## Chapter 5

5.1 (c)
5.2 (b)
5.3 (c)
5.4 (c)
5.5 (d)
5.6 (c)
5.7 ..... (a)
5.8 (b)
5.9 (b)
5.10 (a), (b) and (d)
5.11 (a), (b), (d) and (e)
5.12 (b) and (d)
5.13 (b), (c)
5.14 (c), (d)
5.15 (a), (c)
5.16 Yes, due to the principle of conservation of momentum.Initial momentum $=50.5 \times 5 \mathrm{~kg} \mathrm{~m} \mathrm{~s}^{-1}$

## Exemplar Problems-Physics

Final momentum $=(50 v+0.5 \times 15) \mathrm{kg} \mathrm{m} \mathrm{s}^{-1}$

$$
v=4.9 \mathrm{~m} \mathrm{~s}^{-1} \text {, change in speed }=0.1 \mathrm{~m} \mathrm{~s}^{-1}
$$

5. 17 Let $R$ be the reading of the scale, in newtons.

Effective downward acceleration $=\frac{50 g-R}{50}=g$
$R=5 g=50 \mathrm{~N}$. (The weighing scale will show 5 kg ).
5.18 Zero; $-\frac{3}{2} \mathrm{~kg} \mathrm{~m} \mathrm{~s}^{-1}$
5.19 The only retarding force that acts on him, if he is not using a seat belt comes from the friction exerted by the seat. This is not enough to prevent him from moving forward when the vehicle is brought to a sudden halt.
$5.20 \quad \mathbf{p}=8 \hat{\mathbf{i}}+8 \hat{\mathbf{j}}, \quad \mathbf{F}=(4 \hat{\mathbf{i}}+8 \hat{\mathbf{j}}) \mathrm{N}$
$5.21 f=F$ until the block is stationary.
$f$ remains constant if $F$ increases beyond this point and the block starts moving.

5.22 In transportation, the vehicle say a truck, may need to halt suddenly. To bring a fragile material, like porcelain object to a sudden halt means applying a large force and this is likely to damage the object. If it is wrapped up in say, straw, the object can travel some distance as the straw is soft before coming to a halt. The force needed to achieve this is less, thus reducing the possibility of damage.
5.23 The body of the child is brought to a sudden halt when she/he falls on a cement floor. The mud floor yields and the body travels some distance before it comes to rest, which takes some time. This means the force which brings the child to rest is less for the fall on a mud floor, as the change in momentum is brought about over a longer period.
$5.24 \begin{array}{lll}\text { (a) } 12.5 \mathrm{~N} \mathrm{~s}^{2} & \text { (b) } 18.75 \mathrm{~kg} \mathrm{~m} \mathrm{~s}^{-1}\end{array}$
$5.25 f=\mu R=\mu \mathrm{mg} \cos \theta$ is the force of friction, if $\theta$ is angle made by the slope. If $\theta$ is small, force of friction is high and there is less chance of skidding. The road straight up would have a larger slope.
5.26 AB , because force on the upper thread will be equal to sum of the weight of the body and the applied force.
5.27 If the force is large and sudden, thread CD breaks because as CD is jerked, the pull is not transmitted to $A B$ instantaneously (transmission depends on the elastic properties of the body). Therefore, before the mass moves, CD breaks.
$5.28 T_{1}=94.4 \mathrm{~N}, T_{2}=35.4 \mathrm{~N}$
$5.29 \mathrm{~W}=50 \mathrm{~N}$
5.30 If $F$ is the force of the finger on the book, $F=N$, the normal reaction of the wall on the book. The minimum upward frictional force needed to ensure that the book does not fall is $M g$. The frictional force $=\mu N$. Thus, minimum value of $F=\frac{M g}{\mu}$.
$5.31 \quad 0.4 \mathrm{~m} \mathrm{~s}^{-1}$
$5.32 x=t, y=t^{2}$
$a_{x}=0, \quad a_{y}=2 \mathrm{~m} \mathrm{~s}^{-1}$
$\mathrm{F}=0.5 \times 2=1 \mathrm{~N}$. along $y$-axis.
5.33
$t=\frac{2 \mathrm{~V}}{g+a}=\frac{2 \times 20}{10+2}=\frac{40}{12}=\frac{10}{3}=3.33 \mathrm{~s}$.
(a) Since the body is moving with no acceleration, the sum of the forces is zero $\mathbf{F}_{\mathbf{1}}+\mathbf{F}_{\mathbf{2}}+\mathbf{F}_{\mathbf{3}}=0$. Let $\mathbf{F}_{\mathbf{1}}, \mathbf{F}_{\mathbf{2}}, \mathbf{F}_{\mathbf{3}}$ be the three forces passing through a point. Let $\mathbf{F}_{\mathbf{1}}$ and $\mathbf{F}_{\mathbf{2}}$ be in the plane A (one can always draw a plane having two intersecting lines such that the two lines lie on the plane). Then $\mathbf{F}_{1}+\mathbf{F}_{\mathbf{2}}$ must be in the plane A.
 Since $\mathbf{F}_{\mathbf{3}}=-\left(\mathbf{F}_{\mathbf{1}}+\mathbf{F}_{\mathbf{2}}\right), \mathbf{F}_{\mathbf{3}}$ is also in the plane A.
(b) Consider the torque of the forces about P. Since all the forces pass through P , the torque is zero. Now consider torque about another point 0 . Then torque about 0 is

