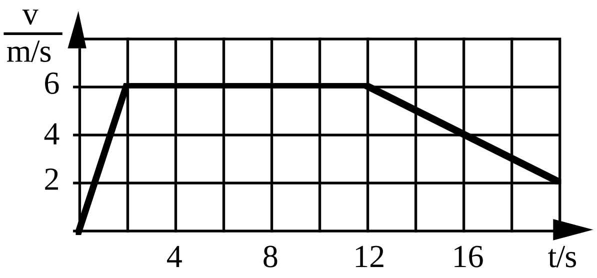
***Question 1*** **[Marks 10]**




(a) A runner runs along a straight line with the velocity-time graph shown in figure. How far does she travel in 20 seconds?

(b) What is the average acceleration of the runner during the first 8.0 seconds?

(c) Displacement of a particle in 3-dimensional space is **s** = (5.0,2.0,–1.0) where coordinates are given in metres. A constant force **F** = (2.0,–0.50,8.0) (in newtons) acts on the particle. Find:

(i) the work done by the force

(ii) the angle between **F** and **s**.

a) *For motion in one dimension*, $v = \frac{ds}{dt}$ so $s = \int v\, dt$ = area under v(t) curve ✓

0-2 s: area of triangle $= \frac{1}{2}(6 \text{ m.s}^{-1})(2 \text{ s}) = 6 \text{ m}$

2-12 s: area of rectangle $= (6 \text{ m.s}^{-1})(10 \text{ s}) = 60 \text{ m}$

21-20 s: area of rectangle + triangle $= \frac{1}{2}(4 \text{ m.s}^{-1})(8 \text{ s}) + (2 \text{ m.s}^{-1})(8 \text{ s}) = 32 \text{ m}$

Distance travelled = 98 m ✓ ✓

b) $\overline{a} \equiv \frac{v_f - v_i}{t} = \frac{6 \text{ m.s}^{-1} - 0}{8 \text{ s}} = 0.75 \text{ m.s}^{-2}$ ✓

c) i) $W = \int \underline{\mathbf{F}}.\underline{\mathbf{ds}} = \underline{\mathbf{F}}.\underline{\mathbf{s}}$ because **F** is independent of **s**. ✓

$= (2.0,-0.50,8.0)\text{N}.(5.0,2.0,-1.0)\text{m} = (10.0 - 1.0 - 8.0) \text{ J} = 1.0 \text{ J}$

✓ ✓

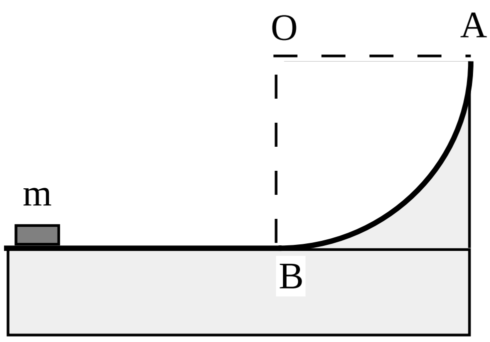
ii) $\underline{\mathbf{F}}.\underline{\mathbf{s}} = Fs \cos\theta$ where θ is the angle between them, so

$\cos\theta = \frac{\underline{\mathbf{F}}.\underline{\mathbf{s}}}{Fs} = \frac{1}{\sqrt{(2^2 + 0.5^2 + 8^2)(5^2 + 2^2 + 1^2)}} = 0.022$

✓ ✓

$\theta = 88.7°$ or 89° ✓

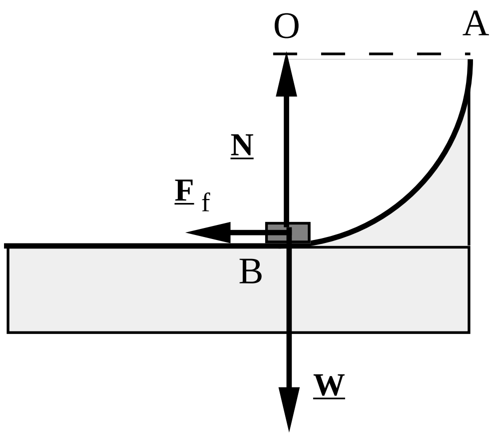
***Question 2*** **[Marks 10]**




A block of mass m = 1.0 kg is sliding along a horizontal frictionless table with speed v = 3.0 $m.s^{-1}$. At the point B, the table is connected with a circular track. The radius of curvature of the track is R = 1.0 m. The angle ABO = 90°. The coefficient of kinetic friction between the block and the track is μ = 0.50.

(a) Show all the forces which act on the block immediately after it passes the point B.

(b) Calculate the vertical and horizontal acceleration of the block at this instant.




✓✓✓

a) *It has just passed B, so it is on the circular track. While the motion is now circular, the motion is initially horizontal and the normal force still vertical. The frictional force is by definition at right angles to the normal force, and, if sliding, in the direction opposite the velocity. So here it is to the left. Hence forces as shown.*

b) *Friction and gravity have acted over negligible distances, so the kinetic energy hasn't changed, so the initial speed is unchanged. Hence it is a particle undergoing* circular motion with speed v.

$$a_c = \frac{v^2}{r} = \frac{(3.0\ m.s^{-1})^2}{1.0\ m} = 9.0\ ms^{-2}. \quad ✓$$

This is the (+ve) vertical acceleration: $a_y = 9.0\ ms^{-2}$.

✓

*To get horizontal acceleration, find friction, ∴ find normal.*

In the vertical direction: $ma_{vert} = N - mg$ ✓

$$\therefore \quad F_f = \mu_k N = \mu_k(ma_{vert} + mg) \quad ✓$$

$$\therefore \quad a_x = -\frac{F_f}{m} = -\frac{\mu_k N}{m} = -\mu_k(a_{vert} + g) \quad ✓✓$$

$$a_x = -9.4\ ms^{-2}. \qquad a_y = 9.0\ ms^{-2}. \quad ✓$$

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