Example 1.

Work done = force (component) × displacement

Hence,

$$W = (40\cos 30°) \times 1$$
$$= 40 \times \frac{\sqrt{3}}{2}$$
$$= 20\sqrt{3} \text{ J}$$

Answer: $20\sqrt{3}$ J (= 34.6 J)

Example 2.
The force direction is always changing ... but it is always *towards the peg*.

Work done = tension × displacement in the direction of the force

= tension × amount of cable passing over the peg

Hence,

$$W = T \times (\text{AP} - \text{BP})$$
$$= 40 \times \left(\frac{\text{AB}}{\cos 30°} - \text{AB} \times \tan 30°\right)$$
$$= 40 \times \left(\frac{2}{\sqrt{3}} - \frac{1}{\sqrt{3}}\right)$$
$$= \frac{40}{\sqrt{3}} \text{ J}$$

Answer: $\frac{40}{\sqrt{3}}$ J (= 23.1 J)

Example 3.

(a) Find acceleration, then infer force from mass × acceleration.

$$\mathbf{r} = t^2\,\mathbf{i} + \sin t\,\mathbf{j} + \cos t\,\mathbf{k}$$

$$\Rightarrow \quad \mathbf{v} \equiv \frac{\mathrm{d}\mathbf{r}}{\mathrm{d}t} = 2t\,\mathbf{i} + \cos t\,\mathbf{j} - \sin t\,\mathbf{k}$$

$$\Rightarrow \quad \mathbf{a} \equiv \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} = 2\mathbf{i} - \sin t\,\mathbf{j} - \cos t\,\mathbf{k}$$

Then

$$\mathbf{F} = m\mathbf{a} \quad = 5(2\,\mathbf{i} - \sin t\,\mathbf{j} - \cos t\,\mathbf{k}) \quad = 10\,\mathbf{i} - 5\sin t\,\mathbf{j} - 5\,\cos t\,\mathbf{k}$$

Answer: $\mathbf{F} = 10\,\mathbf{i} - 5\sin t\,\mathbf{j} - 5\cos t\,\mathbf{k}$.

(b)

$$\text{Power} = \text{force} \times \text{velocity} = \mathbf{F} \bullet \mathbf{v}$$

$$= (10\,\mathbf{i} - 5\sin t\,\mathbf{j} - 5\cos t\,\mathbf{k}) \bullet (2t\,\mathbf{i} + \cos t\,\mathbf{j} - \sin t\,\mathbf{k})$$

$$= 20t - 5\sin t\cos t + 5\cos t\sin t$$

$$= 20t$$

Answer: $20t$.

(c)

Rate of doing work = power

Hence,

$$\frac{\mathrm{d}W}{\mathrm{d}t} = 20t$$

$$\Rightarrow \quad W = \int_0^4 20t\,\mathrm{d}t \quad = [10t^2]_0^4 \quad = 160\ \mathrm{J}$$

Answer: 160 J.

(d) Two vectors will be perpendicular if their scalar product is zero. Note that we are only asked to show this at $t = 0$. (In this case it isn't true for all t). The direction of motion is that of the vector velocity.

When $t = 0$,

$$\mathbf{a} = 2\mathbf{i} - \mathbf{k}, \qquad \mathbf{v} = \mathbf{j}$$

$\Rightarrow \quad \mathbf{a} \bullet \mathbf{v} = 0$

Hence, acceleration is perpendicular to the direction of motion (at $t = 0$).

Example 4.

The work done by the tension T was found in an earlier example to be $\frac{40}{\sqrt{3}}$ J.

(a) Weight (mg) and normal reaction (R).

(b) These do no work because their directions are perpendicular to the displacement.

