥prime}
¥end{array}¥right.

<5-53> (5.4.7)
¥begin{array}{rl}
K^¥prime &=¥displaystyle{¥frac{m_1}{2}}¥vec{v}_1^{¥prime 2}+¥frac{m_2}{2}
¥vec{v}_2^{¥prime2}}¥¥ ¥¥
&=¥displaystyle{¥frac{M}{2}}¥vec{V}^{¥prime2}+¥frac{¥mu}{2}¥vec{v}^{¥prime2}}
¥end{array}

<5-54>
¥vec{P}=m_1¥vec{v}_1+m_2¥vec{v}_2=M¥vec{V}

<5-55>
¥vec{P}^¥prime =m_1¥vec{v}_1^¥prime +m_2¥vec{v}_2^¥prime =M¥vec{V}^¥prime

<5-56> (5.4.8)
K^¥prime=¥frac{M}{2}}¥vec{V}^{2}+¥frac{¥mu}{2}}¥vec{v}^{¥prime2}

<5-57> (5.4.9)
K-K^¥prime=¥frac{¥mu}{2}}¥vec{v}^{2}
¥left[1-¥frac{¥left(¥vec{v}_1^¥prime-¥vec{v}_2^¥prime¥right)^2}{ ¥left(¥vec{v}_1 -¥vec{v}_2
¥right)^2}¥right]

<5-58> (5.4.10)
e=¥frac{|¥vec{v}_1^¥prime-¥vec{v}_2^¥prime|}{|¥vec{v}_1 -¥vec{v}_2|}

<5-59> (5.4.11)
K-K^¥prime=¥frac{¥mu}{2}(1-e^2)

<5-60> (5.4.12)
0¥le e¥le 1

<5-61> (5.4.13)
e=-¥frac{¥vec{v}_1^¥prime-¥vec{v}_2^¥prime}{¥vec{v}_1 -¥vec{v}_2}

<5-62> (5.4.14)
¥begin{array}{l}
mv_1+mv_2=mv_1^¥prime+ mv_2^¥prime ¥¥ ¥¥
¥quad¥Rightarrow¥quad v_1+v_2= v_1^¥prime+ v_2^¥prime
¥end{array}

<5-63> (5.4.15)
¥begin{array}{l}
¥displaystyle{¥frac{1}{2}mv_1^2+¥frac{1}{2}mv_2^2=¥frac{1}{2}mv_1^{¥prime2}+
¥frac{1}{2}mv_2^{¥prime2}} ¥¥ ¥¥
¥quad¥Rightarrow¥quad v_1^2+v_2^2= v_1^{¥prime2}+ v_2^{¥prime2}
¥end{array}

<5-64> (5.4.16)
v_1^¥prime=v_2^¥prime

<5-65>
(v_1+v_2)^2-2v_1v_2=(v_1^¥prime+v_2^¥prime)^2-2 v_1^¥prime v_2^¥prime

<5-66> (5.4.17)
v_1v_2=v_1^¥prime v_2^¥prime

<5-67>
(v_1-v_2)^2=(v_1^¥prime-v_2^¥prime)^2

<5-68> (5.4.18)
¥left¥{
¥begin{array} {ll}
(1) & v_1-v_2=v_1^¥prime-v_2^¥prime ¥¥ ¥¥
(2) & v_1-v_2=-(v_1^¥prime-v_2^¥prime)
¥end{array}¥right.

<5-69> (5.4.19)
¥begin{array} {rl}
mv_1+mv_2&=mv_1^¥prime+mv_2^¥prime ¥¥ ¥¥
&=2mv_1^¥prime ¥¥ ¥¥
&=2mv_2^¥prime
¥end{array}

<5-70> (5.4.20)
v_1^¥prime=v_2^¥prime=¥frac{v_1+v_2}{2}

<5-71>
|¥vec{a}|=¥sqrt{¥vec{a}¥cdot¥vec{a}}

<5-72>
|¥vec{a}|=¥sqrt{a_x^2+ a_y^2+ a_z^2}

<6-1> (6.1.1)
¥begin{array}{l}
|¥vec{r}_i-¥vec{r}_j|=a ¥¥ ¥¥
¥quad(i=1,2,¥ldots,n; j=1,2,¥ldots,n;i¥ne j)
¥end{array}

