Work = Force x displacement

$= (F)(s)$

N m

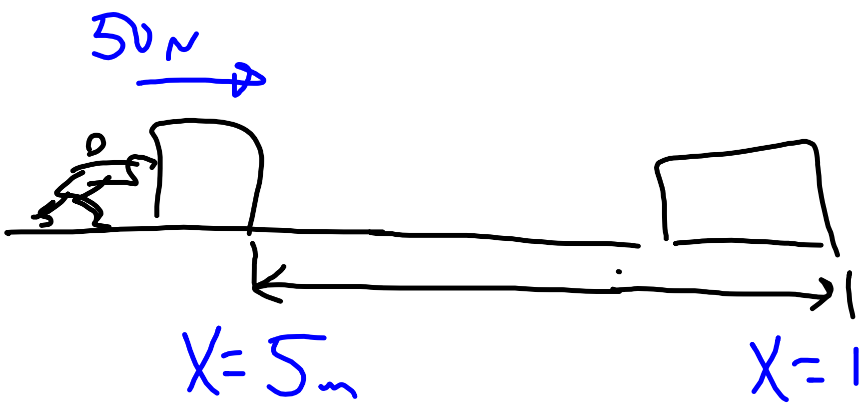
1. How do you calculate Work?

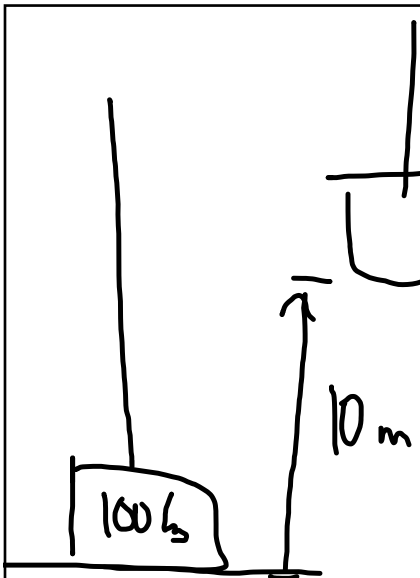
Work = Force x Displacement

W = Fs

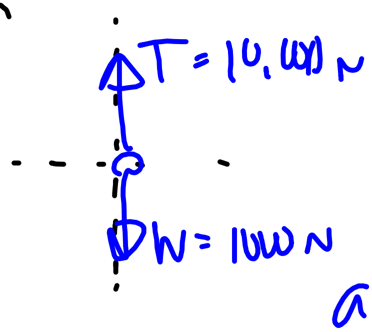
500 Nm

Joules





If the box moves upward at a constant ~~2 m/s~~, how much work was done by the Tension in the rope?

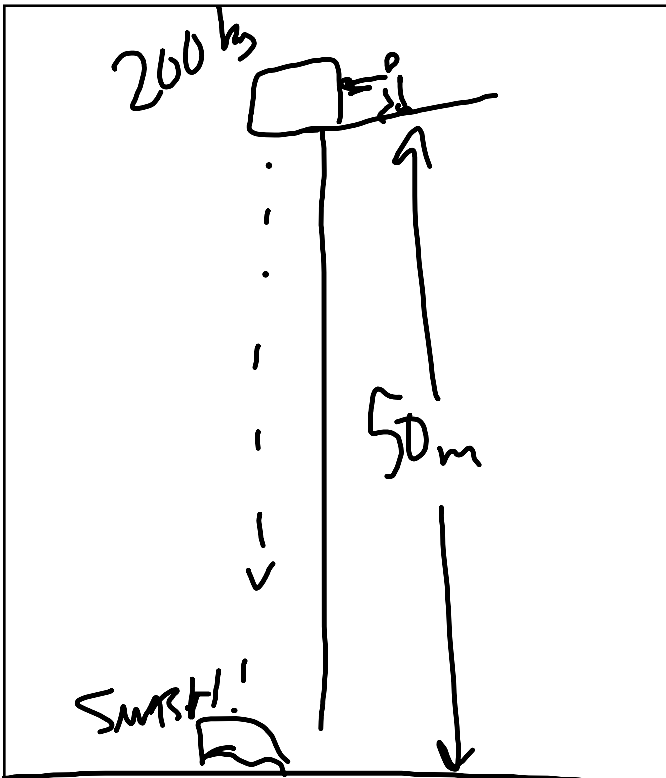


$W = Fs$

$= T(\Delta y)$

$= (1000\ N)(10\ m)$

$= 10{,}000\ J$



The crate topples from rest to smash onto the ground. Find the work done by gravity.

