Work

Problems: Work

Formulae: $W = Fd$ or $W = mgh$

Example Problems:

1. A 15.0 kg object is lifted at constant velocity from the floor to height of 1.50 m. How much work is done on the object?

$$\begin{aligned} W &= mgh \\ &= (15.0\text{ kg})(9.81\text{ m/s}^2)(1.50\text{ m}) \\ &= 221\text{ J} \end{aligned}$$

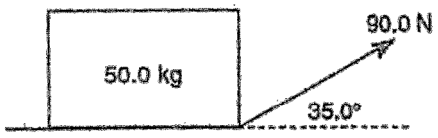
2. A 10.0 kg object is moved horizontally 5.00 m across a level floor using a horizontal force of 3.00 N. How much work is done on the object?

$$\begin{aligned} W &= Fd \\ &= (3.00\text{ N})(5.00\text{ m}) \\ &= 15.0\text{ J} \end{aligned}$$

3. A 3.0 kg object is held 1.2 m above the floor for 15 s. How much work is done on the object?

0

A 50.0 kg box is pulled 11.0 m along a level surface by a rope. If the rope makes an angle with the surface of 35.0°, and the force exerted through the rope is 90.0 N, how much work is done on the box?



Since the object moves horizontally, we must find the horizontal component of the force.

$$\begin{aligned} \cos\theta &= \frac{\text{adj}}{\text{hyp}} \\ \text{adj} &= \cos\theta\,(\text{hyp}) \\ &= (\cos 35.0°)(90.0\text{ N}) \\ &= 73.7\text{ N} \end{aligned}$$

$$\begin{aligned} W &= Fd \\ &= (73.7\text{ N})(11.0\text{ m}) \\ &= 811\text{ J} \end{aligned}$$

5. A 1385 kg car travelling at 61 km/h is brought a stop while skidding 42 m. What is the work done on the car by the frictional forces?

Convert 61 km/h to m/s

$$61\text{ km/h} = 16.9\text{ m/s}$$

$$\begin{aligned} v_f^2 &= v_i^2 + 2ad \\ (16.9\text{ m/s})^2 &= (2)(a)(42\text{ m}) \\ a &= -3.42\text{ m/s}^2 \end{aligned}$$

$$\begin{aligned} F &= ma \\ &= (1385\text{ kg})(-3.42\text{ m/s}^2) \\ &= -4.73 \times 10^3\text{ N} \end{aligned}$$

$$\begin{aligned} W &= Fd \\ &= (4.73 \times 10^3\text{ N})(42\text{ m}) \\ &= -2.0 \times 10^5\text{ J} \end{aligned}$$

NOTE: Answer is negative because the force an the displacement are in opposite directions.

Practice Problems:

1. A 20.0 N object is lifted at a constant velocity from the floor to a height of 1.50 m. How much work is done on the object?

Answer - $W = \vec{F}d$ $W = (20.0)(1.50)$

$W = 30.0\ J$

2. A 15.0 N object is moved horizontally 3.00 m across a level floor using a horizontal force of 6.00 N. How much work is done on this object?

Answer - $W = \vec{F}d$ $W = (6.00)(3.00)$

$W = 18.0\ J$

3. A 2.20 N object is held 2.20 m above the floor for 10.0 s. How much work is done on the object?

Answer - no movement = zero

4. A 10.0 kg object is accelerated horizontally from rest to a velocity of 11.0 m/s in 5.00 s by a horizontal force. How much work is done on this object if it accelerates along a frictionless surface?

Answer - $\vec{v}_f = \vec{v}_o + \vec{a}t \qquad 11 = 0 + \vec{a}(5.00)$

$\vec{a} = +2.2\frac{m}{s^2}$

$\vec{F}_{net} = m\vec{a} \qquad \vec{F}_{net} = (10.0)(+2.2)$

$\vec{F}_{net} = +22\ N$

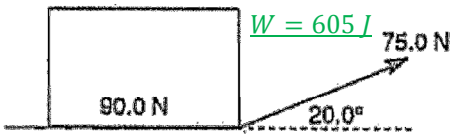
$\vec{v}_f^2 = \vec{v}_o^2 + 2\vec{a}\vec{d} \qquad 11^2 = 2(+2.2)\vec{d}$

$\vec{d} = +27.5\ m$

$W = \vec{F}d \qquad W = (+22)(+27.5)$

$W = 605\ J$

5.



A 90.0 N box is pulled 10.0 m along a level surface by a rope. If the rope makes an angle of 20.0° with the surface, and the force exerted through the rope is 75.0 N, how much work is done on the box?

Answer - $\cos 20 = \frac{x}{75.0} \qquad x = 70.4769$

$W = \vec{F}d \qquad W = (70.5)(10.0)$

$W = 705\ J$

6. A 60.0 kg student runs at a constant velocity up a flight of stairs. If the vertical distance of the stairs is 3.2 m, what is the work done against gravity?

