15. Laws of Motion and Gravitation

Part-A

1. Question

The acceleration in a body is due to _____.

i) balanced force ii) unbalanced force

iii) electro static force

Answer

(ii) is correct.

In case of (i), balanced forces lead to zero net force. So, there is no acceleration as F = ma. For (iii), the force acts only on charged bodies. In most everyday objects, there are no excess charges and they are neutral bodies. So electrostatic force causes no acceleration on uncharged bodies. For (ii), there is a net force, so there is acceleration.

2. Question

The physical quantity which is equal to the rate of change of momentum is

A. displacement

B. acceleration

C. force

D. impulse

Answer

By Newton’s second law, force is defined as the rate of change of momentum. So (iii) is correct. Displacement is the rate of change of position. Acceleration is the rate of change of velocity. Impulse measures the impact of a force, given by force multiplied by time.

3. Question

The momentum of a massive object at rest is _____.

A. very large

B. very small

C. zero

D. infinity

Answer

Momentum is given by the product of mass and velocity. Since the body is at rest, velocity is zero. Hence, momentum is zero.

4. Question

The mass of a person is 50 kg. The weight of that person on the surface of the earth will

be _____.

A. 50 N

B. 35 N

C. 380 N

D. 490 N

Answer

W = mg,

where W is the weight,

m is the mass,

and g is acceleration due to gravity, which is 9.8 m/s^2.

So weight is equal to 50 kg × 9.8 m/s^2 = 490 N.

5. Question

The freezing of biotechnology products like vaccines require _____ freezing system.

A. Helium

B. Nitrogen

C. Ammonia

D. Chlorine

Answer

Liquid N_2 can achieve temperatures as low as -196 degrees C. It's cryogenic. This allows preservation. Moreover, though liquid He is also cryogenic, it leads to formation of ice crystals which may damage the biotechnology products.

6. Question

Two objects of same mass, namely A and B hit a man with a speed of 20 km/hr and

50 km/hr respectively and comes to rest instantaneously. Which object will exert more force on that man? Justify your answer.

Answer

Let both have a mass of m.

Momentum of A = mass × velocity = 20m

Momentum of B = 50m

Force is defined as the rate of change of momentum. Since both A and B come to rest instantaneously,B exerts a greater force because it has greater momentum.

7. Question

An object is moving with a velocity of 20 m/s. A force of 10 N is acting in a direction perpendicular to its velocity. What will be the speed of the object after 10 seconds?

Answer

The velocity will still be 20 m/s. The force acts perpendicular to the velocity hence it has no component in the direction of motion and thus has no effect on the motion.

8. Question

Assertion (A): Liquefied cryogenic gases are sprayed on electric cables in big cities.

Reason(R): Liquefied cryogenic gases prevent wastage of power.

A. A is incorrect and R is correct.

B. A is correct and R is incorrect

C. Both A and R are incorrect.

D. A is correct and R supports A.

Answer

In big cities, it is difficult to set up overhead cables. So power cables are placed underground. But underground cables get heated up and this leads to power loss as well as rise in resistance of wires due to such temperature rise which leads to further power loss. So liquefied cryogenic gases are sprayed on the

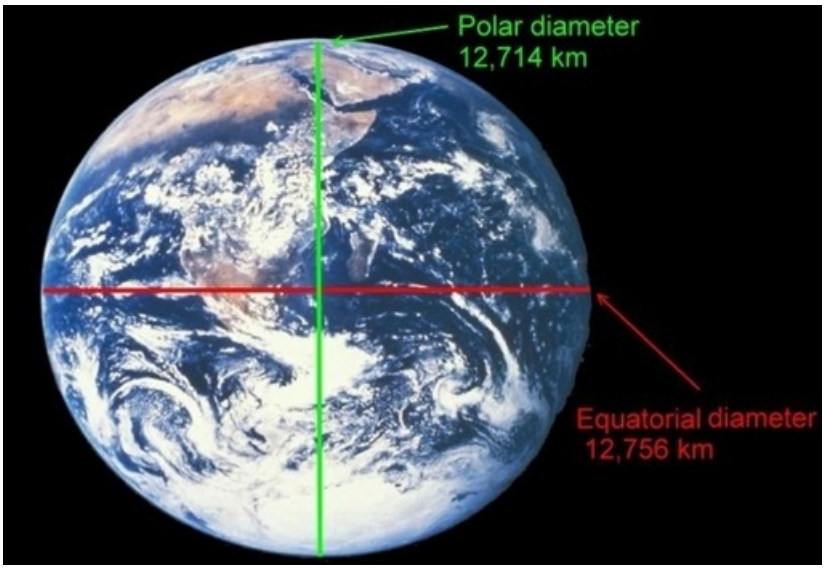
cables to cool them and prevent wastage of power.