<6-2> (6.1.2)
¥vec{r}=¥frac{m(¥vec{r}_1+¥vec{r}_2+¥cdots+¥vec{r}_n)}{M}

<6-3> (6.2.1)
¥left¥{¥begin{array}{l}
x_k=a_k¥cos¥theta_k ¥¥ ¥¥
y_k=a_k¥sin¥theta_k
¥end{array}¥right.

<6-4> (6.2.2)
¥vec{v}_k=¥vec{i}v_{kx}+¥vec{j}v_{ky}+¥vec{k}v_{kz}

<6-5> (6.2.3)
¥left¥{¥begin{array}{l}
¥displaystyle{v_{kx}=¥frac{dx_k}{dt}=-a_k¥omega¥sin¥theta_k } ¥¥ ¥¥
¥displaystyle{v_{ky}=¥frac{dy_k}{dt}=a_k¥omega¥cos¥theta_k} ¥¥ ¥¥
¥displaystyle{v_{kz}=¥frac{dz_k}{dt}=0}
¥end{array}¥right.

<6-6> (6.2.4)
v_k=¥sqrt{v_{kx}^2+ v_{ky}^2+ v_{kz}^2}=a_k¥omega

<6-7>
¥vec{l}_k=¥vec{r}_k¥times¥vec{p}_k

<6-8> (6.2.5)
¥left¥{¥begin{array}{ll}
¥vec{l}_k&=m¥left[¥vec{i}(y_kv_{kz}-z_kv_{ky})+¥vec{j}(z_kv_{kx}-x_kv_{kz})¥right.¥¥ ¥¥
&¥quad+¥left.¥vec{k}(x_kv_{ky}-y_kv_{kx})¥right]¥¥ ¥¥
&=¥vec{k}(ma_k^2¥omega)
¥end{array}¥right.

<6-9> (6.2.6)
¥vec{l}=¥sum_{k=1}^{n}¥vec{l}_k
=¥vec{k}¥left(¥sum_{k=1}^{n}ma_k^2¥right)¥omega

<6-10> (6.2.7)
I=¥sum_{k=1}^{n}ma_k^2

<6-11> (6.2.8)
¥vec{l}=¥vec{k}I¥omega

<6-12> (6.2.9)
¥vec{l}=¥sum_{k=1}^{n}¥vec{l}_k=I¥vec{¥omega}

<6-13>
¥vec{l}_k=¥vec{r}_k¥times¥vec{p}_k

<6-14>
¥frac{d¥vec{l}_k}{dt}=¥frac{d¥vec{r}_k}{dt}¥times¥vec{p}_k
+¥vec{r}_k¥times¥frac{d¥vec{p}_k}{dt}

<6-15>
¥frac{d¥vec{r}_k}{dt}= ¥vec{v}_k=¥frac{1}{m}¥vec{p}_k

<6-16> (6.2.10)
¥frac{d¥vec{l }_k}{dt}=¥vec{r}_k¥times¥vec{F}¥equiv¥vec{N}

<6-17>
I¥frac{d¥vec{¥omega}}{dt}=¥frac{d¥vec{l}_k}{dt}

<6-18> (6.2.11)
I¥frac{d¥vec{¥omega}}{dt}=¥vec{N}

<6-19> (6.2.12)
¥vec{¥omega}=¥mbox{a constant vector}

<6-20>
¥left(¥vec{N}_1=¥vec{r}_1¥times¥vec{F}_1, ¥vec{N}_2=¥vec{r}_2¥times¥vec{F}_2,¥ldots, ¥vec{N}_n=¥vec{r}_n¥times¥vec{F}_n¥right)