(c)

Work done (by all forces) = change in KE

Hence,

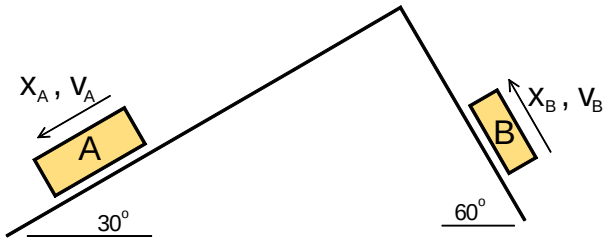
$$\frac{40}{\sqrt{3}} + 0 + 0 = \frac{1}{2}mv^2 - 0$$

$$\Rightarrow \quad v^2 = \frac{2}{m} \times \frac{40}{\sqrt{3}} \quad = \frac{2}{5} \times \frac{40}{\sqrt{3}} \quad = 9.238$$

$$\Rightarrow \quad v = 3.039 \text{ m s}^{-1}$$

Answer: 3.04 m s^{-1}.

Example 5.
If we are careful with signs, the Mechanical Energy Principle will tell us not only how fast the carriages go, but also in which directions they move.



Suppose the displacement of A taken positive down its slope is x_A. We do not know yet whether A actually moves down or up the slope: this will ultimately be determined by whether x_A is positive or negative. Similarly, let the displacement of B taken positive up its slope be x_B. Since B is to move 1 m the final numerical value of x_B will be either +1 or –1: we don't know yet. Let the corresponding velocities in the same directions be v_A and v_B.

Because of the pulley arrangement, carriages A and B do not move by the same distance. The relation between x_A and x_B can be established by considering how much cable passes over the top pulley.

If carriage A moves downslope by x_A ...
... *each* length of cable to A must increase by x_A ...
... so the amount of cable passing over the top pulley is $2x_A$ ...
... but this is also equal to x_B (because there is a single length of cable on B's side)

Hence, equating the amount of cable passing over the top pulley from the two sides:

$$2x_A = x_B$$

$$\Rightarrow \quad x_A = \frac{1}{2}x_B \qquad \text{(and hence, also, } v_A = \tfrac{1}{2}v_B\text{)}$$

Energy principle:

change in (KE + PE) = 0

$$\Rightarrow \quad \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2 - m_A g(x_A \sin 30°) + m_B g(x_B \sin 60°) = 0$$

Substituting for the masses and writing $x_A = \frac{1}{2}x_B$ and $v_A = \frac{1}{2}v_B$:

$$10(\frac{1}{2}v_B)^2 + 5v_B^2 - 20g(\frac{1}{2}x_B \times \frac{1}{2}) + 10g(x_B \times \frac{\sqrt{3}}{2}) = 0$$

$$\Rightarrow \quad 7.5v_B^2 + 35.91x_B = 0$$

$$\Rightarrow \quad v_B^2 = -4.788x_B$$

Now, to move 1 metre, x_B could be +1 or –1; however, v_B^2 must be positive, so we are forced to choose $x_B = -1$. Hence, carriage B actually moves down and carriage A moves up.

$$v_B^2 = 4.788$$

$$\Rightarrow \quad v_B = -2.188 \text{ m s}^{-1}$$

(The sign of the velocity is determined by that of the displacement; however, in this instance we are only interested in the magnitude or speed anyway).

$$v_A = \frac{1}{2} v_B \quad = -1.094 \text{ m s}^{-1}$$

Answer: A rises; speed of A is 1.09 m s^{-1}; speed of B is 2.19 m s^{-1}.

Example 6.

(a)(i)

Unstretched length $L = 0.8$ m

Stretched length = 1.6 m

Extension = 1.6 – 0.8 = 0.8 m

$$\text{EPE} = \frac{1}{2}\frac{\lambda}{L}x^2 \quad = \frac{1}{2} \times \frac{80}{0.8} \times 0.8^2 \quad = 32.0 \text{ J}$$

(ii)

Stretched length = $2 \times \sqrt{1.0^2 + 0.8^2} \quad = 2.561$ m

Extension = 2.561 – 0.8 = 1.761 m

$$\text{EPE} = \frac{1}{2}\frac{\lambda}{L}x^2 \quad = \frac{1}{2} \times \frac{80}{0.8} \times 1.761^2 \quad = 155.1 \text{ J}$$

Answer: (i) 32.0 J; (ii) 155 J.

