a) $\vec{F} = q\vec{E}$ +1 for relation btwn F, E

If $\vec{E} = E\hat{y}$, i.e. $+\hat{y}$ is up

$\vec{F} = -qE\hat{y} \Rightarrow my'' = -QE$. Let $g = \frac{QE}{m}$. 1 for right sign/ direction

Then $y'' = -g$. Looks just like freefall!

+1 for having an equation that demonstrates const. acceleration

Our initial conditions are $y'(0) = v_0 \sin\theta$ +1 for initial conditions

$y(0) = 0$. So $y(t) = -\frac{g}{2}t^2 + v_0 \sin\theta\, t$. +0.5 for correct soln for height as function of time (fine to just use equation given)

$y(t) = 0 \Rightarrow t_i = 0$ or $\frac{g}{2}t_f = v_0 \sin\theta \Rightarrow t_f = \frac{2v_0}{g}\sin\theta$. 0.5 +~~1~~ for correct soln for time to land, based on $y(t)$ from last step

Since $x'' = 0$, $x'(0) = v_0 \cos\theta$, and $x'(0) = 0$,

we have $x(t) = v_0(\cos\theta)t$. So, +0.5 for correct soln for horizontal dist. as function of time (fine to just use equation given)

$x(t_f) = v_0(\cos\theta)\frac{2v_0}{g}\sin\theta = \frac{v_0^2}{g}\sin(2\theta) = \boxed{\frac{mv_0^2}{QE}\sin(2\theta)}$ 0.5 +~~1~~ for correct solution based on t_f, $x(t)$ from last steps (fine to leave as $2\cos\theta\sin\theta$)

b) METHOD 1

Total energy is due to kinetic + electric potential energy.

$KE_i = \frac{1}{2}mv_0^2$

$KE_{max\ height} = \frac{1}{2}mv_x^2 = \frac{1}{2}mv_0^2\cos^2\theta$

Since $KE_{max} < KE_i$, and energy is conserved we must have $PE_{max} > PE_i$, +1 referencing consv. of energy

Electric Potential Energy increases!

+2 correct conclusion

METHOD 2

Electric field lines flow high V to low V. So as height increases,

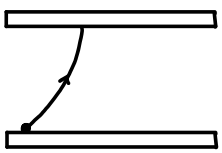
$\Delta V < 0$ +1 V decreases

$U = qV$. So $\Delta U = q\Delta V$

$q = -Q$, so $\Delta U = -Q\Delta V$. So $\boxed{\Delta U > 0}$ +2 U increases

← you can't get both of these points. max +1

c)



+1 increasing, hits top plate

+1 parabolic (concave up)

+1 initial slope matches v_0

d) METHOD 1 +2 for recognizing why it switches

Now KE is increasing (charge picks up speed). So electric potential energy must $\boxed{\text{decrease}}$ due to conservation of energy

+1 for different answer from (b)

METHOD 2

Since $\Delta V < 0$, but now $q = +Q > 0$,

$\boxed{\Delta U < 0}$ as well +2 for recognizing why answer switches

+1 for different answ. from (b).