$$W = Fs$$

$$= mg(\Delta y)$$

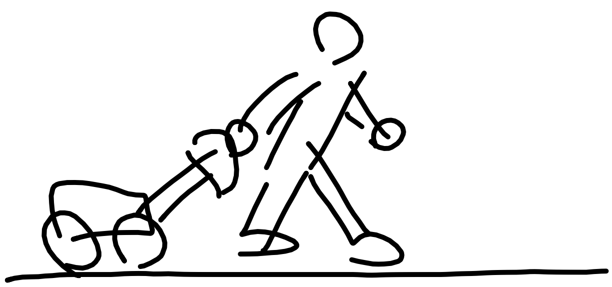
$$= (200)(10)(50)$$

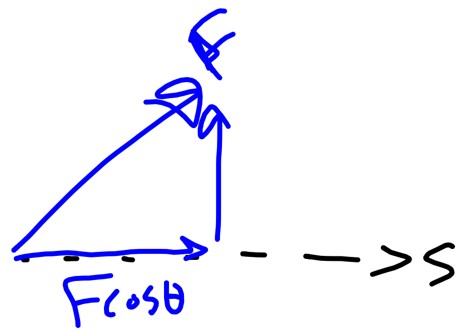
$$= 100{,}000 \text{ J}$$

2. What if there's an angle between the force and displacement?

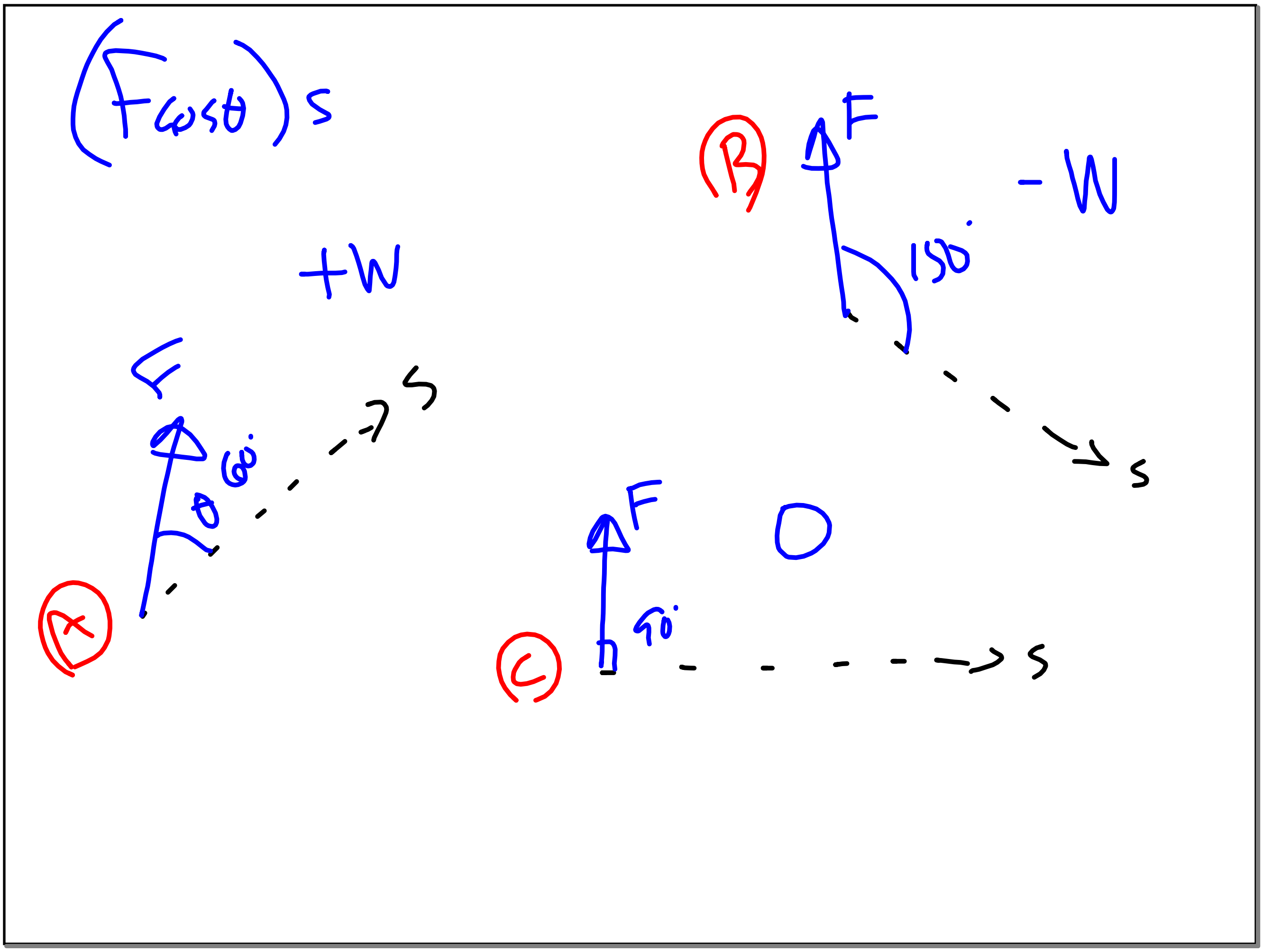
Work = F $s_{component}$

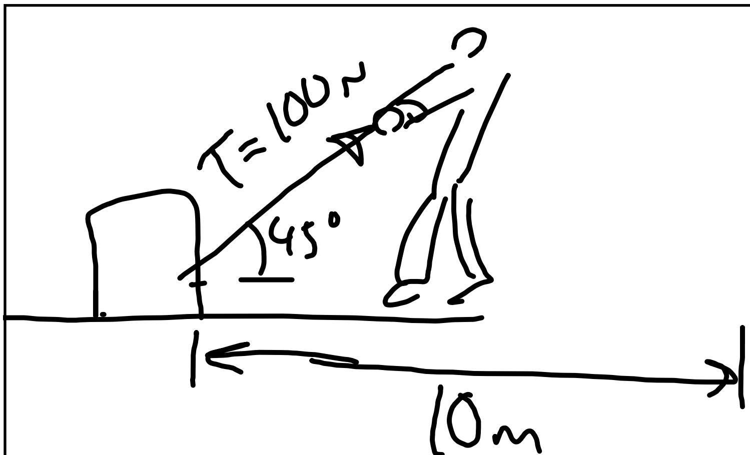
in the directio





$$(F\cos\theta)\ s$$


$(F\cos\theta)s$
+W
A
F
θ
60°
s
B
F
150°
-W
s
C
F
90°
0
s



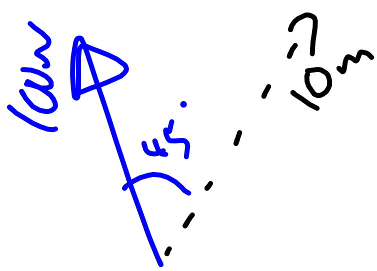
Find the work done by the Tension.

$$= \vec{F} \cdot \vec{s} =$$

$T\cos\theta$

$(100)\cos 45 = 70.7\ N$

$707\ J$



$$W = |F| \cdot |s| \cos\theta$$

In general...

$$W = F\, s \cos\theta$$

magnitude magnitude angle between

F an s

Dot Product

A way of multiplying vectors

The answer is a scalar

$$\vec{A} \cdot \vec{B} = |\vec{A}|\,|\vec{B}| \cos\theta$$

$$W = \vec{F} \cdot \vec{s} = |\vec{F}|\,|\vec{s}| \cos\theta$$

What if you're in i j k notation?