(b)

(i) Fired horizontally:

change in (KE + GPE + EPE) = 0

$$\Rightarrow \quad \frac{1}{2}mv^2 + 0 + (32.0 - 155.1) = 0$$

$$\Rightarrow \quad 1.5v^2 - 123.1 = 0$$

$$\Rightarrow \quad v = 9.059 \text{ m s}^{-1}$$

(ii) Fired vertically:

change in (KE + GPE + EPE) = 0

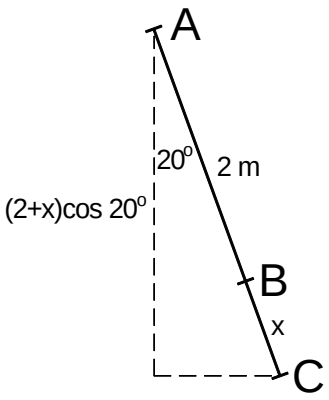
$$\Rightarrow \quad \frac{1}{2}mv^2 + mgh + (32.0 - 155.1) = 0$$

$$\Rightarrow \quad 1.5v^2 + 3 \times 9.81 \times 1 - 123.1 = 0$$

$$\Rightarrow \quad v = 7.902 \text{ m s}^{-1}$$

Answer: (i) 9.06 m s^{-1}; (ii) 7.90 m s^{-1}.

Example 7.
Let the maximum compression of the spring be x.



Apply the energy principle between the point of release (A) and the point of maximum compression (C). The velocity is instantaneously zero at both points.

Change in (KE + GPE + EPE) = 0

$\Rightarrow \quad 0 - mg(2 + x)\cos 20° + \frac{1}{2}kx^2 = 0$

$\Rightarrow \quad -73.75(2 + x) + 1000x^2 = 0$

$\Rightarrow \quad 1000x^2 - 73.75x - 147.5 = 0$

Solving by quadratic formula:

$$x = \frac{73.75 \pm \sqrt{73.75^2 - 4 \times 1000 \times (-147.5)}}{2 \times 1000} \quad = 0.4227 \text{ m}$$

(or a meaningless negative root).

Answer: 0.423 m.

Note. The big advantage of using the energy principle here is that we need only consider changes *between the end points*. In particular, we *do not need to find speed at B*.

Example 8.
The position of the mechanism is completely described by the single degree of freedom θ. Other choices, including h, are possible, but would lead to more complex differentiation.

In a possible displacement of the mechanism only the moment M and load P do work.

In terms of θ,

$$h = 2r\cos\theta$$

$$\delta h = \frac{\mathrm{d}h}{\mathrm{d}\theta}\delta\theta \quad = -2r\sin\theta\,\delta\theta$$

Work done in a small displacement:

$$\delta W = -M\,\delta\theta - P\,\delta h$$

$$= -M\,\delta\theta - P(-2r\sin\theta)\delta\theta$$

Hence,

$$\delta W = (2Pr\sin\theta - M)\,\delta\theta$$

The mechanism is in equilibrium if and only if

$$\delta W = 0 \text{ for all } \delta\theta$$

Hence,

$$M = 2Pr\sin\theta$$

Answer: $2\,\mathrm{Pr}\sin\theta$.

(b) To change the above result into one in terms of h rather than θ, one needs to write $\sin\theta$ in terms of h. Now,

$$\cos\theta = \frac{h}{2r}$$

$$\Rightarrow \qquad \sin\theta = \sqrt{1-\cos^2\theta} \quad = \sqrt{1-\left(\frac{h}{2r}\right)^2}$$

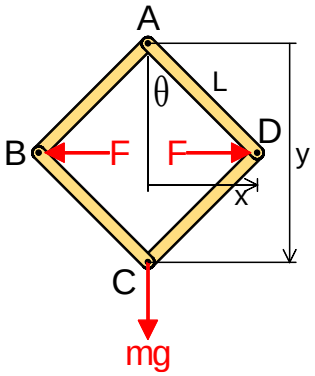
Hence,

$$M = 2Pr\sin\theta = P\times 2r\sqrt{1-\left(\frac{h}{2r}\right)^2} \quad = P\sqrt{4r^2-h^2}$$

Answer: $P\sqrt{4r^2-h^2}$.

Example 9.
Remove the rod and replace it by the two outward thrust forces F that it imposes on the framework at B and D.