9. Question

The acceleration due to gravity on the surface of the earth will be maximum at _____ and minimum at _____

Answer

The earth is an oblate spheroid. This means that the radius is least near the poles and maximum near the equator. Since the acceleration due to gravity on the surface of the earth is inversely proportional to the square of the radius, g is maximum at the poles and minimum at the equator.



10. Question

If the radius of the earth is reduced to half of its present value, with no change in the mass, how will the acceleration due to gravity, be affected?

Answer

The acceleration due to gravity, g is given by

$$\frac{GM}{R^2} = g$$

Where G is the universal gravitational constant (= 6.67×10^{-11} Nm^2kg^{-2}),

M is the mass of the Earth,

R is the radius.

If the radius is reduced to half, g' becomes $\frac{GM}{\left(\frac{R}{2}\right)^2}$

$$= \frac{4GM}{R^2}$$

$$= 4g$$

11. Question

Selvi placed her purse on the passenger's seat of her car when she drove to work.

By the time she reached her office, her purse had fallen on the floor in front of the passenger's seat. Why did this happen? Explain.

Answer

According to Newton's first law, objects tend to resist a change in their state of rest or state of motion. So whenever the brakes are applied, the car comes to rest but the purse tends to stay in its state of motion. So it resists the change and as a result, the purse keeps moving forward and so it falls on the floor in front of

the passenger’s seat.

12. Question

Why does a fielder in the game of cricket pull his hands back when he catches a ball?

Answer

When the ball falls in the fielder’s hands, it has very high speed and as a result, very large momentum. If the ball loses its momentum very quickly, the force exerted on the fielder’s hands will be very large. This could cause grievous injury. So the fielder pulls his hands back to increase the time taken for the ball to come to a stop, so that the rate of change of momentum reduces, the force on the fielder’s hands also reduces and there’s no injury as such.

13. Question

From the following statements, choose that which is not applicable to the mass of an object

i) It is a fundamental quantity. ii) It is measured using physical balance.

iii) It is measured using spring balance.

Answer

(iii) is not applicable. A spring balance measures the weight of an object, which may change slightly from one place to

another. But the mass never changes.

14. Question

List out the names of the organisations which are not associated with Chandrayaan-I

mission from the following: i) ISRO ii) BARC iii) NASA iv) ESA v) WHO vi) ONGC

Answer

Chandrayaan-1, India's first mission to Moon, was launched successfully on October 22, 2008 from SDSC SHAR, Sriharikota.

The following organisations are not associated with Chandrayaan –I

(v)WHO-World Health Organisation

(vi)ONGC-Oil and Natural Gas Corporation

Part-B

1 A. Question

Fill in the blanks.

If force = mass x acceleration, then momentum = _____.

Answer

Momentum = mass × velocity.

Momentum = $\frac{\text{Force}}{\text{Time}}$.

So

Momentum = mass × acceleration × time

= mass × velocity

1 B. Question

Fill in the blanks.

If liquid hydrogen is for rocket, then _____ is for MRI.

Answer

Liquid helium. Maintaining a large magnetic field required in an MRI machine requires superconductivity which is achieved by cooling the wires to very low temperatures to reduce the resistance to almost zero. This cooling is done using a continuous supply of liquid He.

2. Question

Correct the mistakes, if any, in the following statements.

i) One newton is the force that produces an acceleration of 1 ms^{-2} in an object of 1 gram mass.

ii) Action and reaction always act on the same body.

Answer

(i) One newton is the force that produces an acceleration of 1 ms^{-2} in an object of 1 kilogram mass, not gram. This is by definition.

(ii)Action and reaction don't act on the same body. If there are 2 bodies A and B, if A exerts a force(action) on B, B will exert an equal and opposite force(reaction) on A according to Newton's third law.

3. Question

The important use of cryogenics is cryogenic fuels. What do you mean by cryogenic fuels?

