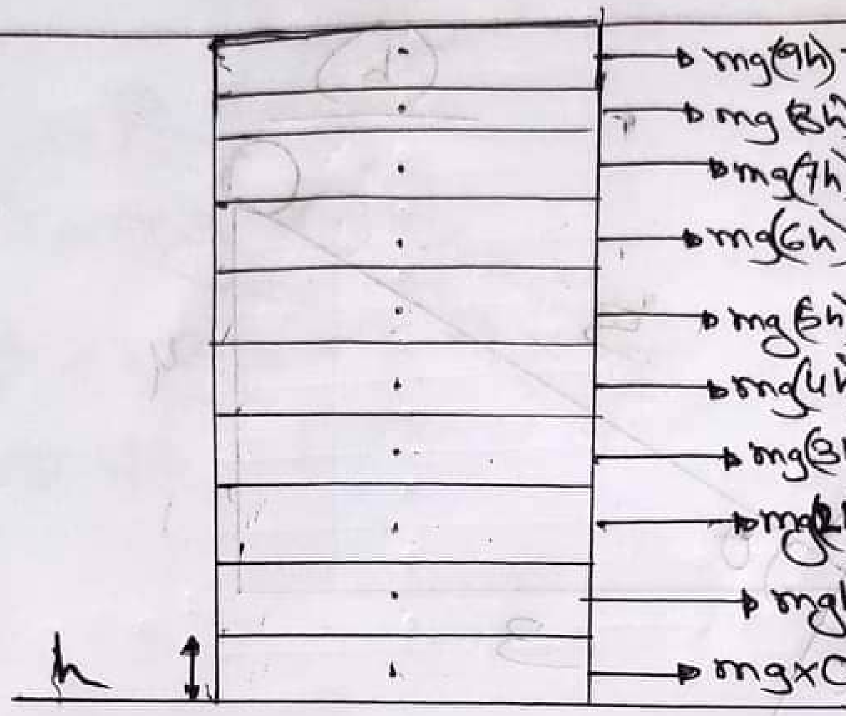


$mg(9h) \rightarrow mg9h = mg(10-1)h$

$mg(8h) \rightarrow mg8h = mg(9-1)h$

$mg(7h) \rightarrow mg7h = mg(8-1)h$

$mg(6h) \rightarrow mg6h = mg(7-1)h$

$mg(5h) \rightarrow mg5h = mg(6-1)h$

$mg(4h) \rightarrow mg4h = mg(5-1)h$

$mg(3h) \rightarrow mg3h = mg(4-1)h$

$mg(2h) \rightarrow mg2h = mg(3-1)h$

$mgh \rightarrow mg.1h = mg(2-1)h$

$mg \times 0 \longrightarrow mgh = 0$

(a)