The mechanism now consists of four pin-jointed rods, whose arrangement is fully defined by a single degree of freedom: the semi-vertex angle θ at A. We need the thrust F that will give equilibrium for angle $\theta = 45°$.



The only forces that do work in a possible displacement (corresponding to a change in θ) are the two thrust forces F and the weight mg. To determine the work that they do in a small displacement, introduce "helper" coordinates x as the horizontal distance from the vertical centreline to D and y as the vertical distance from A to C. The work done by each force F and the weight mg in a small displacement will then be $F\ \delta x$ and $mg\ \delta y$ respectively; we therefore need to write δx and δy in terms of the single degree of freedom $\delta\theta$.

$$x = L\sin\theta \quad \Rightarrow \quad \delta x = \frac{\mathrm{d}x}{\mathrm{d}\theta}\delta\theta \quad = L\cos\theta\ \delta\theta$$

$$y = 2L\cos\theta \quad \Rightarrow \quad \delta y = \frac{\mathrm{d}y}{\mathrm{d}\theta}\delta\theta \quad = -2L\sin\theta\ \delta\theta$$

The work done in a small displacement is

$$\begin{aligned}\delta W &= 2\times F\ \delta x + mg\ \delta y \\ &= 2F(L\cos\theta\ \delta\theta) + mg(-2L\sin\theta\ \delta\theta) \\ &= 2L(F\cos\theta - mg\sin\theta)\ \delta\theta\end{aligned}$$

For equilibrium, require

$$\delta W = 0 \text{ for all } \delta\theta$$

$$\Rightarrow \quad F\cos\theta - mg\sin\theta = 0$$

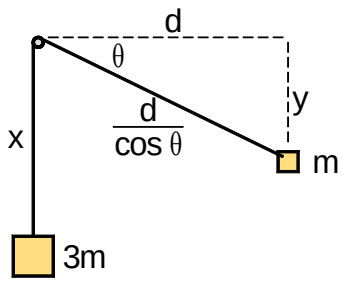
$$\Rightarrow \quad F = mg\tan\theta$$

The particular thrust F which will give equilibrium at $\theta = 45°$ is then

$$F = mg\tan 45° \quad = mg$$

Answer: mg.

Example 10.
The only fixed level is that of the peg, so refer vertical coordinates to this datum.



To write an expression for the total gravitational potential energy we need the vertical distances of the two masses, $3m$ and m below the peg. Call these x and y respectively. Now, the distance from the peg to the ring is $d/\cos\theta$. Hence,

$$x = L - \frac{d}{\cos\theta}$$
$$y = d\tan\theta$$

Thus, the potential energy is that of a mass $3m$ a distance $L - d/\cos\theta$ below the peg, plus that of a mass m a distance $d\tan\theta$ below the peg. Hence,

$$V = -3mg(L - \frac{d}{\cos\theta}) - mg(d\tan\theta)$$

$$\Rightarrow \qquad V = mgd(\frac{3}{\cos\theta} - \tan\theta) - 3mgL$$

V is thus a function of the single parameter θ. Equilibrium corresponds to a stationary point and the equilibrium will be stable if and only if this stationary point is a minimum.

To determine the equilibrium value of θ:

$$\frac{\mathrm{d}V}{\mathrm{d}\theta} = mgd\left[-3(\cos\theta)^{-2}(-\sin\theta) - \sec^2\theta\right]$$
$$= \frac{mgd}{\cos^2\theta}(3\sin\theta - 1)$$

Equilibrium corresponds to $\mathrm{d}V/\mathrm{d}\theta = 0$ and this occurs only where

$$\sin\theta = \frac{1}{3}$$

The question actually asks for the distance $y = d\tan\theta$. If $\sin\theta = \frac{1}{3}$ then

$$\cos\theta = \sqrt{1 - \left(\frac{1}{3}\right)^2} \quad = \sqrt{\frac{8}{9}} \quad = \frac{2\sqrt{2}}{3}$$

$$\Rightarrow \qquad \tan\theta = \frac{\sin\theta}{\cos\theta} \quad = \frac{1}{2\sqrt{2}}$$

