Chapter 3

3.1 (b)

3.2 (a)

3.3 (b)

3.4 (c)

3.5 (b)

3.6 (c)

3.7 (a), (c), (d)

3.8 (a), (c), (e)

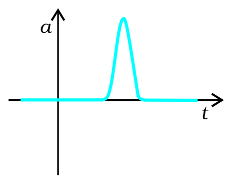
3.9 (a), (d)

3.10 (a), (c)

3.11 (b), (c), (d)

3.12 (a) (iii), (b) (ii), (c) iv, (d) (i)

3.13



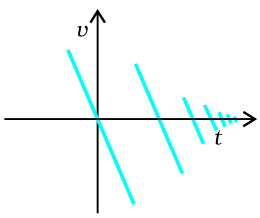
3.14 (i) $x(t) = t - \sin t$

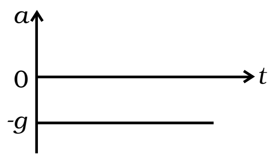
(ii) $x(t) = \sin t$

3.15 $x(t) = A + Be^{-\gamma t}$; A > B, $\gamma > 0$ are suitably chosen positive constants.

3.16 $v = g/b$

3.17 The ball is released and is falling under gravity. Acceleration is $-g$, except for the short time intervals in which the ball collides with





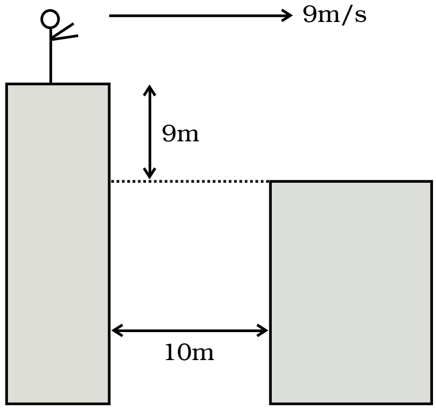
ground, and when the impulsive force acts and produces a large acceleration.

3.18 (a) x = 0, $v = \gamma x_o$

3.19 Relative speed of cars = 45km/h, time required to meet $= \frac{36\text{ km}}{45\text{ km/h}} = 0.80\text{h}$

Thus, distance covered by the bird = 36 km/h × 0.8h = 28.8 km.

3.20 Suppose that the fall of 9 m will take time *t*. Hence



$$y - y_o = v_{oy} - \frac{gt^2}{2}$$

Since $v_{oy} = 0$,

$$t = \sqrt{\frac{2(y-y_o)}{g}} \rightarrow \sqrt{\frac{2\times 9\text{ m}}{10\text{ m/s}^2}} = \sqrt{1.8} \approx 1.34 \text{ seconds.}$$

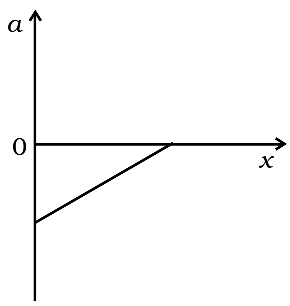
In this time, the distance moved horizontally is

$x\text{-}x_o = v_{ox}t$ = 9 m/s × 1.34s = 12.06 m.

Yes-he will land.

3.21 Both are free falling. Hence, there is no acceleration of one w.r.t. another. Therefore, relative speed remains constant (=40 m/s).

3.22 $v = (-v_o/x_o)\,x + v_o$, $a = (v_o/x_o)^2\, x - v_o^2/x_o$



The variation of *a* with *x* is shown in the figure. It is a straight line with a positive slope and a negative intercept.

3.23 (a) $v = \sqrt{2gh} = \sqrt{2\times10\times1000} = 141\text{m/s} = 510\text{km/h}.$

(b) $m = \frac{4\pi}{3} r^3 \rho = \frac{4\pi}{3}(2\times10^{-3})^3(10^3) = 3.4\times10^{-5}\text{kg}.$

$P = mv \approx 4.7\times10^{-3}\text{kg m/s} \approx 5\times10^{-3}\text{kg m/s}.$

(c) Diameter $\approx 4\text{mm}$

$\Delta t \approx d/v = 28\mu\text{s} \approx 30\mu\text{s}$

(d) $F = \frac{\Delta P}{\Delta t} = \frac{4.7\times10^{-3}}{28\times10^{-6}} \approx 168\text{N} \approx 1.7\times10^2\text{N}.$

(e) Area of cross-section $= \pi d^2/4 \approx 0.8\text{m}^2.$

With average separation of 5 cm, no. of drops that will fall almost simultaneously is $\frac{0.8\text{m}^2}{(5\times10^{-2})^2} \approx 320$.

Net force $\approx$ 54000 N (Practically drops are damped by air viscosity).

3.24 Car behind the truck

Regardation of truck $= \frac{20}{5} = 4\text{ms}^{-2}$

Regardation of car $= \frac{20}{3}\text{ms}^{-2}$

Let the truck be at a distance x from the car when breaks are applied

Distance of truck from A at $t > 0.5$ s is $x + 20t - 2t^2$.

Distance of car from A is $10 + 20(t - 0.5) - \frac{10}{3}(t - 0.5)^2$.

If the two meet

$$x + 20t - 2t^2 = 10 + 20t - 10 - \frac{10}{3}t^2 + \frac{10}{3}t - 0.25\times\frac{10}{3}.$$

$$x = -\frac{4}{3}t^2 + \frac{10}{3}t - \frac{5}{6}.$$

To find x_{min},

$$\frac{dx}{dt} = -\frac{8}{3}t + \frac{10}{3} = 0$$

which gives $t_{min} = \frac{10}{8} = \frac{5}{4}$ s.

Therefore, $x_{min} = -\frac{4}{3}\left(\frac{5}{4}\right)^2 + \frac{10}{3}\times\frac{5}{4} - \frac{5}{6} = \frac{5}{4}$.

Therefore, $x > 1.25$m.

Second method: This method does not require the use of calculus.

If the car is behind the truck,

$V_{car} = 20 - (20/3)(t - 0.5)$ for $t > 0.5$ s as car declerate only after 0.5 s.

$V_{truck} = 20 - 4t$

Find t from equating the two or from velocity vs time graph. This yields $t = 5/4$ s.

In this time truck would travel truck,

$S_{truck} = 20(5/4) - (1/2)(4)(5/4)^2 = 21.875$m and car would travel, S_{car} = 20(0.5) + 20(5/4 – 0.5) –

$$\left(\frac{1}{2}\right)(20/3)\times\left(\frac{5}{4}-0.5\right)^2 = 23.125\text{m}$$

Thus $S_{car} - S_{truck}$ = 1.25m.

If the car maintains this distance initially, its speed after 1.25s will he always less than that of truck and hence collision never occurs.

3.25 (a) (3/2)s, (b) (9/4)s, (c) 0,3s, (d) 6 cycles.

3.26 υ_1=20 m/s, υ_2 = 10m/s, time difference = 1s.