Torque $=\mathbf{O P} \times\left(\mathbf{F}_{\mathbf{1}}+\mathbf{F}_{\mathbf{2}}+\mathbf{F}_{\mathbf{3}}\right)$
Since $\mathbf{F}_{\mathbf{1}}+\mathbf{F}_{\mathbf{2}}+\mathbf{F}_{\mathbf{3}}=0$, torque $=0$

## General case

$s=\frac{1}{2} a t^{2} \Rightarrow t=\sqrt{2 s / a}$
Smooth case
Acceleration $a=g \sin \theta=g / \sqrt{2}$
$\therefore t_{1}=\sqrt{2 \sqrt{2} s / g}$

## Rough case

Acceleration $a=g \sin \theta-\mu g \cos \theta$

$$
=(1-\mu) g / \sqrt{2}
$$

$\therefore t_{2}=\sqrt{\frac{2 \sqrt{2} s}{(1-\mu) g}}=p t_{1}=p \sqrt{\frac{2 \sqrt{2} s}{g}}$
$\Rightarrow \frac{1}{1-\mu}=p^{2} \Rightarrow \mu=1-\frac{1}{p^{2}}$

$$
\begin{aligned}
& 5.36 \\
& v_{x}=2 t \\
& 0<t \leq 1 \\
& v_{y}=t \quad 0<t<1 \mathrm{~s} \\
& =2(2-t) \\
& 1<t<2 \\
& =11<t \\
& =0 \quad 2<t \\
& F_{x}=2 ; 0<t<1 \quad F_{y}=1 \quad 0<t<1 \mathrm{~s} \\
& =-2 ; \quad 1 \mathrm{~s}<t<2 \mathrm{~s} \quad=0 \quad 1 \mathrm{~s}<t \\
& =0 ; \quad 2 \mathrm{~s}<t \\
& \mathbf{F}=2 \hat{\mathbf{i}}+\hat{\mathbf{j}} \quad 0<t<1 \mathrm{~s} \\
& =-2 \hat{\mathbf{i}} 1 \mathrm{~s}<t<2 \mathrm{~s} \\
& =0 \quad 2 \mathrm{~s}<t
\end{aligned}
$$

5.37 For DEF

$$
\begin{aligned}
& \not \mu^{\frac{v^{2}}{R}}=\not ŋ g \mu \mu \\
& v_{\max }=\sqrt{g \mu R}=\sqrt{100}=10 \mathrm{~m} \mathrm{~s}^{-1}
\end{aligned}
$$

For ABC

$$
\frac{v^{2}}{2 R}=g \mu, v=\sqrt{200}=14.14 \mathrm{~m} \mathrm{~s}^{-1}
$$

Time for DEF $=\frac{\pi}{2} \times \frac{100}{10}=5 \pi \mathrm{~s}$
Time for $\mathrm{ABC}=\frac{3 \pi 200}{214.14}=\frac{300 \pi}{14.14} \mathrm{~s}$
For FA and $\mathrm{DC}=2 \times \frac{100}{50}=4 \mathrm{~s}$
Total time $=5 \pi+\frac{300 \pi}{14.14}+4=86.3 \mathrm{~s}$
$5.38 \frac{d \mathbf{r}}{d t}=\mathbf{v}=-\hat{\mathbf{i}} \omega A \sin \omega t+\hat{\mathbf{j}} \omega B \cos \omega t$

$$
\frac{d \mathbf{v}}{d t}=\mathbf{a}=-\omega^{2} \mathbf{r} ; \mathbf{F}=-m \omega^{2} \mathbf{r}
$$

## Answers

$x=A \cos \omega t, y=B \sin \omega t \Rightarrow \frac{x^{2}}{A^{2}}+\frac{y^{2}}{B^{2}}=1$
5.39 For (a) $\frac{1}{2} v_{z}^{2}=g H \quad v_{z}=\sqrt{2 g H}$

Speed at ground $=\sqrt{v_{s}{ }^{2}+v_{z}{ }^{2}}=\sqrt{v_{s}{ }^{2}+2 g H}$
For (b) also $\left[\frac{1}{2} m v_{s}{ }^{2}+m g H\right]$ is the total energy of the ball when it hits the ground.

So the speed would be the same for both (a) and (b).
$5.40 \quad F_{2}=\frac{F_{3}+F_{4}}{\sqrt{2}}=\begin{gathered}2+1 \\ \sqrt{2}\end{gathered}=\frac{3}{\sqrt{2}} \mathrm{~N}$
$F_{1}+\frac{F_{3}}{\sqrt{2}}=\frac{F_{4}}{\sqrt{2}}$
$F_{1}=\frac{F_{4}-F_{3}}{\sqrt{2}}=\frac{1}{\sqrt{2}} \mathrm{~N}$
5.41 (a) $\theta=\tan ^{-1} \mu$
(b) $m g \sin \alpha-\mu m g \cos \alpha$
(c) $m g(\sin \alpha+\mu \cos \alpha)$
(d) $m g(\sin \theta+\mu \cos \theta)+m a$.
5.42 (a) $F-(500 \times 10)=(500 \times 15)$ or $F=12.5 \times 10^{3} \mathrm{~N}$, where $F$ is the upward reaction of the floor and is equal to the force downwards on the floor, by Newton's 3rd law of motion
(b) R $-(2500 \times 10)=(2500 \times 15)$ or $R=6.25 \times 10^{4} \mathrm{~N}$, action of the air on the system, upwards. The action of the rotor on the surrounding air is $6.25 \times 10^{4} \mathrm{~N}$ downwards.
(c) Force on the helicopter due to the air $=6.25 \times 10^{4} \mathrm{~N}$ upwards.