Answer - $W = \vec{F}d \qquad W = (60.0)(9.81)(3.2)$

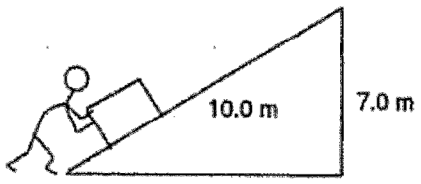
$W = 1883.52\ J \quad or \quad 1.88 \times 10^3 J$

7. A 20.0 kg box is pulled horizontally 9.0 m along a level frictionless surface at a constant velocity. How much work is done on the box?

Answer – inertia needs to be overcome. Meaning a force will be applied over a distance.

However, strictly speaking, an answer of zero in this course is best.

8.



An 80.0 kg box is pushed at a constant velocity along a frictionless incline as shown in the diagram. How much work is done on the box in moving it from the bottom to the top of the incline?

Answer - $W = \vec{F}d \qquad W = (80.0)(9.81)(7.0)$

$W = 5493.6\ J \quad or \quad 5.49 \times 10^3 J$

9. A 25.0 kg object is accelerated from rest through a distance of 6.0 m in 4.0 s across a level floor. If the force due to friction between the object and the floor is 3.8 N, what is the work done in moving the object?

Answer - $\vec{d} = \vec{v}_o t + \frac{1}{2}\vec{a}t^2$ $\quad 6.0 = 0 + (0.5)\vec{a}(4.0)^2$

$\vec{a} = +0.75\frac{m}{s^2}$

$\vec{F}_{net} = m\vec{a}$ $\quad \vec{F}_{net} = (25.0)(+0.75)$

$\vec{F}_{net} = +18.75\ N$

$\vec{F}_{net} = \vec{F}_{net} - \vec{F}_f$ $\quad \vec{F}_{net} = 18.75 - (-3.8)$

$\vec{F} = +22.55\ N$

$W = \vec{F}d$ $\quad W = (+22.55)(6.0)$

$W = 135\ J$

10. A 1165 kg car travelling at 55 km/h is brought to a stop while skidding 38 m. Calculate the work done on the car by the frictional forces.

Answer - $\vec{v}_f^2 = \vec{v}_o^2 + 2\vec{a}\vec{d}$ $\quad 0^2 = (15.27)^2 + 2\vec{a}(38)$

$\vec{a} = -3.068\frac{m}{s^2}$

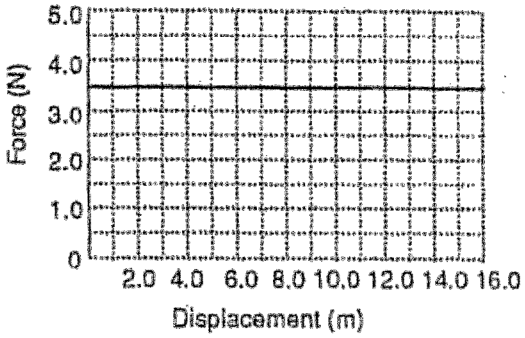
$\vec{F}_{net} = m\vec{a}$ $\quad \vec{F}_{net} = (1165)(-3.068)$

$\vec{F}_{net} = -3574.30\ N$

$W = \vec{F}d$ $\quad W = (-3574.30)(38)$

$W = 135833.21\ J$ $\quad W = 1.36 \times 10^5 J$

11. Given the following force-displacement graph of an object being pulled along a level surface, determine the work done in moving the object 16.0 m.

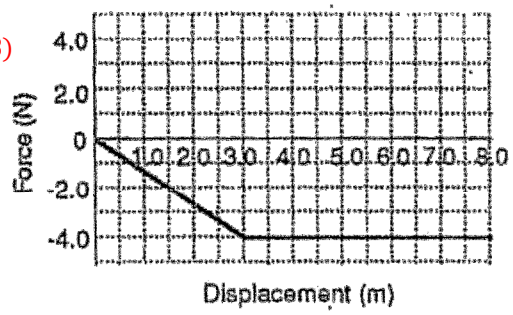


Answer - area under graph is work

$A_{rectangle} = l \times w$ $\quad A_{rectangle} = 3.50 \times 16.0$

$A_{rectangle} = 56.0\ J$

12. Given the following force-displacement graph of an object moving along a horizontal surface, determine the work done in moving the object 8.0 m.



Answer - area under graph is work

$A_{rectangle} = l \times w$ $\quad A_{rectangle} = 5.0 \times 4.0$

$A_{rectangle} = 20.\ J$

$A_{triangle} = l \times w$ $\quad A_{tri} = 0.50 \times 4.0 \times 3.0$

$A_{triangle} = 6.0\ J$

$A_{rectangle} = 26\ J$