Total work done

$$W = mg(2-1)h + mg(3-1)h + mg(4-1)h + \cdots mg(10-1)h$$

$$= mgh(1+2+\cdots 9)$$

$$= mgh \frac{9(9+1)}{2}$$

$$= mgh \frac{9 \times \cancel{10}^{5}}{\cancel{2}}$$

$$= 45mgh$$

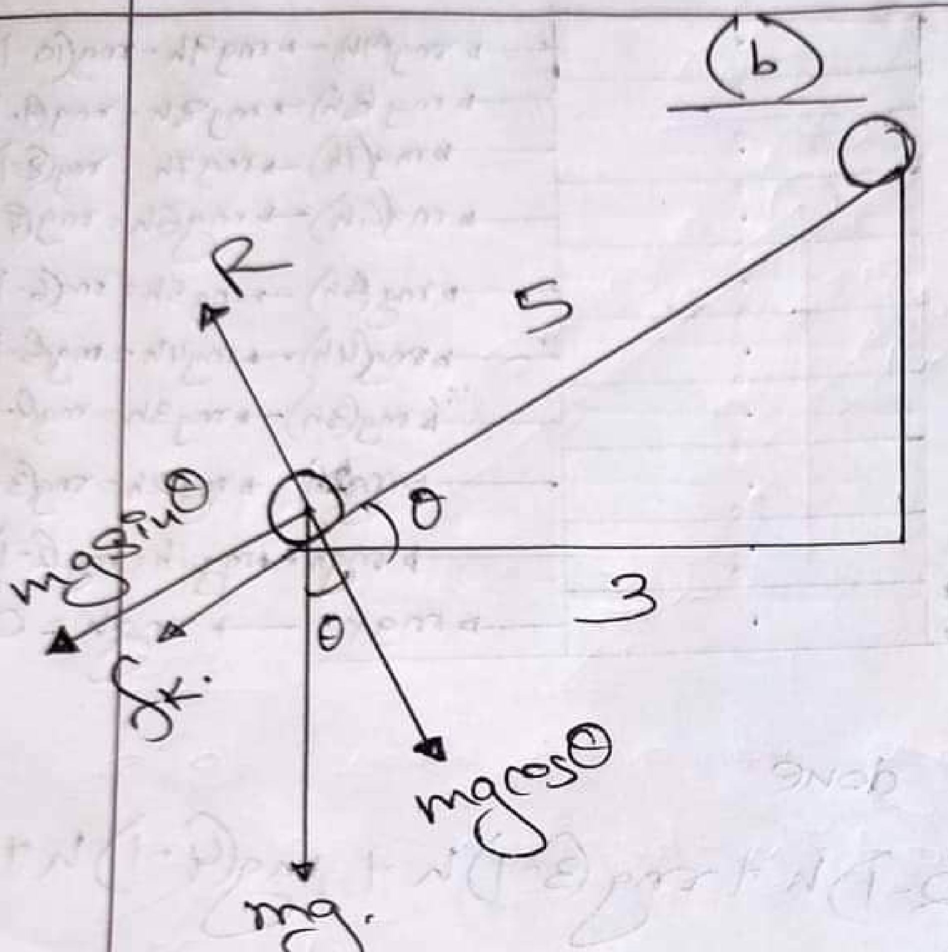
$$= 45 \times 2.5 \times 9.8 \times 0.4$$

$$= 441 J \text{ (Ans)}$$

Given,

$m = 2.5$ kg

$h = 0.4$ m



Given,

$m = 2.5$ kg.

$\mu_K = 0.2$

$g = 9.8\ ms^{-2}$.

Soln: To raise the sphere from bottom to top of the pile, work has to be done against gravitational force and frictional force.

Now,

$R = mg\cos\theta$.

$f_K = \mu_K R$

$= \mu_K mg\cos\theta$

$= 0.2 \times 2.5 \times 9.8 \times \frac{3}{5}$

$= 2.94$ N.

Again,

$\Rightarrow mg\sin\theta$

$= 2.5 \times 9.8 \times \frac{4}{5}$

$= 19.6$ N.

Total force required in lifting

$F = 19.6 + 2.94$

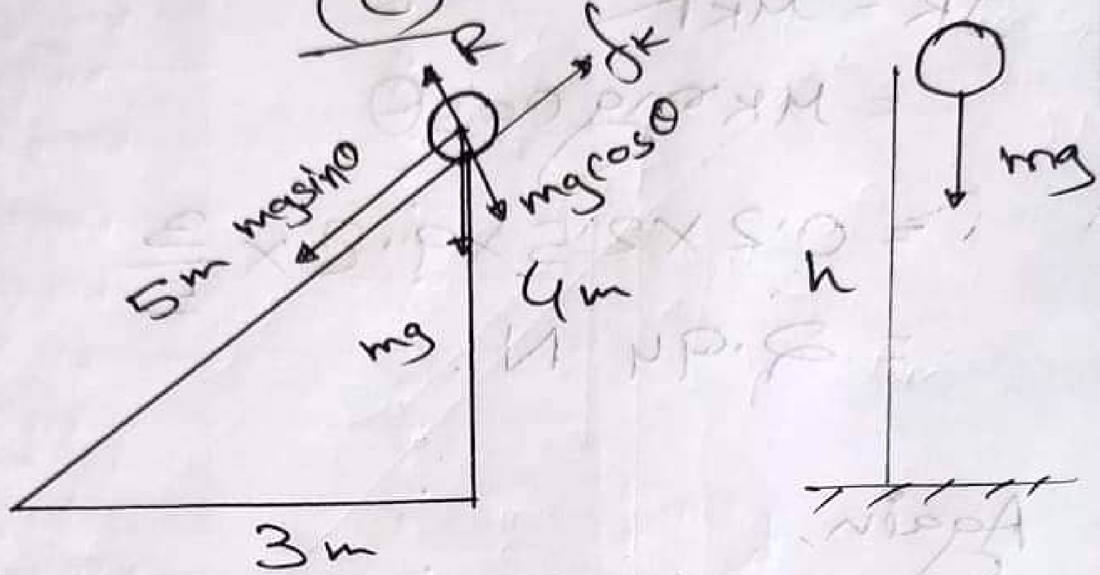
$= 22.54$ N.

Work done, $W = FS$

$= 22.54 \times 5$

$= 112.7$ J (Ans).

