Name: **Index No:**

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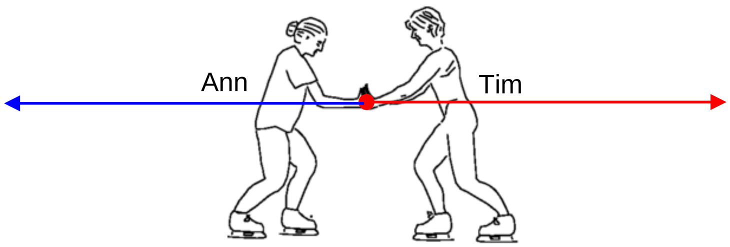
Assignment 04a: Newton's laws of motion

1. Ann and Tim are in the ice-skating rink. Ann pushes Tim with 20 N force.



Complete the blanks to explain the immediate motion of Ann and Tim. [3]

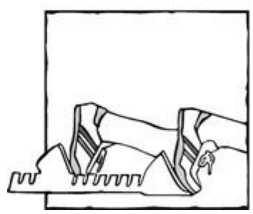
[1]: Ann moves to the …**left**………………… and Tim would moves to the …**right**………………….

[1]: When Ann exerts a …**20**………………… N (leftward/**rightward**) force on Tim, by Newton's 3rd law of motion, Tim exerts a …**20**………………… N (**leftward**/rightward) force on Ann.

[1]: As the horizontal …**normal**………………… force exerted on each of them is greater than the …**frictional**………………… force by the rink ground on the skates, both moved backwards.

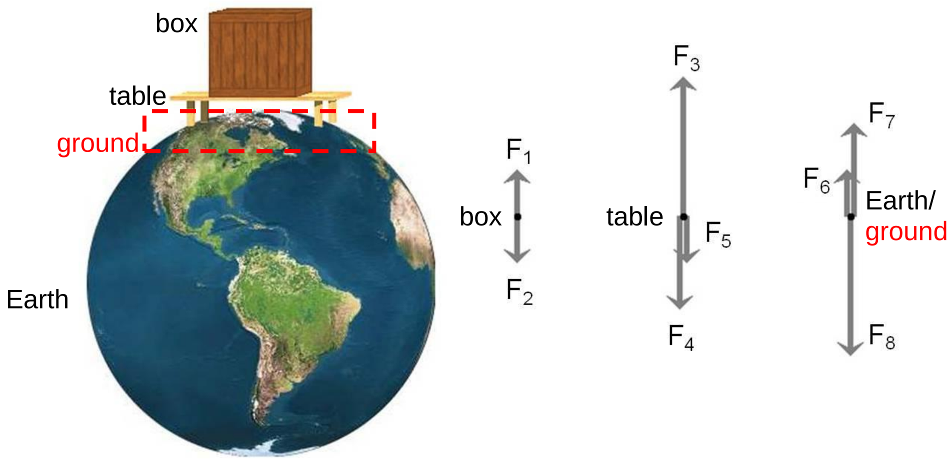
Question: Will Ann and Tim move backwards with the same magnitude of acceleration?

2. Explain why a runner moves forward when he pushes backwards on the starting block. [2]



[1]: As the runner exerts a (normal) force on the block, the block exerts an equal but opposite (normal) force on the runner. [1]: This reaction force propels the runner forward.

3. The diagram below shows a system of 3 bodies - box, table and Earth/ground. The box is resting on the table which is supported by the ground.