Answer

Cryogenic fuels are liquefied gases which have to be stored at very low temperatures. These are used as fuels in rockets. Ordinary fuels can't be used there because of the absence of an environment that supports combustion.

4. Question

As a matter of convention, an anticlockwise moment is taken as _____ and a clockwise moment is taken as _____.

Answer

By convention, anticlockwise moment is taken as positive, and clockwise moments are negative.

5. Question

A bullet of mass 20 g moving with a speed of 75 ms^{-1} hits a fixed wooden plank and comes to rest after penetrating a distance of 5 cm. What is the average resistive force exerted by the wooden plank on the bullet?

Answer

According to the equations of motion,

$v^2 - u^2 = 2as$ ...eq(1)

where v is the final velocity

u is the initial velocity

a is the acceleration

s is the displacement

From eq (1) $a = \frac{v^2-u^2}{2s}$

Here u = 75 m/s

v = 0 m/s

s = 5 cm = 0.05 m

So $a = \frac{0^2-75^2}{2\times0.05}$

= -56250 ms^{-2}

Hence average resistive force = ma = 20 g × -56250 ms^{-2}

= 0.02 kg × -56250 ms^{-2}

= -1125 N

6. Question

A shopping cart has a mass of 65 kg. In order to accelerate the cart by 0.3ms^{-2} what force would you exert on it?

Answer

Since F = ma,

where F is force,

m is mass and,

a is acceleration,

so, F = ma

= 65 kg × 0.3 ms^{-2}

= 19.5 N.

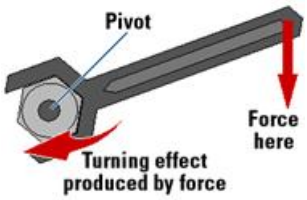
7. Question

Why does a spanner have a long handle?

Answer

A spanner works on the principle of moment.

The diagram is shown below:



It is most effective when a small force creates a large moment. For this to happen, the perpendicular distance between the point of application and point of action of the force, r(in this case, the length of the handle) must be increased, since moment of a force 'F' = r × F. That's why a spanner has a long handle.

8. Question

Why does a boxer always move along the direction of the punch of the opponent?

Answer

When the boxer gets hit, the impact of the force of the punch is reduced if the time of impact is increased. That's why the boxer always move along the direction of the punch of the opponent, to reduce the impact

and thus reduce the chances of injury.

9. Question

The mats used in gyms and the padding used in sports uniforms are made up of soft substances. Why are rigid materials not used?

Answer

If rigid materials are used, a person falling on the mats will suffer great injury. While exercising or engaging in any sports activity, the person is having a considerable momentum. If s/he falls or slips, the momentum reduces to zero. The force exerted on the person's body will depend on the rate of change of momentum, i.e. the time taken to come to rest. This time is large when the mats are soft (the force is small), and small when the mats are made of rigid material (the force is large).

10. Question

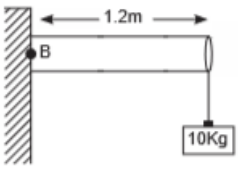
Write two principles that are used in rocket propulsion.

Answer

The first principle involved in rocket propulsion is the Newton's third law of motion: every action has an equal and opposite reaction. The second is the law of conservation of mass.

11. Question

A 10 Kg mass is suspended from a beam 1.2 m long. The beam is fixed to a wall. Find the magnitude and direction (clockwise or anti-clockwise) of the resulting moment at point B.



Answer

Moment is given by r × F.

Here F = mg

where g is the acceleration due to gravity,

m is mass.

So moment = 1.2 × mg

= 1.2 × 10 × 9.8

= 117.6 Nm in the clockwise direction.

12. Question

If the force experienced by a body of unit mass is gravitational field strength, find the gravitational field strength on the surface of the earth.

Answer

F = mg

Where g is the acceleration due to gravity, m is the mass

F = 1 kg×9.8 ms^{-2} = 9.8 N

13. Question

If the density of the earth is doubled to that of its original value, the radius remaining the same, what will be the change in acceleration due to gravity?

Answer

$$g = \frac{GM}{R^2}$$

Where G is the universal gravitational constant (= 6.67 × 10^{-11} Nm^2kg^{-2}),

M is the mass of the earth,

R is the radius of the earth.