(c)



Soln:

Let work done by gravitational force for downward motion of sphere be W_1.

$$W_1 = mgh = 2.5 \times 9.8 \times 4$$
$$= 98 \text{ J.}$$

Again work done in inclined plane be W_2.

$$\text{Net force, } F_{net} = mg\sin\theta - f_k$$
$$= mg\sin\theta - \mu_k mg\cos\theta.$$
$$= mg(\sin\theta - \mu_k\cos\theta)$$

$= 2.5 \times 9.8 \left(\frac{4}{5} - 0.2 \times \frac{3}{5}\right)$

$= 2.5 \times 9.8 \times 0.68$.

$= 16.66\ N$.

$W_2 = F_{net} \times S$.

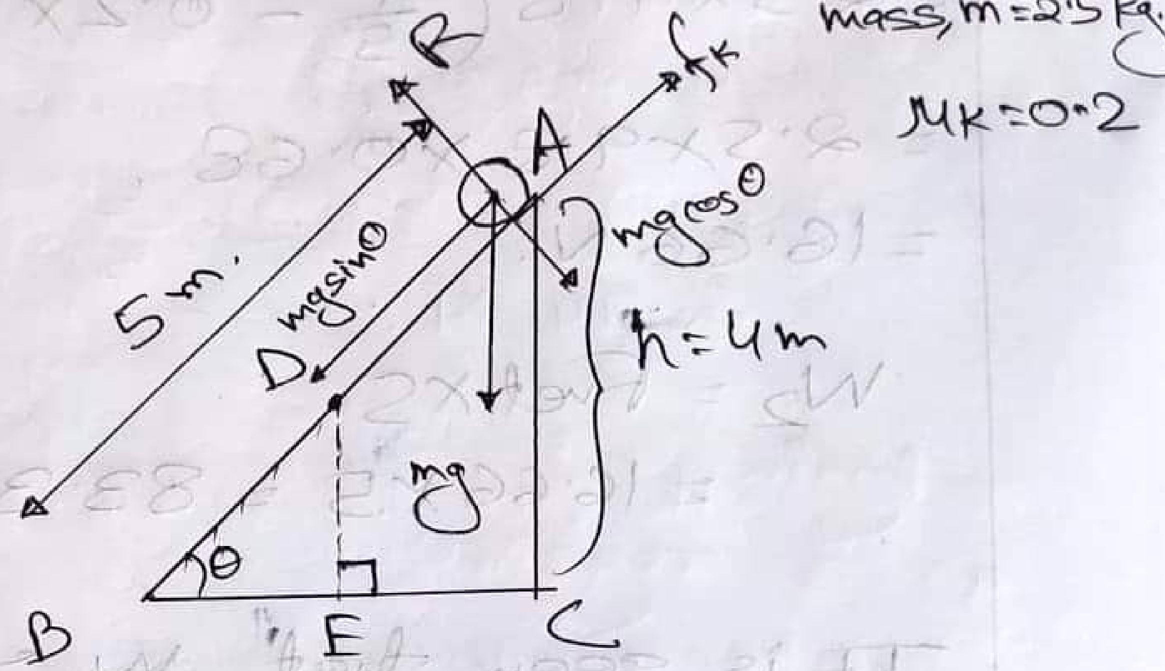
$= 16.66 \times 5 = 83.3\ J$.

It is seen that $W_1 > W_2$. So, the work done will not be equal for both cases.

Logic: For vertically downward motion there is no presence of non conservative force like air resistance, fluid friction etc. But in the case of inclined plane friction is presence for which some energy is lost. So, the work done will not be equal.

(d)

Soln:



Let D be the midpoint along AB. We draw a perpendicular from D on BC, which meets at E.

In ΔABC and ΔDBE.

$$\sin\theta = \frac{4}{5}.$$

For triangle DBE,

$$\frac{DE}{BD} = \sin\theta.$$

or, $\frac{DE}{2.5} = \frac{4}{5}$

or, $DE = \frac{4}{5} \times 2.5$

$\therefore DE = 2\ m.$

At A,

Total energy, E_A = Potential energy + Kinetic energy.

