problem 1 a
let vxf be x the x component of the railcar' s final velocity

In[546]:=
```
Reduce[M vxf + 2 m (vxf + u) == 0, vxf][[2]][[2]] /. {m → 1, M → 10, u → 1}
```

Out[546]= $vxf == -\frac{1}{6}$

Problem 1b: let vx1 be the x component of the railcar's velocity after first elephant has jumped. Let vxf be the x component of the railcar's velocity after second elephant has jumped.

In[547]:=
```
Reduce[{(M + m) vx1 + m (vx1 + u) == 0, (M + m) vx1 == M vxf + m (vxf + u)},
   {vxf, vx1}][[5]][[2]] /. {m → 1, M → 10, u → 1}
```

Out[547]= $vxf == -\frac{23}{132}$

Problem 8a: angular momentum is constant, because the string is not able to exert a torque on the particle, since the force exerted by the string is directed along the line connecting the particle to the axis of rotation.

In[551]:=
```
Reduce[{i0 omega0 == i1 omega1, i0 == m r0^2, i1 == m r1^2}, {omega1}][[1]][[4]]
```

Out[551]= $omega1 == \frac{omega0\ r0^2}{r1^2}$

The force exerted by the string on the particle has only a radial component, no azimuthal component. We can use Newton's 2nd law written in 2D polar coordinates. There is only one force acting on the mass. It is the tension force exerted by the string, and it points radially inward (in the -rhat direction). The radius is changing at constant rate v, so r''[t]==0.

In[605]:=
```
fr == m (r''[t] - r[t] omega[t]^2) == -tension;
tension == r[t] omega[t]^2;
r[t] == r0 - v t;
fphi == m (r[t] omega'[t] + 2 r'[t] omega[t]) == 0;
(r0 - v t) omega'[t] == - 2 v omega[t];
omega'[t] / omega[t] == -2 v / (r0 - v t);
(* the above can be integrated by separation of variables *)
ClearAll["Global`*"];
omega = DSolve[{(r0 - t v) omega′[t] == -2 v omega[t], omega[0] == omega0},
    omega[t], t][[1]][[1]][[2]]
```

Out[612]= $\frac{omega0\ (r0 - t\ v)^2}{r0^2}$

In[613]:=
```
F[t] == tension == r[t] omega[t]^2 == (r0 - v t) (omega[t])^2;
tension = (r0 - v t) omega^2
```

Out[614]= $\frac{\text{omega0}^2 (\text{r0} - t\,v)^5}{\text{r0}^4}$

Problem 2a

```
Tan[thetamax] == mu
```

Problem 2b

In[648]:=
```
(* downhill (call it "x") component of newton's 2nd law *)
m a Cos[theta] == m g Sin[theta] + fxstatic;
(* upward normal (call it "y") component of newton's 2nd law *)
m a Sin[theta] == - m g Cos[theta] + fnormal;
ClearAll["Global`*"];
fnormal = Reduce[m a Sin[theta] == - m g Cos[theta] + fnormal , fnormal][[2]]
```

Out[651]= m (g Cos[theta] + a Sin[theta])

In[663]:=
```
amax = Reduce[m a Cos[theta] == m g Sin[theta] + mu fnormal, a][[2]][[2]][[2]]
```

Out[663]= $\frac{-g\,\text{mu}\,\text{Cos}[\text{theta}] - g\,\text{Sin}[\text{theta}]}{-\text{Cos}[\text{theta}] + \text{mu}\,\text{Sin}[\text{theta}]}$

In[664]:=
```
amin = Reduce[m a Cos[theta] == m g Sin[theta] - mu fnormal, a][[2]][[2]][[2]]
```

Out[664]= $\frac{-g\,\text{mu}\,\text{Cos}[\text{theta}] + g\,\text{Sin}[\text{theta}]}{\text{Cos}[\text{theta}] + \text{mu}\,\text{Sin}[\text{theta}]}$

In[668]:=
```
amax /. {g → 9.8, mu -> 0.1, theta → 30 Degree}
```

Out[668]= 7.04476

In[667]:=
```
amin /. {g → 9.8, mu -> 0.1, theta → 30 Degree}
```

Out[667]= 4.42269