Work & Power Intro

Energy ***is the capability to do work.*** Energy can be in many different forms including Work, Kinetic Energy, Potential Energy (gravitational, food, spring energies), Electrical Energy, Heat Energy and others..

Work is done when a ***force*** acts on an object and it has a ***displacement*** it ***in the same direction*** as the force. (Notice: the symbol for work, **W**, is used instead of just **W** to distinguish its symbol from weight.)

Work = Force x displacement Units: **[joules] = [newtons] [metres]**

W=Fd **[J] = [N][m]**

Example 1: The Physics text weighs 14 N so it requires a force of 14 N upward to raised it from the floor to an arm's length over your head, a displacement of about 2.0 m upward. How much work is required to do this?

F = 14 N up	W = Fd
d = 2.0 m up	W = (14 N) (2.0 m) direction is the same
W = ?	W = <u>28 J of work is required to lift the Physics text.</u>

The above problem is an example of **work done against gravity** changing into gravitational **potential energy.** So there is a **special condition...** $\mathbf{W_{done} = PE_{gain}}$ We'll deal with these "conditions" later.

Example 2: It requires a force of 32 N east to drag and displace the podium 4.0 m east. How much work is required to do this?

F = 32 N east	W = Fd
d = 4.0 m east	W = (32 N) (4.0 m) direction is the same
W = ?	W = 128 J = 0.128 kJ ~ <u>0.13 kJ of work to drag podium.</u>

This is an example of **work done against friction** changing into **heat energy.** So there is a special condition... $\mathbf{W_{done} = Heat_{gain}}$ We'll deal with these "conditions" later.

Power is the ***rate of doing work*** or the rate of producing or consuming energy.

Units:

$$\text{Power} = \frac{\text{Work}}{\text{time}} \quad \text{or} \quad \text{Power} = \frac{\Delta\text{Energy}}{\text{time}} \qquad [\text{Watts}] = \frac{[\text{Joules}]}{[\text{seconds}]}$$

$$P = \frac{W}{t} \quad \text{or} \quad P = \frac{\Delta\text{Energy}}{t} \qquad [W] = \frac{[J]}{[s]}$$

For Example: If the podium in the example on the previous page was dragged that distance in 6.0 s, what was the power output of the person pushing the podium?

W = 128 J (calculated previously)	P = W / t
t = 6.0 s	P = 128 J / 6.0 s
	P = 21.33 W ~ 21 W of power output by the person.

Note: James Watt invented the steam engine that was used to operate factories and power tractors. The original unit for describing power was **horsepower**. This must have allowed the comparison to the amount of work that a good team of horses could do in a certain period of time (that is, how many **lbs.** of force they exerted to move something so many **feet** in a **minute** of time. 1 hp = 33,000 ft.lb/min or 1 hp = 550 ft.lb/sec More importantly, this is the metric conversion. **1 hp = 746 W**

Work - Typical Problems

1. The **force** of gravity on a typical 3-hole punch is **15.68 N** (its weight). In order to just lift the punch at constant velocity (without acceleration) a person has to exert an upward force equal to its weight. If the punch is to be lifted a **distance** of **2.0 m** to the top shelf of a cupboard, how much **work** is required? (31 J)

   Note: **This work is done against gravity.** The work is converted into something called "gravitational potential energy". That is, the hole punch now has the *potential* to fall back down and gain the energy of motion, called "kinetic energy". We'll study these briefly soon.

2. Suppose a **28 N force** was required to slide an empty desk a **distance** of 3.0 m across the floor. How much **work** would be done to do this? (84 J)

   Note: The work done to slide the desk across the floor with constant velocity is **work done against friction**. This work is converted into heat energy when the legs of the desk rub on the floor. Rub your hand quickly back and forth across the top of the desk or along you shirt sleeve... it should heat up!

3. If a hammer can do **70 J** of **work** in a single blow when it strikes a nail and the nail requires a force of **3500 N** to drive it into a piece of hardwood (like oak), then what **distance** (in centimetres) will the nail be driven into the wood? (2.0 cm)

   Note: The work done to drive in the nail is **work done against friction**. The work done is converted into heat energy due to the friction between the nail and the wood... so 70 J of heat energy would be produced. Have you ever felt a nail heat up while you've hammered it in?

4. A person's bite can exert incredibly large forces. This is why dentists or denturists must ensure that bridges or false teeth are properly fitted. It is estimated that it requires **17 J** or **work** just to take that first big bit of an apple. If a person sinks there teeth in a **distance** of **4.0 cm** into the apple, what **force** must the teeth have exerted on the apple? (425 N)

5. Some people find recreation in playing war games using guns that shoot paint balls. These balls are shot at very high speeds by compressed air and strike a person with a hefty force, often leaving bruises! For example, 4.0 g paint ball moving at 75 m/s would have **11.25 J** of kinetic energy that is converted into **work** to dent in the skin. If the skin in pushed in a **distance** of **0.50 cm** during the impact, how much **force** is exerted on impact? (2250 N - ouch!)

6. From road test data it can be calculated that a VW Rabbit engine can exert a deliver **360 kJ** of **work** (to accelerate from 0 km/h to 108 km/h in 6.0 s). If the car traveled a **distance** of **90 m** in that time, what **force** must the engine have delivered in order to accelerate at this rate? (4 000 N)

Note: This is **work done to accelerate** an object.

Work - Tougher Problems

Usually Physics questions require the use of more than one formula at a time. These "tougher" questions may require you to use the "acceleration" equation and the "force" equation and/or the "Work" equation.

7. The objective of drag racing is who can get their car to go a distance of 400 m (1/4 mile) in the least amount of time. One of the best times ever recorded was for a "funny car" with a **mass** of **800 kg** that started from **rest** and reached a speed of **160 m/s** (576 km/h) and took **5.0 s** of **time** to go the **400 m distance**. How many MegaJoules (millions of Joules) of **work** did its engine have to do? (10.2 MJ)

Hints: Identify the initial velocity, final velocity and time; then calculate acceleration using

Calculate the Force using **F = ma**.

Calculate the Work using **W = Fd**.

8. Suppose an Olympic cyclist, in a **8.0 s** of **time** had burst of energy that could output **11.2 kJ** of **work** to accelerate herself (**60 kg**) and her racing bike (**10 kg**) from an **initial velocity** of **2.0 m/s**. What will her **final velocity** be after this outburst of work if the **distance** she travelled was **80 m**?

(18 m/s or 65 km/h)

Hints: Identify the Work and the distance; then calculate the Force using **W = Fd**.

Calculate the acceleration using **F = ma.**

Identify the initial velocity, time; using the acceleration from step 2, calculate the final velocity using