(multiply like components)

$$\vec{F} = (3\hat{i} + 2\hat{j} - 5\hat{k})\,N$$

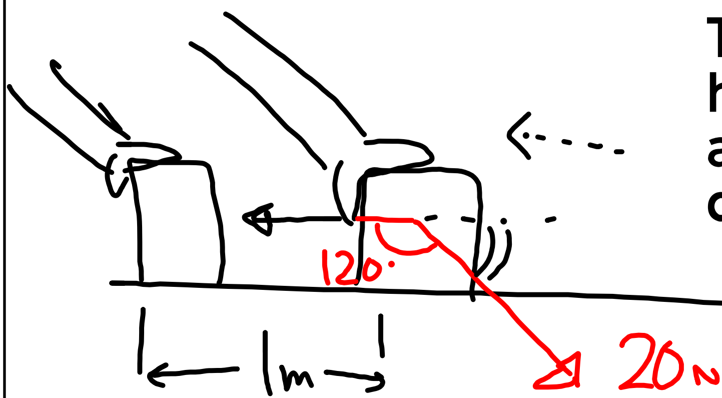
$$\vec{s} = (-2\hat{i} + 5\hat{j} - 6\hat{k})\,m$$

$$-6 + 10 + 30 = 34\,J$$

$$\vec{F} = (6\hat{i} - 5\hat{j} + 0\hat{k})\ N$$

$$\vec{S} = (3\hat{i} + 2\hat{j} + 6\hat{k})\ m$$

$$18 \quad -10 \quad 0 \quad = 8\ J$$

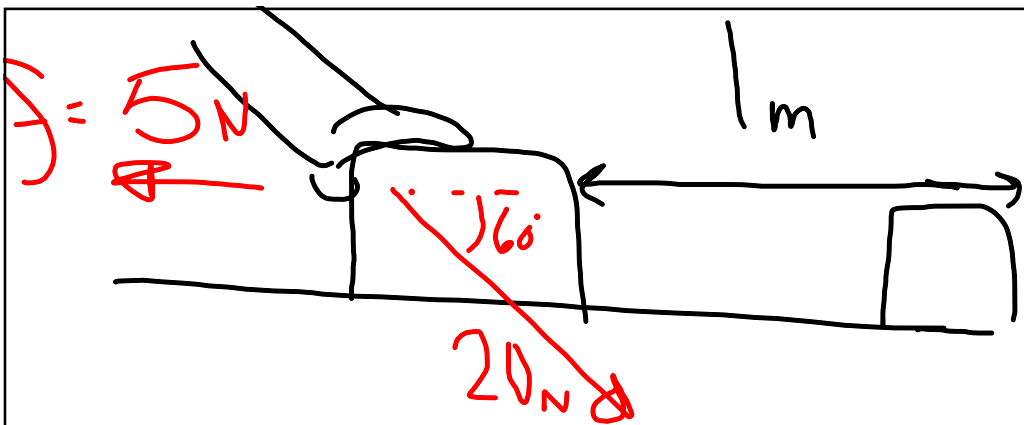


The box is brought to a halt by a push at an angle. Find the work done by the hand.

$$W = |\vec{F}| \cdot |\vec{s}| \cos\theta$$

$$= (20\,N)(1\,m)\cos 120^\circ$$

$$= -10\,J$$



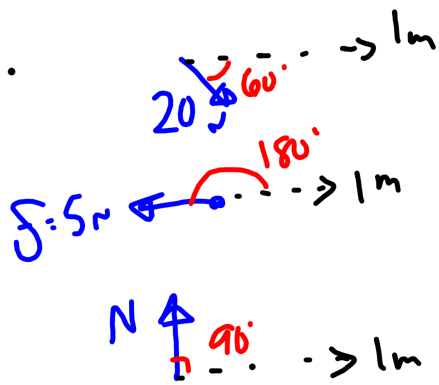
Find the work done by...

a) The push from the hand. 10 J

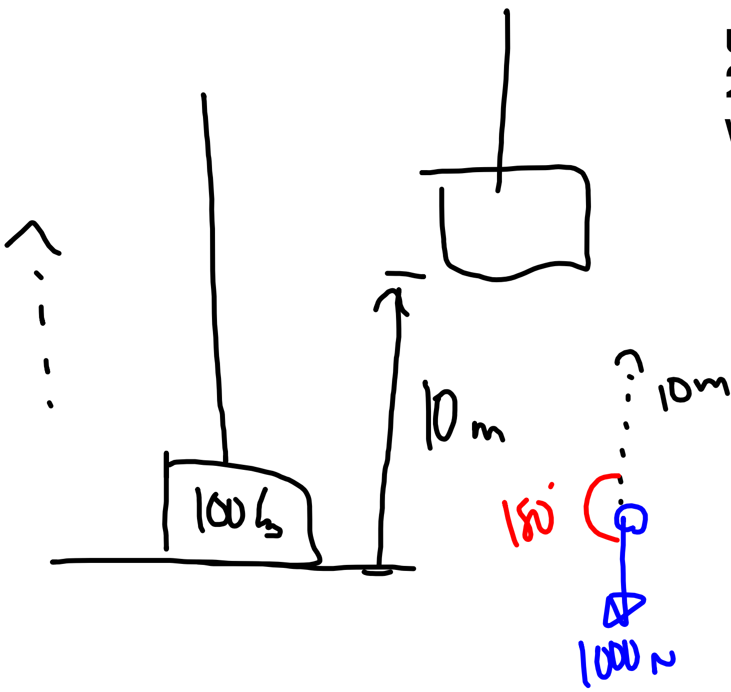
b) Friction. −5 J

c) Normal. 0 J

5 J



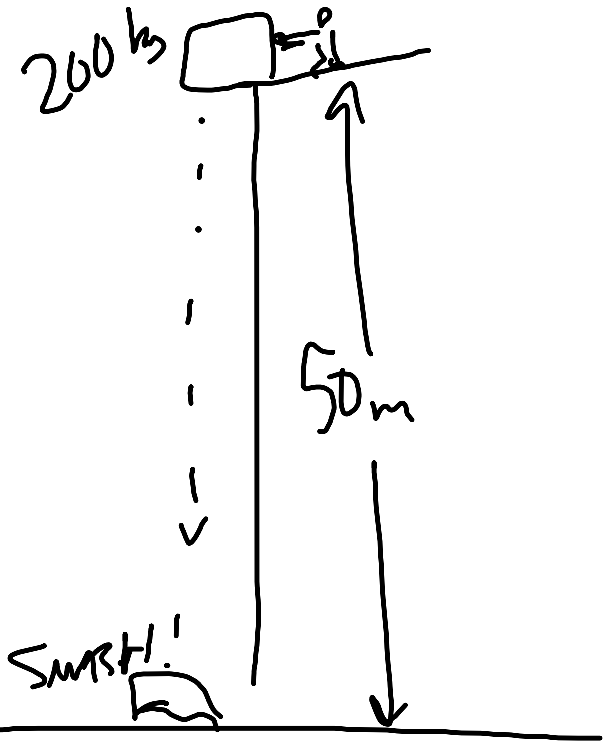
The crate moves upward at a constant 2 m/s. Now find the work done by gravity.