(Alternatively, deduce this by drawing the right-angled triangle with opposite side and hypotenuse of lengths 1 and 3 respectively.) Hence,

$$y = d\tan\theta \quad = \frac{d}{2\sqrt{2}}$$

To show that this is a minimum stationary point one could differentiate again and show that $\mathrm{d}^2V/\mathrm{d}\theta^2 > 0$. However, this is unnecessary here as it is easy to deduce the sign of $\mathrm{d}V/\mathrm{d}\theta$ near the turning point. $mgd/\cos^2\theta$ is always positive and (in the possible angle range) $3\sin\theta - 1$ is an increasing function of θ. Hence,

- at the turning point, $\mathrm{d}V/\mathrm{d}\theta = 0$
- if θ is slightly smaller, $\mathrm{d}V/\mathrm{d}\theta < 0$
- if θ is slightly larger, $\mathrm{d}V/\mathrm{d}\theta > 0$

The local shape of $V(\theta)$ is therefore

_/

This is a minimum and hence a stable equilibrium point.

Answer: stable equilibrium when the ring is distance $\frac{d}{2\sqrt{2}}$ below the peg.

Example 11.
(a) The total potential energy comprises gravitational potential energy of the bar (determined from its centroid) and elastic potential energy of the spring (determined by its extension).

Gravitational PE
Use the pivot O as datum. As the centre of the bar is a vertical distance $\frac{1}{2}a\cos\theta$ above,

$$\text{GPE} = mg(\frac{1}{2}a\cos\theta)$$

Elastic PE

Length of the spring: $2\times a\sin\frac{1}{2}\theta$ (isosceles triangle)

Extension: $2a\sin\frac{1}{2}\theta - \frac{1}{2}a$

Then,

$$\begin{aligned}\text{EPE} &= \frac{1}{2}k(2a\sin\frac{1}{2}\theta - \frac{1}{2}a)^2\\ &= \frac{1}{2}\times\frac{mg}{a}\times a^2(2\sin\frac{1}{2}\theta - \frac{1}{2})^2\\ &= \frac{1}{2}mga(2\sin\frac{1}{2}\theta - \frac{1}{2})^2\end{aligned}$$

Total PE:

$$V = \text{GPE} + \text{EPE} \quad = \frac{1}{2}mga\cos\theta + \frac{1}{2}mga(2\sin\frac{1}{2}\theta - \frac{1}{2})^2$$

$$\Rightarrow \qquad V = \frac{1}{2}mga\left\{\cos\theta + (2\sin\frac{1}{2}\theta - \frac{1}{2})^2\right\}$$

(b) Equilibrium positions occur at stationary points, where $\mathrm{d}V/\mathrm{d}\theta = 0$. These are stable if and only if they are minimum stationary points.

$$\begin{aligned}\frac{\mathrm{d}V}{\mathrm{d}\theta} &= \frac{1}{2}mga\left\{-\sin\theta + 2(2\sin\frac{1}{2}\theta - \frac{1}{2})\times 2\times\frac{1}{2}\cos\frac{1}{2}\theta\right\}\\ &= \frac{1}{2}mga\left\{-2\sin\frac{1}{2}\theta\cos\frac{1}{2}\theta + 2(2\sin\frac{1}{2}\theta - \frac{1}{2})\cos\frac{1}{2}\theta\right\}\\ &= mga(\sin\frac{1}{2}\theta - \frac{1}{2})\cos\frac{1}{2}\theta\end{aligned}$$

Hence, stationary points occur (in $0 \le \theta \le 180°$) where:

$\sin\frac{1}{2}\theta = \frac{1}{2}$ corresponding to $\frac{1}{2}\theta = 30°$, i.e. $\theta = 60°$.

$\cos\frac{1}{2}\theta = 0$ corresponding to $\frac{1}{2}\theta = 90°$, i.e. $\theta = 180°$.

The nature of the stationary point (maximum, minimum, point of inflexion with zero slope) may be determined from $\mathrm{d}^2V/\mathrm{d}\theta^2$ or simply from the sign of the slope $\mathrm{d}V/\mathrm{d}\theta$ at nearby angles.