Source: http://canu.ucalgary.ca/map/content/force/newton3/simulate/box_on_table/applet.html

(a) Complete the table below, stating the type of force, the body which exerts the force and the body which the force is exerted on. [4]

F_1:	normal	force exerted by the	table	on the	box
F_2:	gravitational	force exerted by the	Earth	on the	box
F_3:	normal	force exerted by the	ground	on the	table
F_4:	gravitational	force exerted by the	Earth	on the	table
F_5:	normal	force exerted by the	box	on the	table
F_6:	gravitational	force exerted by the	box	on the	Earth
F_7:	gravitational	force exerted by the	table	on the	Earth
F_8:	normal	force exerted by the	table	on the	ground

(b) Hence, identify the four pairs of action-reaction forces. [4]

1. ______**F_1**____ and ____ **F_5**______	3. ____ **F_4**______ and ____ **F_7**______
2. ______ **F_2**____ and ____ **F_6**______	4. ____ **F_3**______ and ____ **F_8**______

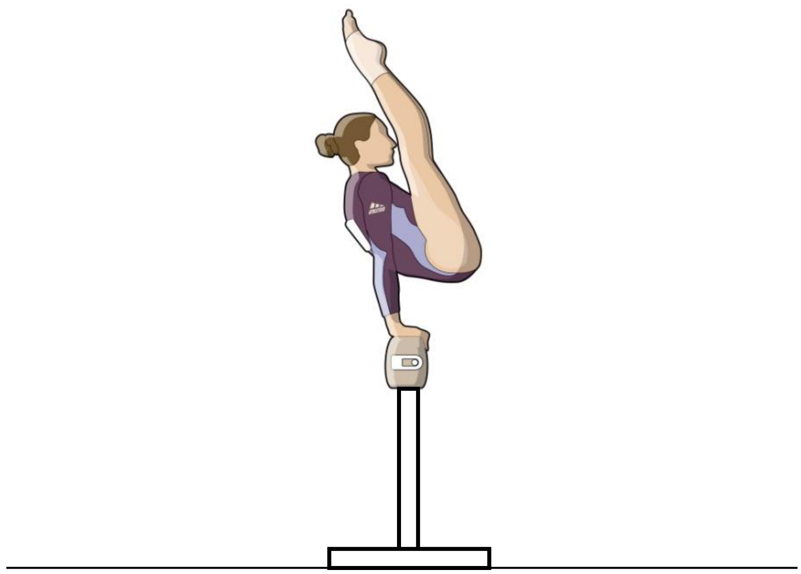
(c) The box has a mass of 5.00 kg. It is pulled horizontally across the rough table from rest, by a constant force of 30.0 N. The speed of the box is 2.00 m s^{-1} when it has moved 50.0 cm. Determine the constant friction f acting on the box as it moves. [2]

$(2.00 \text{ m s}^{-1})^2 = 0^2 + 2\,a\,(0.500 \text{ m})$
$a = 4.00 \text{ m s}^{-2}$ [1]

$30.0 \text{ N} - f = (5.00 \text{ kg})(4.00 \text{ m s}^{-2})$
$f = 10.0$ N (to 3 s.f.) [1]

4. For the system below,
(a) identify the action and reaction forces between the interacting free-bodies which are underlined,
(b) draw and label the **vertical** forces which act on the given free-bodies. When you label each force, state the **type of force**, the **body which exerts the force** and the **body which the force is exerted on**.

A **50** kg **gymnast** balances on a **100** kg **beam** which stands on the **ground / Earth**. (Ignore the gravitational forces between the gymnast and the beam.)

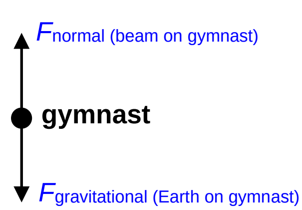


The four pairs of action and reaction forces are: [4]