If the density is doubled, the mass gets doubled. So

$$g' = \frac{GM}{R^2}$$

$$= \frac{2GM}{R^2}$$

= 2g

14 A. Question

Renu is standing in a dining line 6.38 x 10^3 km from the centre of the earth. The mass of the earth is 6 x 10^{24} kg.

Find the acceleration due to gravity.

Answer

Mass of the earth, M = 6 × 10^{24} kg

Radius of the earth, R = 6.38 x 10^3 km = 6.38 × 10^3 × 10^3 m

= 6.38 x 10^6 m

$$g = \frac{GM}{R^2}$$

Where G is the universal gravitational constant (= 6.67 × 10^{-11} Nm^2kg^{-2}),

M is the mass of the Earth,

R is the radius.

So g = $\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.38 \times 10^6)^2}$

= 0.9831 × 10

= $\underline{9.83\ ms^{-2}}$

14 B. Question

Renu is standing in a dining line 6.38 x 10^3 km from the centre of the earth. The mass of the earth is 6 x 10^{24} kg.

Will the value change after she finishes her lunch?

Answer

No, g is independent of her mass, so it will not change after she finishes her lunch though her mass has changed slightly.

15. Question

If an angel visits an asteroid called B 612 which has a radius of 20 m and mass of 104 kg, what will be the acceleration due to gravity in B 612?

Answer

$$g = \frac{GM}{R^2}$$

Where G is the universal gravitational constant (= 6.67 × 10^{-11} Nm^2kg^{-2}),

M is the mass of the earth,

R is the radius of the earth.

$M_{asteroid}$ = 104 kg

$R_{asteroid}$ = 20 m

$$g_{asteroid} = \frac{GM_{asteroid}}{R^2_{asteroid}} = \frac{104 \times 6.67 \times 10^{-11}}{20^2} = 1.73 \times 10^{-11} ms^{-2}$$

16. Question

A man of mass ‘m’ standing on a plank of mass ‘M’ which is placed on a smooth horizontal surface, is initially at rest. The man suddenly starts running on the plank with a speed of ‘v’ m/s with respect to the ground. Find the speed of the plank with respect to the ground.

Answer

According to the law of conservation of momentum,

Initial momentum = Final momentum

Initial momentum = 0(because the system is initially at rest, velocity is zero)

0 = mv + MV (V is unknown)

$$V = -\frac{mv}{M}$$

17. Question

Two balls of masses in ratio 2:1 are dropped from the same height. Neglecting air resistance, find the ratio of

(i) the time taken for them to reach the ground.

(ii) the forces acting on them during motion.

(iii) their velocities when they strike the ground.

(iv) their acceleration when they strike the ground.

Answer

(i) 1:1. This is because the equations of motion are independent of the masses of the 2 balls. So they take

equal amounts of time to reach the ground.

(ii) 2:1. We know F = ma. 'a' in this case is the acceleration due to gravity, g. So force depends only on m, and here the masses are in 2:1 ratio.

(iii) 1:1. This is because the equations of motion are independent of the masses of the 2 balls.

(iv) 1:1. The acceleration due to gravity, g is independent of the masses of the 2 balls.

18. Question

An object of mass 1 kg is dropped from a height of 20 m. It hits the ground and rebounds with the same speed. Find the change in momentum. (Take g = 10 m/s^2)

Answer

According to the equations of motion,

$V^2 = u^2 + 2as$

where v is the final velocity

u is the initial velocity

a is the acceleration

s is the displacement

Here acceleration is acceleration due to gravity,g.

So $v = \sqrt{(u^2 + 2gs)}$

$= \sqrt{(0 + 2\times9.8\times20)}$

$= \sqrt{196}$

= 14 m/s

Initial momentum = mv

Final momentum = -mv

Change in momentum = mv-(-mv) = 2mv = 2×1×14 = $\underline{28\ kgms^{-1}}$

19. Question

What will be the acceleration due to gravity on the surface of the moon, if its radius is 1/4th the radius of the earth and its mass is 1/80 times the mass of the earth.