$W_T = 10{,}000\ J$

$W_{mg} = -10{,}000\ J$

$W_{net} = 0$

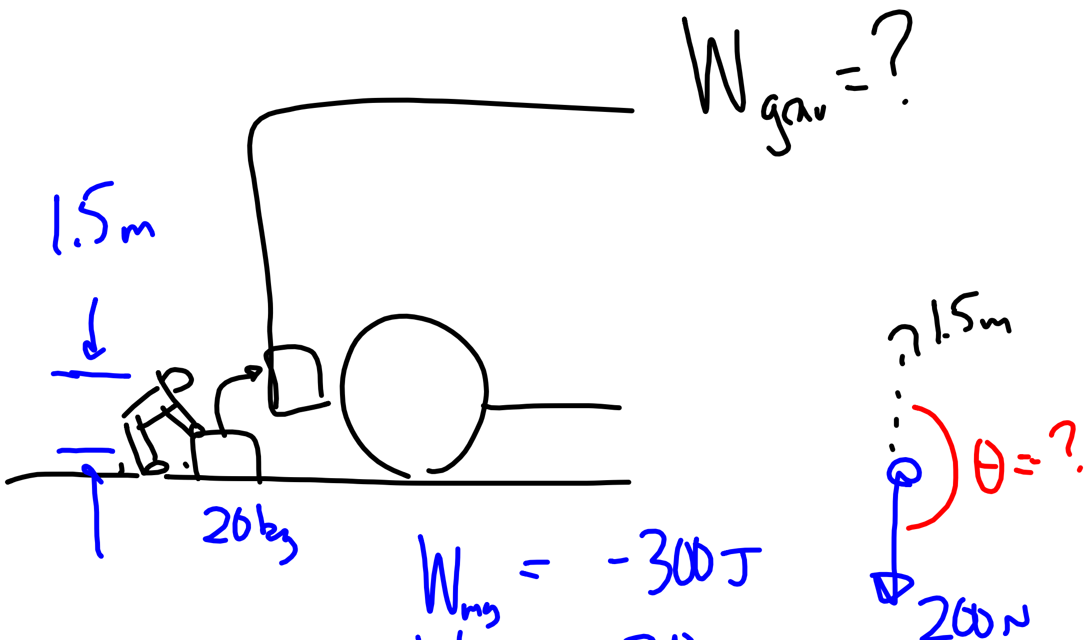


How much work was done by the ground?

$$W_{mg} = 100{,}000\ J$$

$$W_{gnd} = -100{,}000\ J$$

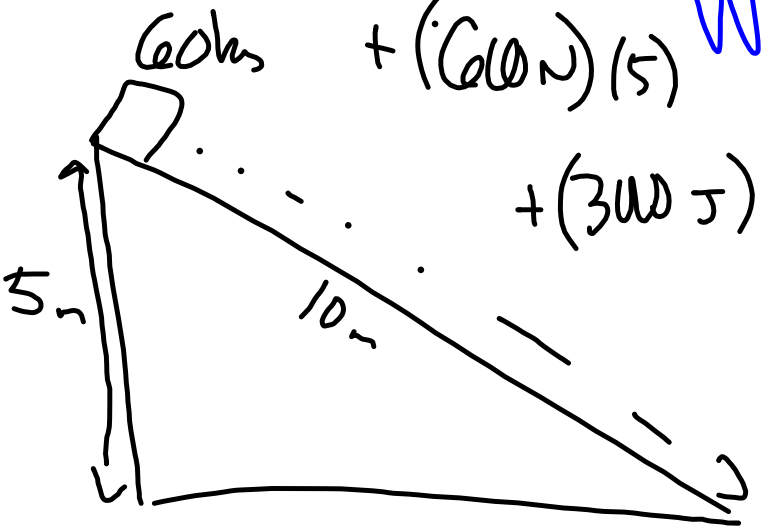
$$W_{net} = 0$$



$$W_{mg} = -300\text{ J}$$
$$W_{pm} = 300\text{ J}$$
$$\overline{\qquad\qquad 0 \qquad\qquad}$$

Another way of looking at it...

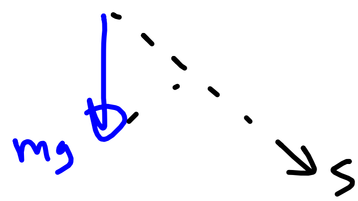
Work = Fs component in the direction of F



$+(600\,N)(5)$

$+(300\,J)$

$W = (F\cos\theta)\,s$



$(F)(s\cos\theta)$

$W_{total} = K_f - K_i$

$300\,J = \frac{1}{2} m v_f^2$

$300 = \frac{1}{2}(60)\,v_f^2$

$$\boxed{\begin{aligned}\Delta x &= \tfrac{1}{2}(v_0+v)t\\ \Delta x &= v_0 t + \tfrac{1}{2}at^2\\ v &= v_0 + at\\ v^2 &= v_0^2 + 2a\Delta x\end{aligned}} \longleftarrow a \longrightarrow \boxed{\sum F = ma}$$