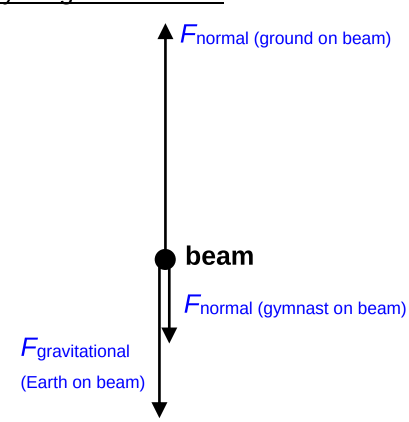
- $F_{gravitational}$ (Earth on gymnast) and $F_{gravitational}$ (gymnast on Earth)
- $F_{gravitational}$ (Earth on beam) and $F_{gravitational}$ (beam on Earth)
- F_{normal} (gymnast on beam) and F_{normal} (beam on gymnast)
- F_{normal} (beam on ground) and F_{normal} (ground on beam)

Note: $F_{gravitational}$ (beam on gymnast) and $F_{gravitational}$ (gymnast on beam) is always assumed to be negligible.

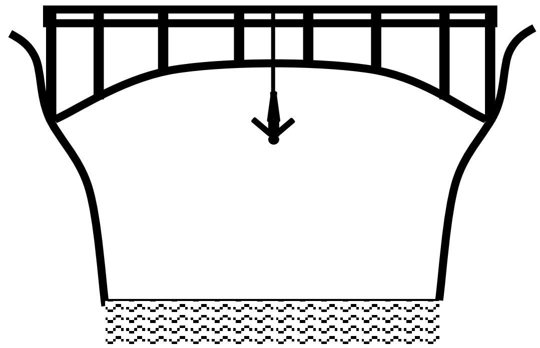
free-body diagram of gymnast [2]



free-body diagram of beam [3]

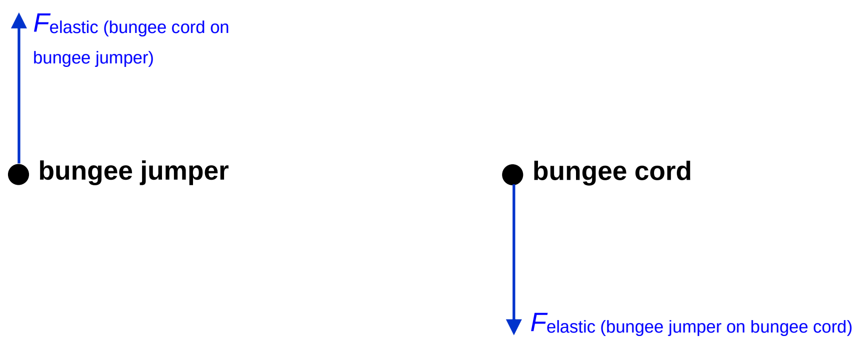


5. A bungee jumper is attached by an elastic bungee cord which is tied to a bridge connecting two sides of mountain rocks. The bungee jumper jumps off from rest and stretches the elastic bungee cord as he falls.



(a) The diagrams below show the free-bodies of the bungee jumper and the stretched bungee cord.

Draw and label the pair of action and reaction forces between the two free-bodies. When you label each force, state the **type of force**, the **body which exerts the force** and the **body which the force is exerted on**. [$F_{tension}$ is accepted.] [2]



(b) The bungee jumper is 80.0 kg. Assume acceleration due to gravity g = 10 m s^{-2} and ignore air resistance. Take positive velocity to be downward direction.

(i) As the bungee jumper falls, calculate his instantaneous acceleration when the force in the stretched cord is 6.00 X 10^2 N. [2]

[1]: (80.0 kg)(10 m s^{-2}) - 6.00 X 10^2 N = (80.0 kg) a [i.e. $mg - F_{elastic} = ma$]
[1]: a = 2.50 m s^{-2}

(ii) State the force in the stretched cord, at a particular instant when the falling bungee jumper's acceleration is zero. [1]

8.00 x 10^2 N [accept 800 N] [Since a = 0 m s^{-2}, $mg = F_{elastic}$.]

(iii) The bungee jumper continues falling until he reaches the lowest point of descent. At this instant, the force in the cord is 1.20 X 10^3 N.