Answer

$$g_{earth} = \frac{GM}{R^2}$$

Where G is the universal gravitational constant(= 6.67×10^{-11} Nm^2kg^{-2}),

M is the mass of the earth,

R is the radius of the earth.

$$\frac{M_{moon}}{M_{earth}} = \frac{1}{80}$$

$\frac{R_{earth}}{R_{moon}} = 4$ (given)

Now $g_{moon} = \frac{GM_{moon}}{R^2_{moon}}$

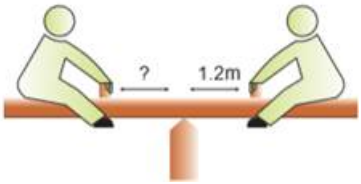
$$= g_{earth} \times \frac{M_{moon}}{M_{earth}} \times \left(\frac{R_{earth}}{R_{moon}}\right)^2$$

= 9.8× (1/80) × 4^2

= $\underline{1.96\ ms^{-2}}$

20. Question

A boy weighing 20 kg is sitting at one end of a see-saw at a distance of 1.2 m from the centre. Where should a man weighing 60 kg sit on the see-saw, so that it stands balanced?



Answer

To balance the seesaw, the weight moments on both sides should be balanced.

20×1.2 = 60×d

$$d = 20 \times \frac{1.2}{60}$$

$$= 0.4\ m$$

21. Question

A cart driver prods his horse to move forward. The horse refuses to budge and explains:

“According to Newton’s III Law, I am pulling the cart, with a certain force and the cart, in turn pulls me back with an equal amount of force. As they are equal in magnitude and act in opposite directions, they cancel each other.”

Do you agree with the explanation given by the horse? Support your answer with proper reasons.

Answer

No, the horse exerts the reaction using its feet on the ground. It pushes the ground backwards and so the cart moves forward. The horse is just being lazy and stubborn!

Part-C

1 A. Question

Space Stations are used to study the effects of long-space flight on the human body. justify.

Answer

Space Stations are used to study the effects of long-space flight on the human body since they provide zero gravity environments just like in outer space and there are adequate facilities for supporting human survival for long periods.

1 B. Question

$F = \frac{Gm_1m_2}{d^2}$ is the mathematical form of Newton’s law of gravitation, G - gravitational constant, m_1m_2, are the masses of two bodies separated by a distance d, then give the statement of Newton’s law of gravitation.

Answer

Newton’s law of gravitation states that the gravitational force between 2 objects is proportional to the product of the masses of the 2 objects and inversely proportional to the square of the distance between them.

2 A. Question

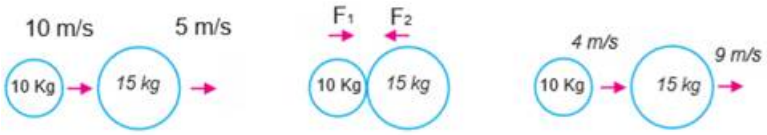
Newton’s first law of motion gives a qualitative definition of force. Justify.

Answer

Newton's first law of motion states that objects tend to stay in their state of rest or state of motion. This property of an object is called inertia. So this law is often called the law of inertia. It gives us a qualitative idea about force as it tells us that force tends to change the state of motion of a body.

2 B. Question

The figure represents two bodies of masses 10 kg and 15 kg, moving with an initial velocity of 10 ms^{-1} and 5 ms^{-1} respectively. They collide with each other. After collision, they move with velocities 4 ms^{-1} and 9 ms^{-1} respectively. The time of collision is 2 s. Now calculate F_1 and F_2



Answer

Acceleration of 10 kg mass = $\frac{v-u}{t} = \frac{4-10}{2} = -3\ ms^{-2}$

Acceleration of 15 kg mass = $\frac{v-u}{t} = \frac{9-5}{2} = 2\ ms^{-2}$

Where v is the final velocity,

u is the initial velocity,

t is the time taken.

Force on 15 kg mass,

$F_1 = m_1a_1$

$= 15 \times 2$

$= \underline{30\ N}$

Force on 10 kg mass,

$F_2 = m_2a_2$

$= 10 \times (-3)$

$= \underline{-30\ N}$

3. Question

A 5 N force acts on a 2.5 kg mass at rest, making it accelerate in a straight line.

(i) What is the acceleration of the mass?

(ii) How long will it take to move the mass through 20m?

(iii) Find its velocity after 3 seconds.

Answer

(i)a = $\frac{F}{m}$

Where a is acceleration, F is force and m is mass.