$$W = \vec{F}\cdot\vec{s} = |\vec{F}|\cdot|\vec{s}|\cos\theta$$

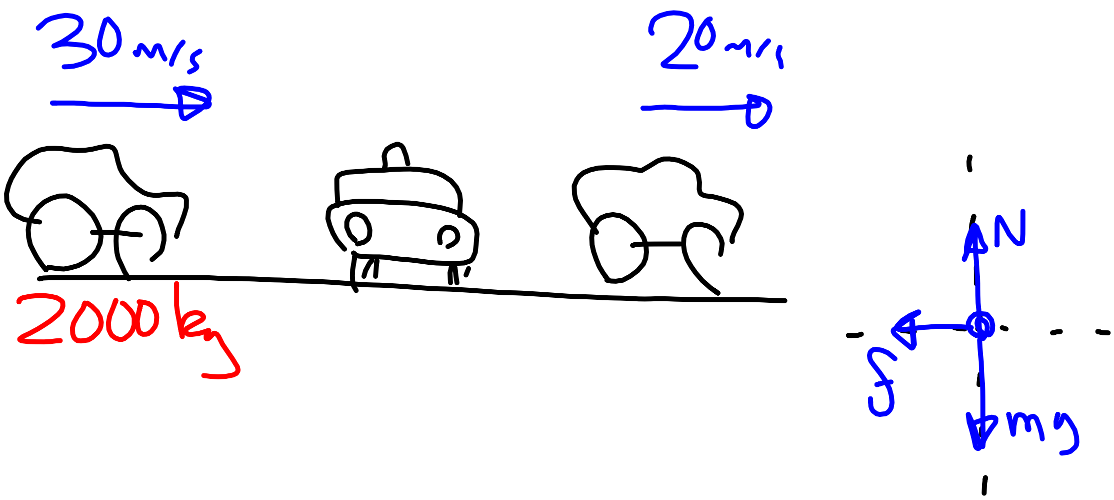
$$\boxed{W_{TOTAL} = \Delta K}$$

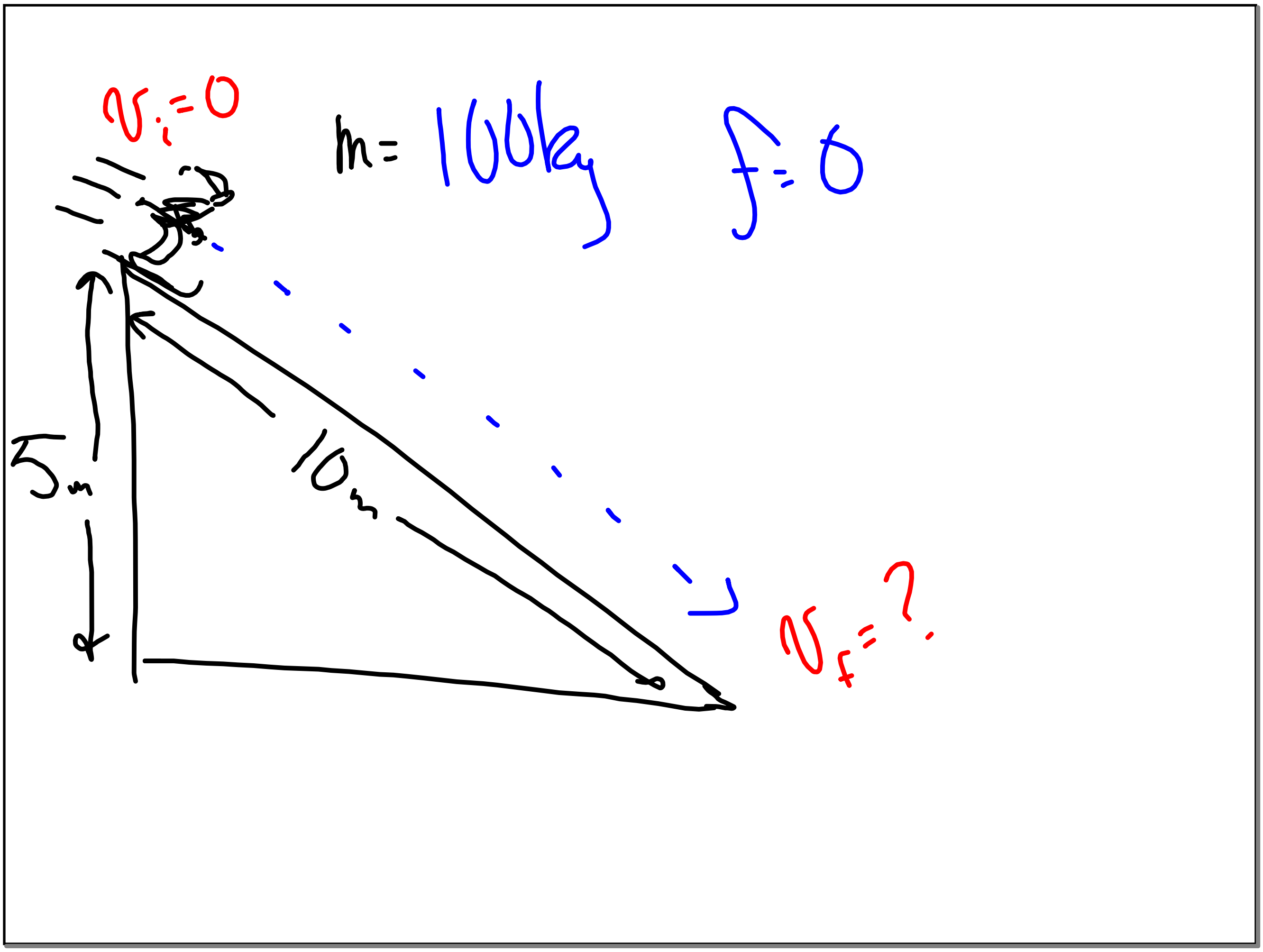
$$W = F_x\Delta x + F_y\Delta y + F_z\Delta z$$

