NEWTON'S LAWS

Check List

Make sure you ….

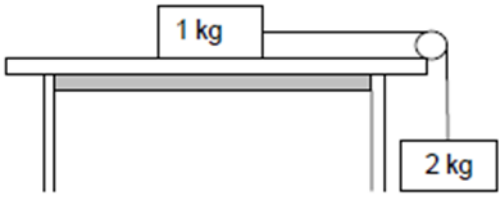
- state Newton's first, second and third law of motion as well Newton's law of Universal Gravitation.
- can draw free-body and force diagrams
- know the difference between kinetic and static friction
- can calculate friction
- can calculate resultant force
- know how to use the equations $F_{net} = ma$ and $F = \frac{Gm_1m_2}{r^2}$

Exam Questions

Question 1

(Adapted from Grade 11 DoE Exemplar 2013)

In the diagram below, a 1 kg mass on a rough horizontal surface is joined to a 2 kg mass by a light, inextensible string running over a frictionless pulley. The coefficient of kinetic friction between the 1 kg mass and the surface is 0,13.



1.1. State Newton's second law of motion in words (2)

1.2. Calculate the magnitude of the:

1.2.1. Kinetic frictional force acting on the 1 kg mass (3)
1.2.2. Acceleration of the 1 kg mass (5)

The rough horizontal surface is now replaced with a smooth frictionless surface. The 2 kg mass is again released and strikes the ground before the 1 kg mass reaches the end of the horizontal surface.

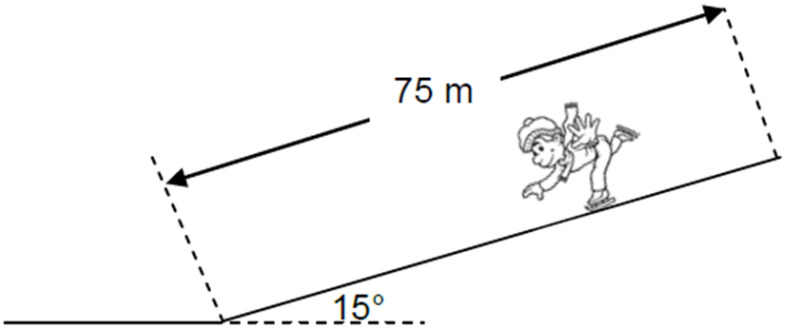
1.3. Will the 1 kg mass move at a LOWER, a HIGHER or a ZERO ACCELERATION? Briefly explain the answer by referring to Newton's laws of motion. (4)

[14]

Question 2

(Adapted from Grade 11 DoE Exemplar 2013)

A skier of mass 60 kg skies from rest down a slope inclined at an angle of 15°. The length of the incline is 75 m. He reaches the end of the incline at a velocity of 15 m.s^{-1}. A constant frictional force acts on the skier on his way down.



2.1. Write down an expression for the magnitude of the normal force acting on the skier and then calculate its magnitude. (2)

2.2. Draw a labelled free-body diagram showing ALL the forces acting on the skier as he skies down the slope. (3)

2.3. Calculate the average frictional force acting on the skier during his motion down the incline. (7)

[12]

Question 3

(Adapted from Grade 11 DoE Exemplar 2013)

Satellite A with a mass of 615 kg is in orbit around the earth.

3.1. State Newton's law of universal gravitation in words. (3)

3.2. If the earth exerts a force of 5 000 N on satellite A to keep it in orbit, calculate the height, in kilometres, of the satellite **above the surface** of the earth. (5)

3.3. Another satellite of mass double that of satellite A, orbits at a distance twice that of satellite A from the centre of the earth. Write down the magnitude of the force of attraction of the earth on this satellite. (2)

[10]

SOLUTIONS TO NEWTON'S LAWS

Question 1

1.1. When a resultant force acts on an object, the object accelerates in the direction of the force. This acceleration is directly proportional to the force and inversely proportional to the mass of the object ✓✓ (2)

1.2.1. $f_k = \mu_k N$ ✓

$= (0{,}13)(1)(9{,}8)$ ✓

$= 1{,}27\ N$ ✓ (3)

1.2.2.

For 2 kg mass	For 1 kg mass
$F_{net} = ma$ ✓	$F_{net} = ma$
$F_g - F_T = ma$	$F_T - f_k = ma$
$(2)(9{,}8) - F_T = 2a$ ✓	$F_T - 1{,}27 = 1a$ ✓ … (2)
$19{,}6 - F_T = 2a$ … (1)	

(1) + (2) ✓

$19{,}6 - F_T = 2a$

$\underline{F_T - 1{,}27 = 1a}$

$18{,}33 = 3a$

$\therefore a = 6{,}11\ m.s^2$ ✓ (5)

1.3. Zero acceleration ✓

F_{net} on the 1 kg is zero ✓

According to Newton's second of law of motion, its acceleration will be zero ✓

According to Newton's first law of motion, it will continue to move at constant velocity, unit ti reaches the edge of the surface ✓ (4)

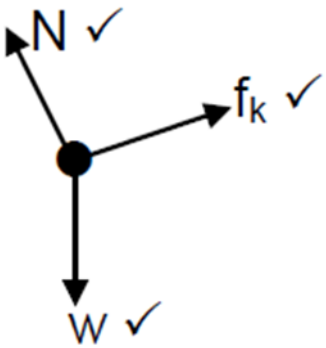
Question 2

2.1. $N = F_g = mg\cos\theta$ ✓

$= (60)(9{,}8)\cos 15°$

$= 567{,}96\ N$ ✓ (2)

2.2.



Accepted labels

w – F_g / F_w / force of earth on skier / weight / 588 N / mg / gravitational force

N – F_N / normal / 567,96 N

f_k – frictional force / F_f

(3)

2.3. $v_f^2 = v_i^2 + 2a\Delta x$ ✓

$(15)^2 = (0)^2 + 2a(75)$ ✓

$150a = 225$

$\therefore\ a = 1{,}5\ m.s^{-1}$

$F_{net} = ma$ ✓

$F_{g\parallel} + f_k = ma$

$mg\sin\theta + f_k = ma$

$(60)(9{,}8)(\sin 15°)$ ✓ $+ f_k = (60)(1{,}5)$ ✓

$\therefore\ f_k = -62{,}19$

$= 62{,}19\ N$ ✓ *up the incline* ✓ (7)

Question 3

3.1. Any two objects in the universe attract each other ✓with a force directly proportional to eh the product of their masses ✓and inversely proportional to the square of the distance between their centres ✓ (3)

3.2. $F = \frac{Gm_1m_2}{r^2}$ ✓

$5\ 000$ ✓ $= \frac{(6{,}67 \times 10^{-11})(5{,}98 \times 10^{24})(615)}{r^2}$ ✓

$r^2 = \frac{(6{,}67 \times 10^{-11})(5{,}98 \times 10^{24})(615)}{5\ 000}$

$r^2 = 4{,}91 \times 10^{13}$

$\therefore\ r = 7{,}00 \times 10^6\ m$

$Height = r - r_{earth}$

$= 7{,}00 \times 10^6 - 6{,}38 \times 10^6$ ✓

$= 6{,}20\ \times 10^5\ m$

$= 620\ km$ ✓ (5)

3.3. $F = \frac{Gm_1m_2}{r^2} = 5000$

$F_{new} = \frac{Gm_1 2m_2}{(2r)^2}$

$= \frac{2Gm_1m_2}{4r^2}$

$= \frac{2}{4}(5000)$

$= 2\ 500$ ✓✓N (2)