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## NCERT Class 11 Physics Solutions: Chapter 6 - Work, Energy, and Power Part 6

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## Question 6.11:

A body constrained to move along the z -axis of a coordinate system is subject to a constant force ; given by $F=-\hat{i}+2 \hat{j}+3 \hat{k} N$

Where $\hat{i}, \hat{j}, \hat{k}$ are unit vectors along the $x, y$ and -axis of the system respectively. What is the work done by this force in moving the body a distance of $4 m$ along the -axis?

## Answer:

Force exerted on the body, $F=-\hat{i}+2 \hat{j}+3 \hat{k} N$
Displacement, $s=4 \widehat{k} m$
Work done, $W=F \bullet s$

$$
\begin{aligned}
& =(-\hat{i}+2 \hat{j}+3 \hat{k}) \cdot(4 \hat{k}) \\
& =0+0-3 \times 4 \\
& =12 \mathrm{~J}
\end{aligned}
$$

Hence, $12 J$ of work is done by the force on the body. Question 6.12:
An electron and a proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV , and the second with 100 keV . Which is faster, the electron or the proton? Obtain the ratio of their speeds. (electron mass $=9.11 \times 10-31 \mathrm{~kg}$, proton mass
$=1.67 \times 10-27 \mathrm{~kg}, 1 \mathrm{eV}=1.60 \times 10-19 \mathrm{~J})$.

## Answer:

Electron is faster; Ratio of speeds is $13.54: 1$
Mass of the electron, $m_{e}=9.11 \times 10^{-31} \mathrm{~kg}$
Mass of the proton, $m_{p}=1.67 \times 10^{27} \mathrm{~kg}$
Kinetic energy of the electron, $E_{k e}=10 \mathrm{kev}=10^{4} \mathrm{eV}$

$$
\begin{aligned}
& =10^{4} \times 1.60 \times 10^{-19} \\
& =1.60 \times 10^{-15} \mathrm{~J}
\end{aligned}
$$

Kinetic energy of the proton,

$$
E_{k p}=100 \mathrm{keV}=10^{5} \mathrm{eV}=1.60 \times 10^{-14} \mathrm{~J}
$$

For the velocity of an electron $v_{c}$, its kinetic energy is given by the relation:

$$
\begin{aligned}
& E_{k e}=\frac{1}{2} m \cdot v_{c}^{2} \\
& \therefore v_{c}=\sqrt{\frac{2 \times E_{k e}}{m}} \\
& =\sqrt{\frac{2 \times 1.60 \times 10^{-15}}{9.11 \times 10^{-31}}} \\
& =5.93 \times 10^{7} \mathrm{~m} / \mathrm{s}
\end{aligned}
$$

For the velocity of a proton $v_{v_{p}}$, its kinetic energy is given by the relation:

$$
\begin{aligned}
& E_{k p}=\frac{1}{2} m \cdot v_{p}^{2} \\
& \therefore v_{p}=\sqrt{\frac{2 \times E_{k p}}{m}} \\
& \therefore v_{p}=\sqrt{\frac{2 \times 1.6 \times 10^{-14}}{1.67 \times 10^{-27}}} \\
& =4.38 \times 10^{6} \mathrm{~m} / \mathrm{s}
\end{aligned}
$$

Hence, the electron is moving faster than the proton.
The ratio of their speeds:

$$
\begin{aligned}
& \frac{v_{c}}{v_{p}}=\frac{5.93 \times 10^{7}}{4.38 \times 10^{6}} \\
& =13.54: 1
\end{aligned}
$$

## Question 6.13:

A rain drop of radius 2 mm falls from a height of 500 m above the ground. It falls with decreasing acceleration (due to viscous resistance of the air) until at half its original height, it attains its maximum (terminal) speed, and moves with uniform speed thereafter. What is the work done by the gravitational force on the drop in the first and second half of its journey? What is the work done by the resistive force in the entire journey if its speed on reaching the ground is $10 \mathrm{~ms}-1$ ?

## Answer:

Radius of the raindrop, $r=2 \mathrm{~mm}=2 \times 10^{-3} \mathrm{~m}$
Volume of the raindrop, $V=\frac{4}{3} \pi r^{3}$

$$
=\frac{4}{3} \times 3.14 \times\left(2 \times 10^{-3}\right)^{3} m^{-3}
$$

Density of water, $\rho=10^{3} \mathrm{kgm}^{-3}$
Mass of the raindrop, $m=\rho V$

$$
=\frac{4}{3} \times 3.14 \times\left(2 \times 10^{-3}\right)^{3} \times 10^{3} \mathrm{~kg}
$$

Gravitational force, $F=m \bullet g$

$$
=\frac{4}{3} \times 3.14 \times\left(2 \times 10^{-3}\right)^{3} \times 10^{3} \times 9.8 N
$$

The work done by the gravitational force on the drop in the first half of its journey:

$$
\begin{aligned}
& W_{1}=F_{s} \\
& =\frac{4}{3} \times 3.14 \times\left(2 \times 10^{-3}\right)^{3} \times 10^{3} \times 9.8 \times 250 \mathrm{~N} \\
& =0.082 \mathrm{~J}
\end{aligned}
$$

This amount of work is equal to the work done by the gravitational force on the drop in the second half of its journey,
i.e.. , $W_{I I},=0.082 \mathrm{~J}$

As per the law of conservation of energy, if no resistive force is present, then the total energy of the raindrop will remain the same.

Total energy at the top:

$$
\begin{aligned}
& E_{r}=m \cdot g \cdot h+0 \\
& =\frac{4}{3} \times 3.14 \times\left(2 \times 10^{-3}\right)^{3} \times 10^{3} \times 9.8 \times 500 \times 10^{-5} \\
& =0.164 \mathrm{~J}
\end{aligned}
$$

Due to the presence of a resistive force, the drop hits the ground with a velocity of $10 \mathrm{~m} / \mathrm{s}$.
$\therefore$ Total energy at the ground:

$$
\begin{aligned}
& E_{G}=\frac{1}{2} m v^{2}+0 \\
& =\frac{1}{2} \times \frac{4}{3} \times 3.14 \times\left(2 \times 10^{-3}\right)^{3} \times 10^{3} \times 9.8 \times(10)^{2} \\
& =1.675 \times 10^{-3} \mathrm{~J}
\end{aligned}
$$

$\therefore$ Resistive force $=E_{G}-E_{r}=-0.162 J$