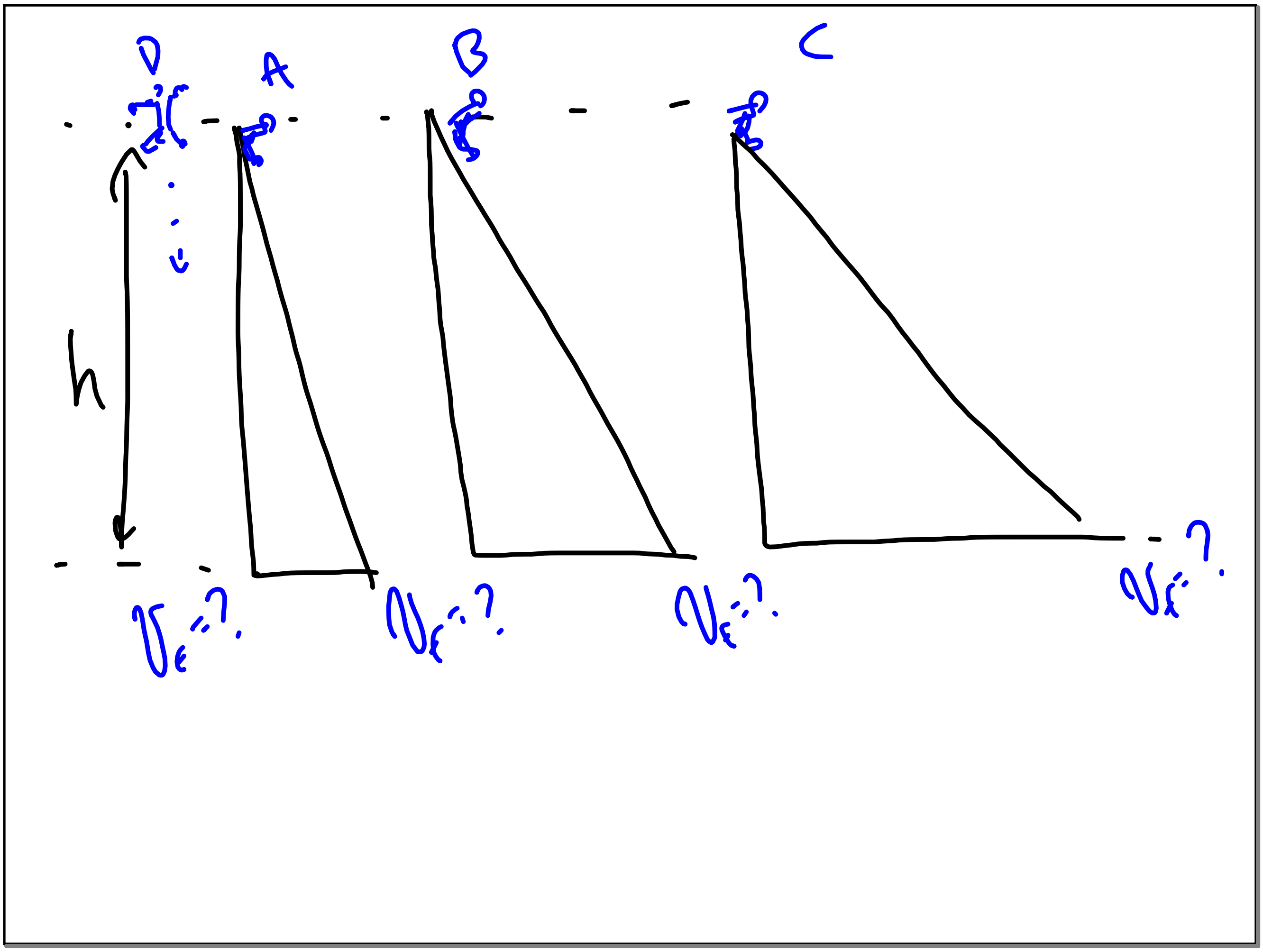
$$\Delta K = W_{TOTAL}$$

$$\tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 = W_{TOTAL}$$

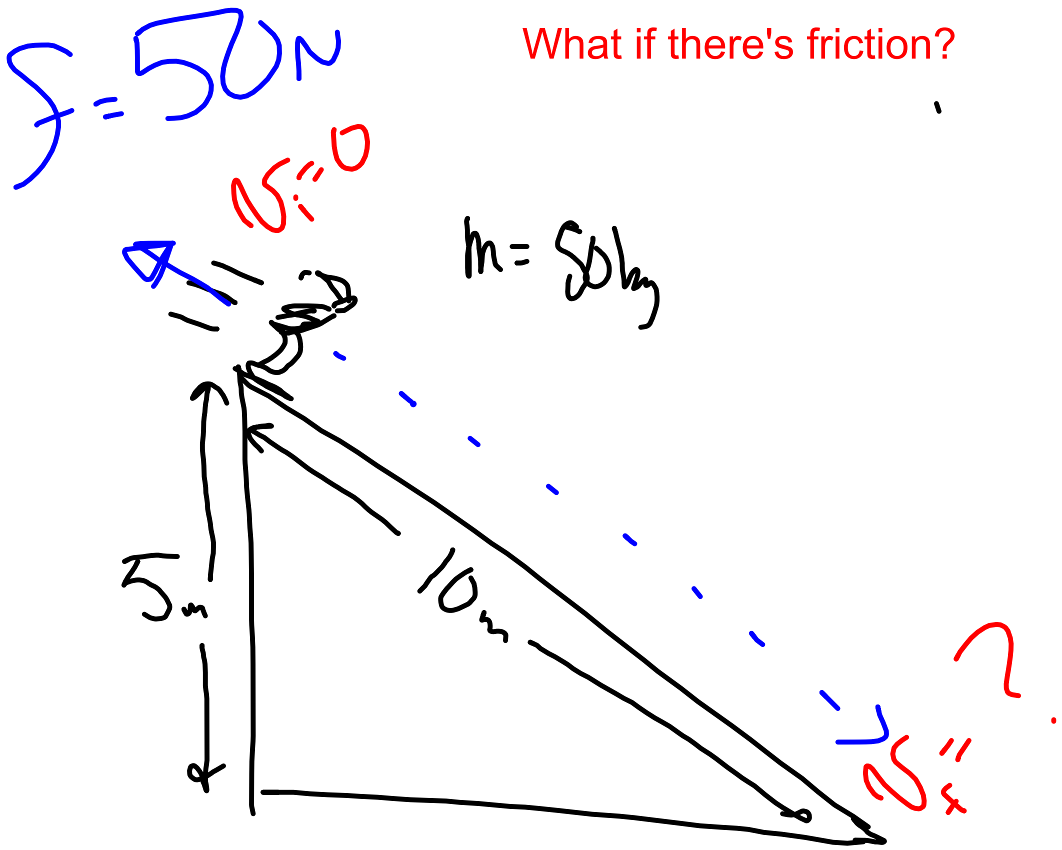
$W_{brakes} = ?$

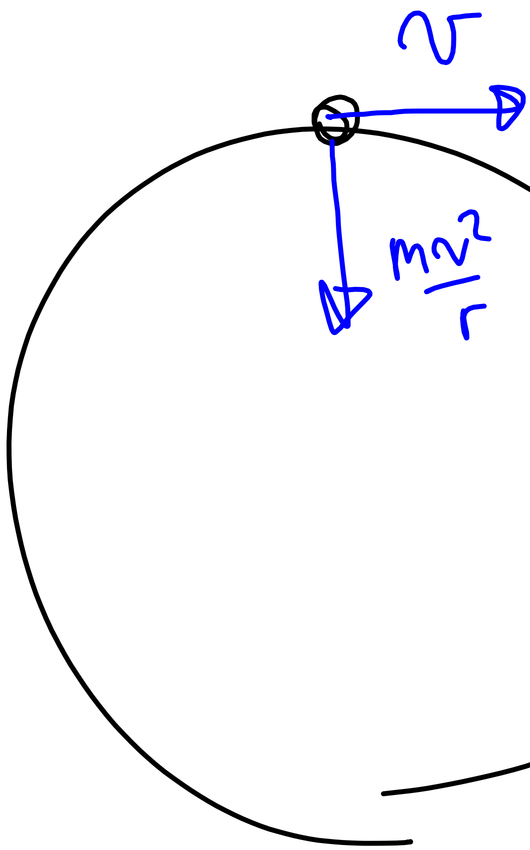



vi=0
m= 100kg
f=0
5m
10m
vf=?