Method 1: second derivative

By the product rule:

$$\frac{\mathrm{d}^2V}{\mathrm{d}\theta^2} = mga\left\{\cos\frac{1}{2}\theta\cos\frac{1}{2}\theta - (\sin\frac{1}{2}\theta - \frac{1}{2})\sin\frac{1}{2}\theta\right\}$$
$$= mga\,(\cos\theta + \frac{1}{2}\sin\frac{1}{2}\theta)$$

where we have used a double-angle formula in the form $\cos^2(\frac{1}{2}\theta) - \sin^2(\frac{1}{2}\theta) = \cos\theta$.

When $\theta = 60°$ this gives $\mathrm{d}^2V/\mathrm{d}\theta^2 = mga \times (3/4)$, which is positive; this is a minimum of potential energy and hence a stable equilibrium point.

When $\theta = 180°$ this gives $\mathrm{d}^2V/\mathrm{d}\theta^2 = mga \times (-1/2)$, which is negative; this is a maximum of potential energy and hence an unstable equilibrium point.

Method 2: local slopes

Consider the factors in

$$\frac{\mathrm{d}V}{\mathrm{d}\theta} = mga(\sin\frac{1}{2}\theta - \frac{1}{2})\cos\frac{1}{2}\theta$$

Near $\theta = 60°$ ($½\theta = 30°$), $\cos\frac{1}{2}\theta$ is positive and factor $(\sin\frac{1}{2}\theta - \frac{1}{2})$ is an increasing function which passes through 0 at the stationary point. Hence, $\mathrm{d}V/\mathrm{d}\theta$ goes from negative, through zero, to positive, and $V(\theta)$ has shape _/. Thus, $\theta = 60°$ is a minimum stationary point, corresponding to stable equilibrium.

Near $\theta = 180°$ ($½\theta = 90°$), factor $(\sin\frac{1}{2}\theta - \frac{1}{2})$ is positive, whilst factor $\cos\frac{1}{2}\theta$ is a decreasing function which passes through 0 at the stationary point. Hence, $\mathrm{d}V/\mathrm{d}\theta$ goes from positive, through zero, to negative, and $V(\theta)$ has shape /‾\. Thus, $\theta = 180°$ is a maximum stationary point, corresponding to unstable equilibrium.

Answer: $\theta = 60°$, stable; $\theta = 180°$, unstable.

Example 12.
First find the maximum friction force ($F_{\max} = \mu R$) and confirm that the block does move.

To find R resolve forces vertically:

$$R + T\sin 30° - mg = 0$$

$$\Rightarrow \quad R = mg - T\sin 30° \quad = 5 \times 9.81 - 40 \times \tfrac{1}{2} \quad = 29.05 \text{ N}$$

Then

$$F_{\max} = \mu R \quad = 0.2 \times 29.05 \quad = 5.81 \text{ N}$$

The motive force along the plane is

$$T\cos 30° = 40 \times \frac{\sqrt{3}}{2} \quad = 34.64 \text{ N}$$

This exceeds the maximum friction force; hence, the block *does* move and friction is maximal: $F = F_{\max} = 5.81$ N.

The velocity of the block could be found by energy or by finding the acceleration, then applying constant-velocity formula. The former is more direct.

Change in (KE + PE) = work done by non-conservative forces

$$\frac{1}{2}mv^2 + 0 = T\cos 30° \times 1 - F \times 1$$

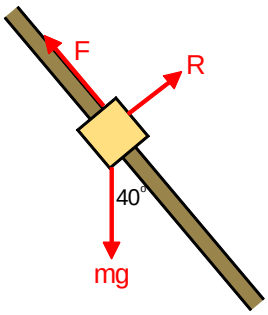
$$\Rightarrow \quad 2.5v^2 = 34.64 - 5.81$$

$$\Rightarrow \quad v = 3.396 \text{ m s}^{-1}$$

Answer: 3.40 m s^{-1}.

Example 13.

(a) To find the friction force, first find the normal reaction R.