<6-21> (6.2.13)
I¥frac{d¥vec{¥omega}}{dt}=¥sum_{k=1}^{n} ¥left(¥vec{r}_k¥times¥vec{F}_k¥right)
=¥sum_{k=1}^{n} ¥vec{N}_k

<6-22> (6.3.1)
I=I_G+Md^2

<6-23> (6.3.2)
I_z=I_x+I_y

<6-24> (6.4.1)
I_1= M¥ell^2

<6-25> (6.4.2)
¥begin{array}{rl}
I_2&=¥displaystyle{M¥left(¥frac{¥ell}{2}¥right)^2+ M¥left(¥frac{¥ell}{2}¥right)^2} ¥¥ ¥¥
&=¥displaystyle{¥frac{M¥ell^2}{2}
¥end{array}

<6-26> (6.4.3)
¥begin{array}{rl}
I_2&=¥displaystyle{I_1-2M¥left(¥frac{¥ell}{2}¥right)^2} ¥¥ ¥¥
&= ¥displaystyle{M¥ell^2-2M¥left(¥frac{¥ell}{2}¥right)^2} ¥¥ ¥¥
&=¥displaystyle{ ¥frac{M¥ell^2}{2}}
¥end{array}

<6-27> (6.4.4)
¥begin{array}{rl}
I_1&=¥displaystyle{m¥left[¥left(¥frac{¥ell}{2N}¥right)^2+¥left(2¥frac{¥ell}{2N}¥right)^2
+¥ldots+¥left(2N¥frac{¥ell}{2N}¥right)^2¥right]} ¥¥ ¥¥
&= ¥displaystyle{ m¥left(¥frac{¥ell}{2N}¥right)^2¥left[1^2+2^2+¥ldots+(2N)^2¥right]}
¥¥ ¥¥
&=¥displaystyle{ ¥frac{m¥ell^2}{4N^2}¥times¥frac{(2N)(2N+1)(4N+1)}{6}} ¥¥ ¥¥
&=¥displaystyle{ ¥frac{M¥ell^2}{8N^3}¥times¥frac{(2N)(2N+1)(4N+1)}{6}}
¥quad(¥because 2m=M)
¥end{array}

<6-28> (6.4.5)
¥sum_{k=1}^{N} k^2=¥frac{N(N+1)(2N+1)}{6}

<6-29>
I_1=¥frac{M¥ell^2}{8}¥frac{2¥{2+(1/N)¥}¥{4+(1/N)¥}}{6}

<6-30>
I_1=¥frac{1}{3}M¥ell^2

<6-31> (6.4.7)
¥begin{array}{rl}
I_2&=¥displaystyle{2¥times m¥left[¥left(¥frac{¥ell}{2N}¥right)^2
+¥left(2¥frac{¥ell}{2N}¥right)^2+¥cdots+¥left(N¥frac{¥ell}{2N}¥right)^2¥right]} ¥¥ ¥¥
&=¥displaystyle{ 2¥times¥frac{M¥ell^2}{8N^3}¥times¥frac{(2N)(2N+1)(4N+1)}{6}}
¥quad(¥because 2m=M)
¥end{array}

<6-32> (6.4.8)
I_2=¥frac{1}{12}M¥ell^2

<6-33> (6.4.9)
I_1=I_2+M¥left(¥frac{ ¥ell}{2}¥right)^2

<6-34> (6.4.10)
I_2=I_1-M¥left(¥frac{ ¥ell}{2}¥right)^2=¥frac{1}{12}M¥ell^2

<6-35>
¥frac{1}{3}M¥ell^2

<6-36>
¥frac{1}{12}M¥ell^2

<6-37>
M¥ell^2

<6-38>
¥frac{1}{2}M¥ell^2

<6-39>
¥frac{1}{8}Mb^2

<6-40>
¥frac{M}{8}(a^2+b^2)

<6-41>

¥frac{M}{4}a^2

<6-42>
¥frac{M}{2}a^2

<6-43>
¥frac{2M}{5}a^2

<6-44>
¥frac{M}{4}a^2+¥frac{M}{3}h^2

<6-45>
¥frac{M}{2}a^2