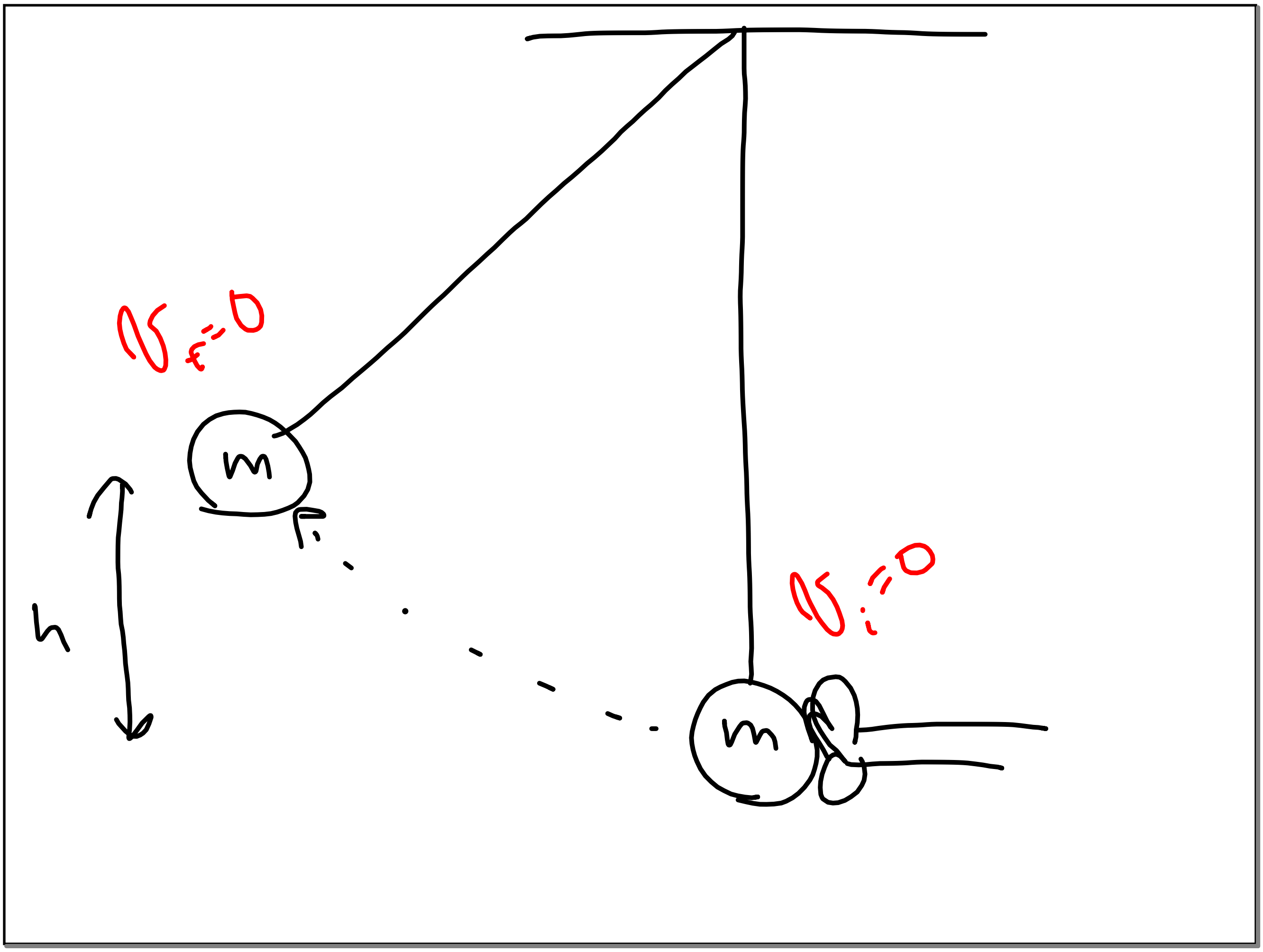

D
A
B
C
h
v_f = ?
v_f = ?
v_f = ?
v_f = ?

What if there's friction?

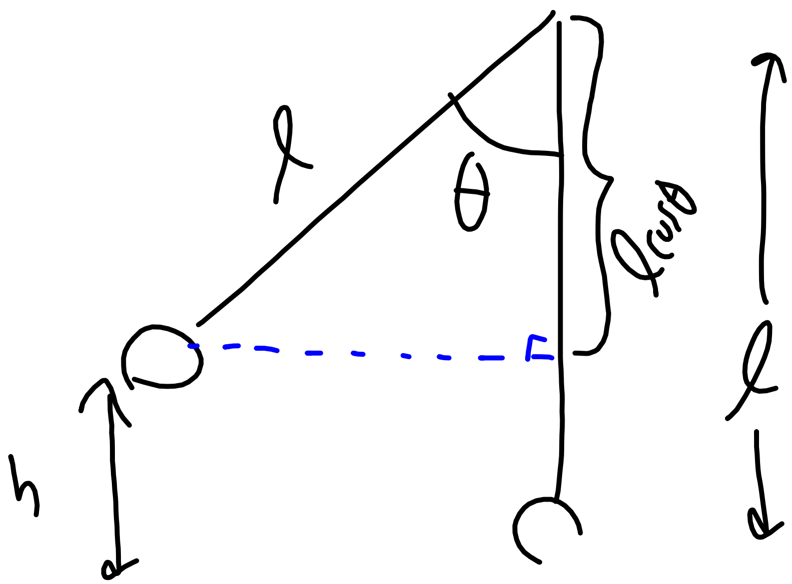




$$W = \vec{F} \cdot \vec{s}$$
$$= |\vec{F}||\vec{s}|\cos\theta$$



$v_f = 0$
m
h
$v_i = 0$
m



$$h = \ell - \ell\cos\theta$$

The many ways to calculate Work

$W = Fs$

$W = Fs\cos\theta$

$W = F$ (s in the direction of F)

$W =$ (F in the direction of s) s

$W = F_x\Delta x + F_y\Delta y + F_z\Delta z$

$W = \int F dx$

Find the work done by the force going from the start position to the end position.

$$F = 2_N\,\hat{i} - 5_N\,\hat{j}$$

start: $3m\,\hat{i} - 2m\,\hat{j}$

end: $4m\,\hat{i} + 4m\,\hat{j}$

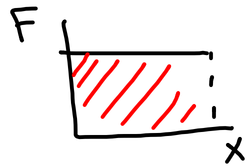
answer: -28 J

Non-constant Forces

$$F = -4x$$

Find the work done by the force from x = 1 to x = 2.