$= mgh + 0$

$= 2.5 \times 9.8 \times 4$

$= 98\ J.$

Net force on sphere,

$F_{net} = mg\sin\theta - f_k$

$= mg\sin\theta - \mu_k mg\cos\theta$

$= mg(\sin\theta - \mu_k\cos\theta)$

A.T-B,

$$\cancel{m}a = \cancel{m}g(\sin\theta - \mu_k \cos\theta)$$

$$\therefore a = g(\sin\theta - \mu_k \cos\theta)$$

Velocity at B.

$$V_B^2 = U^2 + 2as_1$$

$$V_B^2 = 2as$$

$$V_B = \sqrt{2as_1}$$

$$= \sqrt{2 \times g(\sin\theta - \mu_k \cos\theta) \times 2.5}$$

$$= \sqrt{2 \times 9.8\left(\frac{4}{5} - 0.2 \times \frac{3}{5}\right) \times 2.5}$$

$$= 5.772\ ms^{-1}.$$

At B,

Total energy.

E_B = Potential energy + Kinetic energy

$= mg(DE) + \frac{1}{2} m V_B^2$

$= 2.5 \times 9.8 \times 2 + \frac{1}{2} \times 2.5 \times (5.772)^2$

$= \cancel{122}\ 49 + 41.64$

$= 90.64\ J.$

~~At C,~~

~~Total en~~

Velocity at C,

$$V_c = \sqrt{2as}$$

$$= \sqrt{2 \times g(\sin\theta - \mu_k \cos\theta) \times s}$$

$$= \sqrt{2 \times 9.8\left(\frac{4}{5} - 0.2 \times \frac{3}{5}\right) \times 5}$$

$$= 8.16 \, ms^{-1}.$$

At C,

Total energy,

E_c = Potential energy + Kinetic energy

$$= 0 + \frac{1}{2} m V_c^2$$

$$= \frac{1}{2} \times 2.5 \times (8.16)^2$$

$$= 83.23 \, J.$$

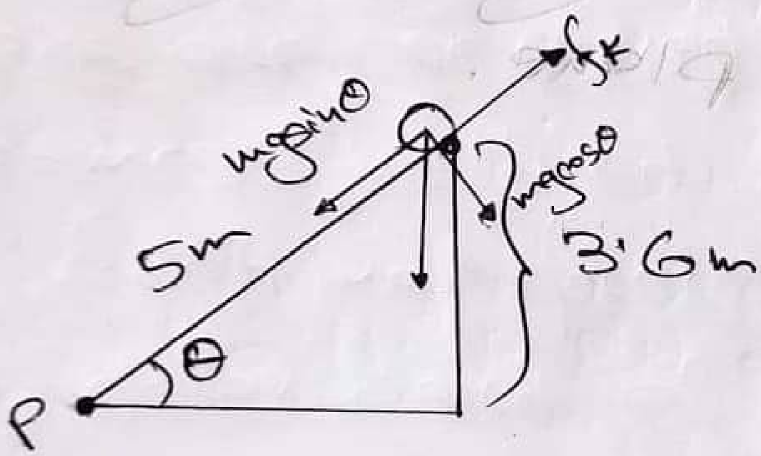
Hence, we can see that

$E_A \neq E_B \neq E_C$. Thus conservation of energy will not be applicable while the body falling over inclined plane.

(e)

When one rectangular body is removed, then height becomes

$$h_1 = 9 \times 0.4 = 3.6\ m.$$



$\sin\theta = \frac{3.6}{5}$.

$\cos\theta = \frac{3.47}{5}$.

$$F_{net} = mg\sin\theta - f_k$$
$$= mg\sin\theta - \mu_k mg\cos\theta$$
$$= mg(\sin\theta - \mu_k\cos\theta).$$

A.T.Q,

$$\cancel{m}a = \cancel{m}g(\sin\theta - \mu_k\cos\theta)$$

$$\therefore a = g(\sin\theta - \mu_k\cos\theta).$$

Velocity at P

$$V_1 = \sqrt{2as}$$

$$= \sqrt{2 \times g(\sin\theta - \mu_k \cos\theta) \times S}$$

$$= \sqrt{2 \times 9.8\left(\frac{3.6}{5} - 0.2 \times \frac{3.47}{5}\right) \times 5}$$

$$= 7.54 \text{ ms}^{-1}.$$

Again if another body is removed,

$$h_2 = 8 \times 0.4 = 3.2.$$

$$\sin\theta = \frac{3.2}{5}$$

$$\cos\theta = \frac{3.84}{5}.$$

$$V_2 = \sqrt{2as}$$

$$= \sqrt{2 \times 9.8\left(\frac{3.2}{5} - 0.2 \times \frac{3.84}{5}\right) \times 5}$$

$$= 6.904 \text{ ms}^{-1}.$$

From the above calculation, we may come to a conclusion that if one block is removed then its speed decreases. The more blocks are removed, more it becomes inclined. As a result, the frictional force increases and downward effective force decreases. This is why speed changes.