# Solutions

All questions carry 25 marks each.

1. a) State the following:

   i) SI unit of force in terms of base units.
   ii) dimension of force.

   b) The turning effect of a force, $M$, is defined by $M = Fd$, where is force and $d$ is perpendicular distance between the direction of $F$ and the pivot. Find the dimension of $M$ and state its SI unit.

   c) The work done by a constant force, $W$, is defined by $W = Fs$, where $F$ is force and $s$ is displacement in the direction of $F$. Show that the dimensions of $W$ is the same as that of $M$.

   d) Can the SI unit of $M$ also be written as joule (J)? Give reason for your answer.

   e) Explain why the equation $v^2 = v_{0x}^2 + a(x - x_0)$ is dimensionally correct but physically incorrect. The variables in the equation have their usual meaning.

a) i) $F = ma$ = kg m/s$^2$ (SI base unit)
   ii) [M][L][T]$^{-2}$ (Dimension)

b) Dimension of work $M$ is [M][L][T]$^{-2}$ × [L] = [M][L]$^2$[T]$^{-2}$
SI unit of $M$ is N m.

c) Dimension of moment $W$ is [M][L][T]$^{-2}$ × [L] = [M][L]$^2$[T]$^{-2}$
SI unit of $W$ is N m.
Special name is joule (J)

d) The SI unit of $M$ cannot be written as joule (J) because $M$ and $W$ are different physical quantities.

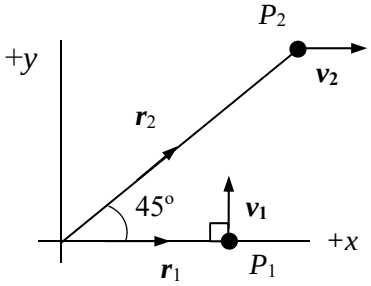
e) The missing number 2 in the equation has no dimension.

2. A particle moves with a constant speed 2.0 m/s from $P_1$ to $P_2$ along a path (which is not shown in the diagram below). In the diagram, $r_1$ is 1.0 m and $r_2$ is 2.0 m. The journey took 2.0 s.

a) Sketch one possible path traversed by the particle, taking note that $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are instantaneous velocities at $P_1$ and $P_2$ respectively and are perpendicular to each other.

b) Express the following in terms of **i** and **j**:

i) $\boldsymbol{r}_1$, $\boldsymbol{r}_2$ and $\Delta\boldsymbol{r}$.
ii) average velocity, $\boldsymbol{v}_{av}$, for the journey.
iii) $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$.
iv) average acceleration, $\boldsymbol{a}_{av}$, for the journey.




c) Using the dot product, find the angle between $\boldsymbol{v}_{av}$ and $\boldsymbol{v}_1$.

a) Any path such that $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are tangent to the path.

b) i) $\boldsymbol{r}_1 = 1.0\,\mathbf{i}$ m
$\boldsymbol{r}_2 = 1.4\,\mathbf{i} + 1.4\,\mathbf{j}$ m
$\Delta\boldsymbol{r} = 1.4\,\mathbf{i} + 1.4\,\mathbf{j} - 1.0\,\mathbf{i} = 0.4\,\mathbf{i} + 1.4\,\mathbf{j}$ m

ii) $\boldsymbol{v}_{av} = (0.4\,\mathbf{i} + 1.4\,\mathbf{j})/2.0 = 0.2\,\mathbf{i} + 0.7\,\mathbf{j}$ m/s

iii) $\boldsymbol{v}_1 = 2.0\,\mathbf{j}$ m/s
$\boldsymbol{v}_2 = 2.0\,\mathbf{i}$ m/s

iv) $\boldsymbol{a}_{av} = (2.0\,\mathbf{i} - 2.0\,\mathbf{j})/2.0 = 1.0\,\mathbf{i} - 1.0\,\mathbf{j}$ m/s$^2$

c) $\boldsymbol{v}_{av} \cdot \boldsymbol{v}_1 = v_{av} v_1 \cos\theta$

$(0.2\,\mathbf{i} + 0.7\,\mathbf{j}) \cdot (2.0\,\mathbf{j}) = 1.4$

$v_{av} = \sqrt{0.2^2 + 0.7^2} = 0.728$

$v_1 = \sqrt{2.0^2} = 2.0$

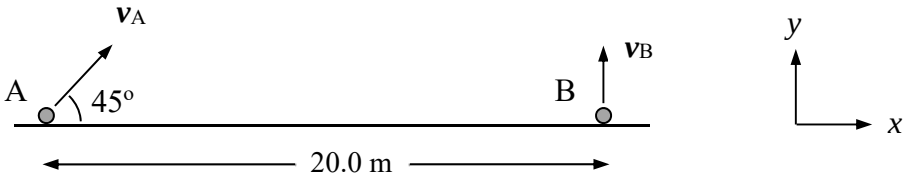
$\cos\theta = \dfrac{1.4}{2.0 \times 0.728}$