$$W = \vec{F} \cdot \vec{s} = Fx$$



$$W = \int F \, ds$$

$$= \int F_x \, dx + \int F_y \, dy + \int F_z \, dz$$

$$= \int_1^2 (-4x) \, dx$$

$$= \left[-\frac{4x^2}{2} \right]_1^2 = \left[-2x^2 \right]_1^2$$

$$= \left[-2(2)^2 - -2(1)^2 \right]$$

$$= -8\,J + {}^{+}2\,J$$

$$-6\,J$$

$F = 6x^2$

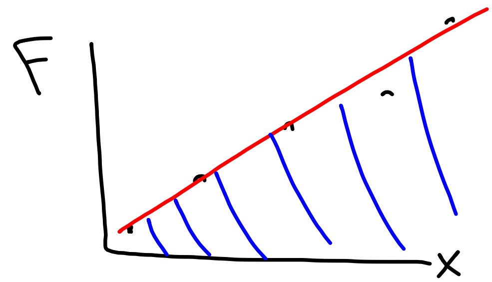
Work done from $x=0$ to $x=1$.

$$W = \int F_x \, dx$$

$$= \int_0^1 (6x^2)\, dx$$

$$= \left[\frac{6x^3}{3}\right]_0^1 = \left[2x^3\right]_0^1$$

$$= \left[2(1)^3 - 2(0)^3\right]$$



$y = mx + b$

$F = -kx$

$F = -2x$

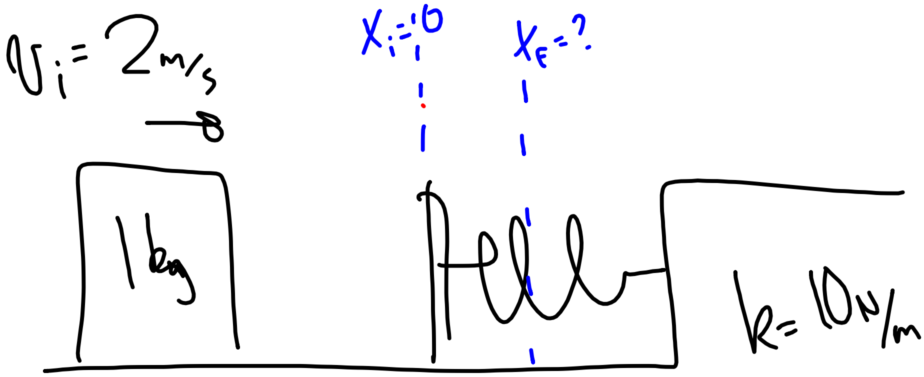
$$W_s = \int_{x_i}^{x_f} F\,dx$$

$$= \int_{x_i}^{x_f} (-kx)\,dx$$

$$\left[-\frac{kx^2}{2}\right]_{x_i}^{x_2}$$

$$-\frac{1}{2}kx_f^2 - -\frac{1}{2}kx_i^2$$

$$-\frac{1}{2}k\left(x_f^2 - x_i^2\right)$$



$$W_{total} = \Delta K$$

$$W_{total} = \Delta K$$

$$W_{mg} + W_N + W_s = \Delta K$$

$$= \frac{1}{2} m (v_f^2 - v_i^2)$$

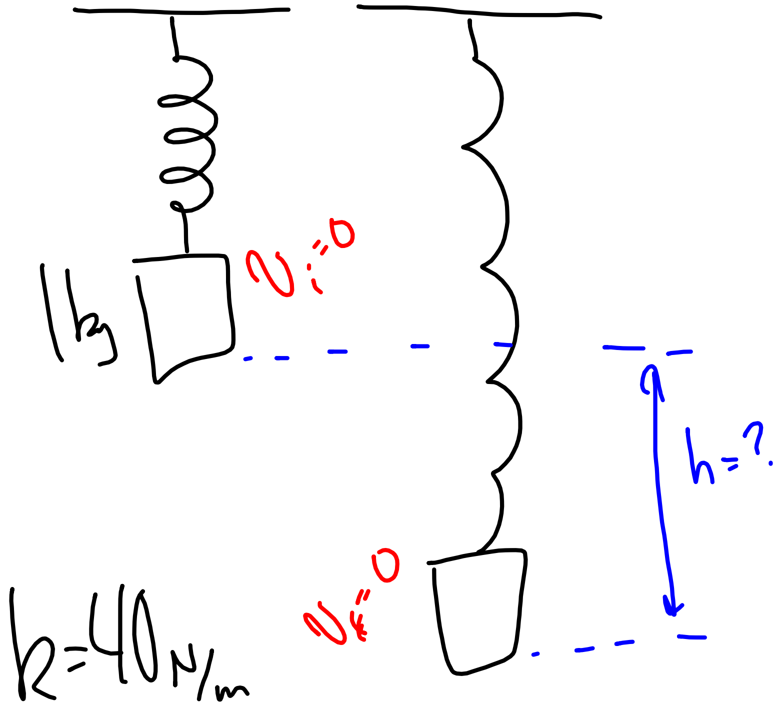
$$= \frac{1}{2}(1)(0^2 - 2^2)$$

$$-\frac{1}{2} k (x_f^2 - x_i^2) = -2\,J$$

$$-\frac{1}{2}(10)(x_f^2 - 0^2) = -2$$

$$-5(x_f^2) = -2$$

$$x_f^2 = 0.4 \qquad x_f = 0.63\,m$$



$$W_{mg} + W_s = \Delta K$$

$$+mgh - \frac{1}{2}k\left(x_f^2 - x_i^2\right) = 0$$

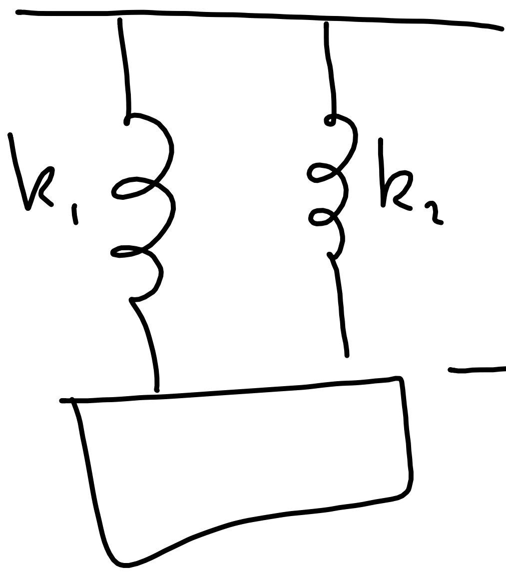
$$(1)(10)h - \frac{1}{2}(40)(h^2 - 0) = 0$$

$$10h - 20h^2 = 0$$

$$h(10 - 20h) = 0$$

$h = 0$ OR $10 - 20h = 0$

$$h = 0.5\,m$$



$$k = (k_1 + k_2)$$