Resolving normal to the rod:

$$R - mg\sin 40° = 0$$

$$\Rightarrow \quad R = mg\sin 40° \quad = 5 \times 9.81 \times \sin 40° \quad = 31.53 \text{ N}$$

The maximum friction force is

$$F_{\max} = \mu R \quad = 0.4 \times 31.53 \quad = 12.61 \text{ N}$$

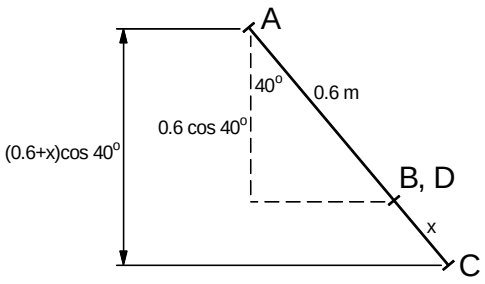
The (initial) motive force is

$$mg\cos 40° = 5 \times 9.81 \times \cos 40° \quad = 37.57 \text{ N}$$

This exceeds $F_{\max}$; hence, the collar does slide and friction is maximal: $F = F_{\max} = 12.61$ N.

Answer: 12.6 N.

(b)



Apply the energy principle from release (A) to where the collar strikes the spring (B):

Change in (KE + PE) = work done by friction

$$\Rightarrow \quad \frac{1}{2}mv^2 - mg(0.6\cos 40°) = -F \times 0.6$$

$$\Rightarrow \quad 2.5v^2 - 22.54 = -12.61 \times 0.6$$

$$\Rightarrow \quad v = 2.447 \text{ m s}^{-1}$$

Answer: 2.45 m s^{-1}.

(c) Apply the energy principle from release (A) to the point of maximum deflection x (C):

Change in (KE + PE) = work done by friction

$$\Rightarrow \quad 0 - mg(0.6 + x)\cos 40° + \frac{1}{2}kx^2 = -F \times (0.6 + x)$$

$$\Rightarrow \quad -37.57(0.6 + x) + 250x^2 = -12.61 \times (0.6 + x)$$

$\Rightarrow \quad 250x^2 - 24.96x - 14.98 = 0$

Solving by quadratic formula:

$$x = \frac{24.96 \pm \sqrt{24.96^2 - 4 \times 250 \times (-14.98)}}{2 \times 250} \quad = 0.2997 \text{ m}$$

(or a meaningless negative root).

Answer: 0.300 m.

(d) Apply the energy principle from release to the point where the spring has just uncompressed (A → B → C → D). Note that friction reverses direction when the collar starts rising back up the rod; the work that it does is based on the total distance of travel, $0.6 + 2x$, not just the net displacement of 0.6 m; this is because friction is a non-conservative force. (Actually, you also need to check that friction is insufficient to prevent the collar from moving back up the rod: at maximum displacement the net upward motive force is $kx - mg\cos 40° = 112.3$ N, which is greater than the maximum friction force.)

Change in (KE + PE) = work done by friction

$\Rightarrow \quad \frac{1}{2}mv^2 - mg(0.6\cos 40°) = -F \times (0.6 + 2x)$

$\Rightarrow \quad 2.5v^2 - 22.54 = -12.61 \times (0.6 + 2 \times 0.2997)$

$\Rightarrow \quad v = 1.722 \text{ m s}^{-1}$

Answer: 1.72 m s^{-1}.

Example 14.
The input power is given (1000 W). For efficiency, we need to know the output power.

$$\text{Power out} = \text{rate of doing work}$$
$$= \text{rate of supplying energy}$$
$$= \text{rate that the lifted mass gains PE (since its KE is constant)}$$
$$= \frac{mgh}{t} \quad = \frac{900 \times 9.81 \times 5}{60} \quad = 735.8 \text{ W}$$

Then,

$$\eta = \frac{\text{power out}}{\text{power in}} \quad = \frac{735.8}{1000} \quad = 0.7358$$

Answer: 0.736 (= 73.6%).

Alternative method for output power

To move the mass at steady speed requires a force equal to the weight:

$$F = mgh$$

The velocity is

$$v = \frac{h}{t}$$

Output power is then

$$Fv = mg \times \frac{h}{t} \quad = \frac{mgh}{t}$$

as above.