How Big is ‘BIG!’?
Comparing Forms of Energy Release

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National Air and Space Museum
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The **Smithsonian Institution** is the world’s largest complex of museums and research centers.

Named for James Smithson (1765-1829)

The Smithsonian Castle (1846)

Secretary Wayne Clough >
National Air and Space Museum

(1903 Wright Flyer)

Steven F. Udvar-Hazy Center (Dulles airport)
Some Definitions

Energy is the capacity of a physical system to perform work.

Work is the sum total of force applied over a distance of displacement.

Power is the rate at which energy is transferred.
Kinetic (the energy of motion)
Potential (stored energy)
Thermal (heat)
Chemical (chemical reactions)
Electrical (electrons)
Nuclear (atoms)

Forms of Energy

Mechanical
Electrochemical
Electromagnetic
Sir Isaac Newton
(1642-1727)

He established the mathematical basis for understanding nature

(‘Newtonian Physics’)
Two Important Equations

**Kinetic Energy** = \( \frac{1}{2} m v^2 \)
- \( m \) (mass) in Kilograms
- \( v \) (velocity squared) in Meters per second

**Potential Energy** = \( m g h \)
- \( m \) (mass) in Kilograms
- \( g \) (acceleration of gravity) = 9.81 Meters per second per second
- \( h \) (height) in Meters
James P. Joule
(1818-1889)

He demonstrated the mechanical equivalent of heat

4.18 Joules = 1 calorie

(Joule’s experiment, 1845)
So, a chemical explosion produces heat and throws objects over great distances, but all of these are forms of the same energy.
He showed that mass is equivalent to energy

\[ E = m \cdot c^2 \]

(mass) Kilograms

(speed of light) Meters per second per second
So, *energy* can take many forms ...

Energy forms are interchangeable ...

The Joule is the (metric) unit for *energy*...

\[ E = mc^2 \]
<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese Firecracker</td>
<td>30 J</td>
</tr>
<tr>
<td>1 Stick of Dynamite</td>
<td>$2 \times 10^6$ J</td>
</tr>
<tr>
<td>1 Ton of TNT</td>
<td>$4.2 \times 10^9$ J</td>
</tr>
<tr>
<td>Combustion of 1 Barrel of Oil</td>
<td>$6 \times 10^9$ J</td>
</tr>
<tr>
<td>Kinetic Energy of Int. Space Station</td>
<td>$1.3 \times 10^{13}$ J</td>
</tr>
<tr>
<td>Small Nuclear Bomb (15 kT)</td>
<td>$6.3 \times 10^{13}$ J</td>
</tr>
</tbody>
</table>
Decide (as a group) the order of the five events listed on the screen, from the least to the most:

Most energy released

Least energy released

1. A 1 km-diameter asteroid hits the Earth
2. The Krakatau eruption (August 27, 1883)
3. The Japan earthquake (March 11, 2011)
4. A large hurricane (Katrina, 2006)
5. Global use of energy (during 2008)
The Japan Earthquake

$10^{19}$ J

Fourth

The Krakatau Eruption

$10^{17}$ J

Least

Fifth
Global Energy Use (during 2008)

\[ 5 \times 10^{20} \text{ J} \]

Second

1 km Asteroid Impact

\[ 3 \times 10^{20} \text{ J} \]

Third
Now that is a **LOT** of energy!

Large Hurricane

$10^{21} \text{ J}$
Energy Flux from the Sun \[4 \times 10^{24} \text{ J/year!}\]

Global Supply: All Fossil Fuels \[\sim 10^{24} \text{ J}\]

10 km-diameter Impact \[3 \times 10^{23} \text{ J}\]

Decide (as a group) the order of the five events listed on the screen, from the least to the most:

Most energy released

4 (hurricane) \[10^{21} \text{ J}\]

5 (global energy) \[5 \times 10^{20} \text{ J}\]

1 (1 km impact) \[3 \times 10^{20} \text{ J}\]

3 (earthquake) \[10^{19} \text{ J}\]

Least energy released

2 (eruption) \[10^{17} \text{ J}\]
Review

Energy can take **many forms**

Energy forms are **interchangeable**

The **Joule** is the (metric) unit for energy

The energy of events **can** be compared