

State Examination Commission – Physics Higher Level, 2009

Question 6

State Newton's laws of motion. (12)

Show that $F = ma$ is a special case of Newton's second law. (10)

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and is at an angle of 20° to the horizontal. The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.



Calculate

(i) the average acceleration of the skateboarder on the ramp.

(ii) the component of the skateboarder's weight that is parallel to the ramp.

(iii) the force of friction acting on the skateboarder on the ramp. (18)

The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m.

What is the initial centripetal force acting on him?

What is the maximum height that the skateboarder can reach? (12)

Sketch a velocity-time graph to illustrate his motion. (4)

(acceleration due to gravity = 9.8 m s^{-2})

State Newton's laws of motion. (12)

[Textbook](#)

Show that $F = ma$ is a special case of Newton's second law. (10)

[Newton's second states the resultant force on a body is proportional to its rate of change of momentum](#)

$$F \propto \frac{d(mv)}{dt},$$

but if m is constant,

$$F \propto m \frac{dv}{dt},$$

$$F \propto ma,$$

$$F = kma,$$

Now, 1 Newton is that force that accelerates 1 kg by 1 m s^{-2} , so $k=1$.

$$F = ma$$

(non-calculus version in textbook)

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and is at an angle of 20° to the horizontal. The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.

Calculate

(i) the average acceleration of the skateboarder on the ramp.

$$u = 0, v = 12.2 \text{ m s}^{-1}, s = 25 \text{ m}$$

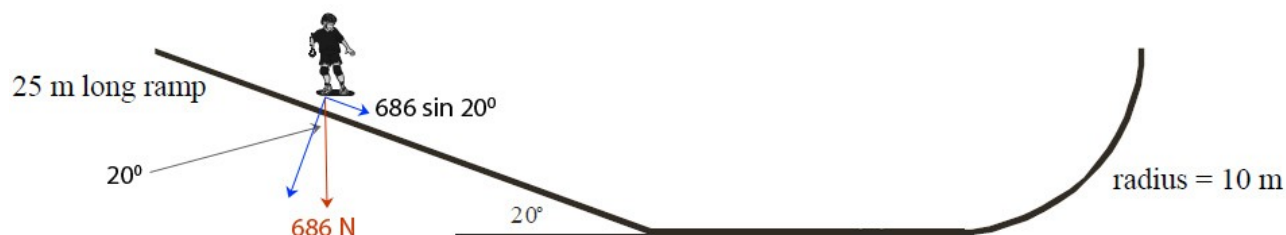
$$v^2 = u^2 + 2as$$

$$a = \frac{v^2 - u^2}{2s},$$

$$a = \frac{148.84 - 0}{2 \times 25},$$

$$a = 2.98 \text{ m s}^{-2}$$

(ii) the component of the skateboarder's weight that is parallel to the ramp.



The component of the weight of skateboarder parallel to the ramp is $F_{\text{parallel}} = 686 \sin 20^\circ = 234.6 \text{ N}$

(iii) the force of friction acting on the skateboarder on the ramp. (18)

The skateboarder is accelerating at 2.98 m s^{-2} , so there is a resultant force of $F_{\text{resultant}} = ma = 70 \times 2.98 = 208.6 \text{ N}$. However, the gravitational component down the ramp is 234.6 N , so the frictional force opposing motion must be,
 $F_{\text{friction}} = 234.6 - 208.6 = 26.0 \text{ N}$

The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m . What is the initial centripetal force acting on him?

$$F = mv^2/r = (70 \times 10.5^2)/10 = 771.8 \text{ N}$$

What is the maximum height that the skateboarder can reach? (12)

Initial $E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 70 \times 10.5^2 = 3858.75 \text{ J}$
 If this is all converted to gravitational potential energy, then,
 $E_p = 3858.75 = mgh$
 $h = 3858.75 / (70 \times 9.8) = 5.63 \text{ m}$

Sketch a velocity-time graph to illustrate his motion. (4)