$\theta = 16.0^\circ$

3. a) Define "projectile motion".

b) Object A is launched with an initial speed $v_A$ = 20.0 m/s at 45° with respect to the ground. Object B is launched with an initial speed $v_B$ = 15.0 m/s vertically. The launch point of B is 20.0 m from A as shown in the diagram.

i) How high is B at $t$ = 1.0 s?
ii) Write the vertical and horizontal components of initial velocities, $\boldsymbol{v}_A$ and $\boldsymbol{v}_B$, respectively, in terms of unit vectors **i** and **j**.
iii) How long does it take A to travel 20.0 m horizontally?
iv) Show that A and B will not collide.




a) Projectile motion is the motion of an object due to force of gravity only.

b) i) $y_B = v_B t - \frac{1}{2} g t^2$

$= 15 \times 1.0 - \frac{1}{2} 9.8 \times 1.0^2$

$= 10.1$ m

ii) $\boldsymbol{v}_A = 20.0 \cos 45° \, \mathbf{i} + 20.0 \sin 45° \, \mathbf{j}$ m/s

$= 14.1 \, \mathbf{i} + 14.1 \, \mathbf{j}$ m/s

$\boldsymbol{v}_B = 15 \, \mathbf{j}$ m/s

iii) $\text{speed} = \frac{\text{distance}}{\text{time}}$

$\text{time} = \frac{20}{14.1} = 1.42$ s

iv) A and B will not collide because at 1.42 s, A and B are at heights given by

$y_A = u_A t - \frac{1}{2} g t^2$

$= 20.0 \sin 45° 14.1 \times 1.42 - \frac{1}{2} \times 9.8 \times 1.42^2$

$= 14.1 \times 1.42 - \frac{1}{2} \times 9.8 \times 1.42^2$

$= 10.1$ m

$y_B = v_B t - \frac{1}{2} g t^2$

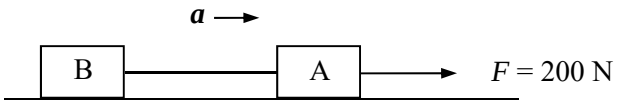
$= 15.0 \times 1.42 - \frac{1}{2} \times 9.8 \times 1.42^2$

$= 11.4$ m

4. a) Define friction.

b) The diagram below shows two objects A and B resting on a rough surface and connected by a 2.0 m string. Object A is towed by a 200 N horizontal force to the right. The mass of A is 20 kg while that of B is 10 kg. The coefficient of kinetic friction for both objects is 0.5.

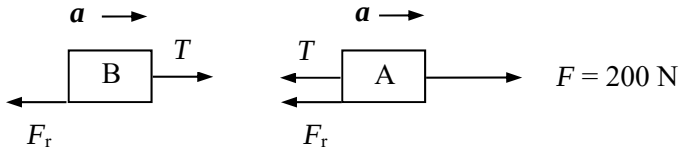
i) Draw the free body diagrams of A and B.
ii) Determine the tension in the string and acceleration of the two objects.
iii) Determine the velocity of A and B when $t$ = 5.0 s.




c) If at $t$ = 5.0 s, $F$ is removed, describe the motion of A and B and determine if A and B will collide.

a) Friction is the force that resists motion.

b) i)




ii) $F_r = \mu mg$

For A, $200 - T - 20 \times 9.8 \times 0.5 = 20a$ ...(1)

For B, $T - 10 \times 9.8 \times 0.5 = 10a$ ...(2)

$(1) + (2)$ $53 = 30a$

$a = 1.8$ m/s$^2$

$T = 67$ N

iii) $v = at = 1.8 \times 5.0$

$= 9.0$ m/s

c) If $F$ is removed, both A and B will decelerate at the same rate to a stop.

given by $F_r = \mu mg = ma$ or $a = \mu g$.

$a_A = -0.5 \times 9.8 = -4.9$ m/s$^2$

$a_B = -0.5 \times 9.8 = -4.9$ m/s$^2$

Hence A and B will not collide.

**********End**********