$= \frac{5}{2.5}$

$= 2\ ms^{-2}$

(ii) According to the equations of motion,

T = $\sqrt{\frac{2s}{a}} = \sqrt{2 \times \frac{20}{2}} = 4.47\ s$

(iii) According to the equations of motion,

v = u + at

Where v is the final velocity,

u is the initial velocity,

a is the acceleration,

t is the time taken.

v = u + at

= 2×3 + 0 = 6 m/s

4. Question

State the law of conservation of momentum. Two billion people jump above the earth's surface with a speed of 4m/s from the same spot. The mass of the earth is $6x10^{24}$ kg.

The average mass of one person is 60 kg.

i) What is the total momentum of all the people?

ii) What will be the effect of this action on the earth?

Answer

The law of conservation of momentum states that there is no change in momentum in an isolated system.

(i)Total momentum = mass × velocity = $10^8 \times 60 \times 4 = 2.4 \times 10^{10}$kgm/s

(ii)According to the law of conservation of momentum, the earth will gain the same momentum in the opposite direction so that there is no change in the momentum of the system (total momentum remains zero).

So the recoil velocity of the Earth = $\frac{2.4 \times 10^{10}}{6 \times 10^{24}}$

= 4×10^{-15} m/s

This velocity is negligibly small. So there's no observable effect.

5. Question

State Newton's law of gravitation. Write an expression for acceleration due to gravity on the surface of the earth. If the ratio of acceleration due to gravity of two heavenly bodies is 1:4 and the ratio of their radii is 1:3, what will be the ratio of their masses?

Answer

Newton's law of gravitation states that the gravitational force between 2 objects is proportional to the product of the masses of the 2 objects and inversely proportional to the square of the distance between them.

Now $g = \frac{GM}{R^2}$

Where G is the universal gravitational constant(= 6.67×10^{-11} Nm^2kg^{-2}),

M is the mass of the earth,

R is the radius of the earth.

$\frac{R_1}{R_2} = \frac{1}{3}$ $\frac{g_1}{g_2} = \frac{1}{4}$ (given)

So, $\frac{g_1}{g_2} = \left(\frac{R_1}{R_2}\right)^2 \times \frac{M_1}{M_2}$

$\frac{1}{4} = 3^2 \times \frac{M_1}{M_2}$

$$\frac{M_1}{M_2} = \frac{1}{36}$$

6. Question

A bomb of mass 3 kg, initially at rest, explodes into two parts of 2 kg and 1 kg. The 2 kg mass travels with a velocity of 3 m/s. At what velocity will the 1 kg mass travel?

Answer

Let M = 3 kg(the mass of the bomb)

m_1 = 2 kg(mass of one of the pieces)

m_2 = 1 kg(mass of the other piece)

v =0 m/sv_1 = 3 m/s

v_2 = ?

Initial momentum = 0(because the bomb was at rest)

According to, **the law of conservation of linear momentum** ,

Initial momentum = final momentum

$M \times v = m_1 \times v_1 + m_2 \times v_2 3 \times 0 = 2 \times 3 + 1 \times v_2$

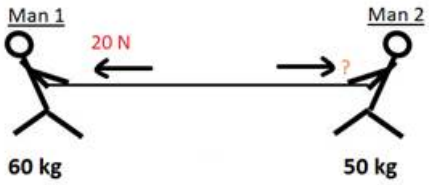
$$\frac{-m_1 v_1}{m_2} = -2\ ms^{-1} \times \frac{3\ kg}{1\ kg} = -6\ ms^{-1} = v_2$$

7. Question

Two ice skaters of weight 60 kg and 50 kg are holding the two ends of a rope. The rope is taut. The 60 kg man pulls the rope with 20 N force. What will be the force exerted by the rope on the other person? What will be their respective acceleration?

Answer

The figure of the question is given below:



It is given in the question that the rope is taut, it means the rope is very tight.

Hence, the force exerted will be the same when on both the sides of the rope. i.e. The force exerted by the rope on the other person will also be 20 N, according to Newton's 3rd law of motion.

Now, the acceleration of the 60 kg man $= \frac{\text{Force}}{m_1}$

$$= \frac{20\ N}{60\ kg}$$

$$= \frac{20\ kg - ms^{-2}}{60\ kg}$$

= $0.33\ ms^{-2}$

The acceleration of the 50 kg man $= \frac{\text{Force}}{m_2}$

$$= \frac{20\ N}{50\ kg}$$

$$= \frac{20\ \text{kg} - \text{ms}^{-2}}{50\ \text{kg}}$$

$= \underline{0.4\ \text{ms}^{-2}}$