Calculate his acceleration at this instant. [2]

[1]: (80.0 kg)(10 m s^{-2}) - 1.20 X 10^3 N = (80.0 kg) a
[1]: a = - 5.00 m s^{-2} (to 3 s.f.)

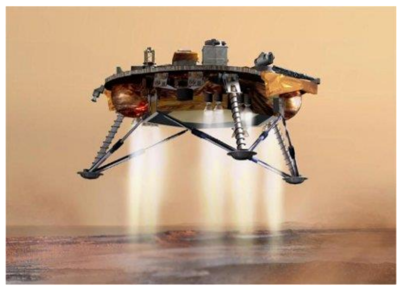
(iv) Hence, state the direction of net force and the velocity of the bungee jumper when he is at the lowest point of descent. [2]

Direction of net force: ……upward……….

Velocity of bungee jumper: …0 m s^{-1}………… [momentarily at rest before being pulled up the next instant]

6. **<u>Data-based question: Mars mission</u>**

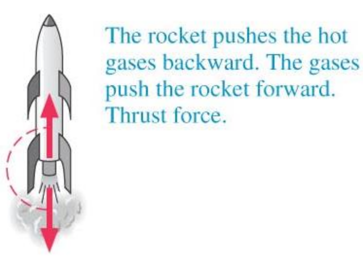
Phoenix was a robotic spacecraft on a space exploration mission on Mars under the Mars Scout Program. The Phoenix lander descended on Mars on May 25, 2008. Mission scientists used instruments aboard the lander to search for environment suitable for microbial life on Mars and to research the history of water there. During the first part of the descent, it moved vertically towards the surface of Mars with a constant speed of 5.0 m s^{-1}. The craft has a mass of 18000 kg. Neglect air resistance in this question.

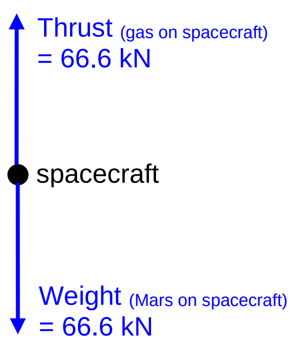


Source: http://www.slipperybrick.com/wp-content/uploads/2008/05/phoenix-mars-lands-on-mars.jpg

(a) During the first part of the descent, the constant upward thrust of the fuel gases burnt by the spacecraft was 66.6 kN.

Draw a labelled free–body diagram, showing clearly all forces acting on the spacecraft during the descent. For each force, state the type of force and its numerical value. [2]

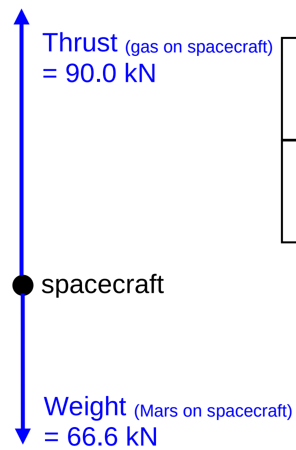




arrows have equal vertical lengths, in opposite directions: [1]
correct labelling and values for weight and <u>thrust</u>: [1] Note: NOT "upthrust"!

(b) During the last part of the descent, more fuel gases were burnt and the upward thrust was increased to a constant force of 90.0 kN.

(i) Draw a labelled free-body diagram to show the forces acting on the spacecraft during this stage of the descent. [1]



arrow for thrust longer than weight
correct labelling (and values) for weight and thrust: [1]

(ii) Determine the magnitude and the direction of the net force acting on the spacecraft. [2]

F_{net} = 66.6 kN – 90.0 kN
= -23.4 kN

F_{net} = 23.4 kN [1], upward [1]

(iii) Hence, describe the acceleration of the spacecraft and calculate its value. [2]

[1]: Constant negative acceleration
[1]: a = -1.3 m s^{-2}

Working: $F_{net} = ma$
-23.4 kN = 18000 x a
a = -1.3 m/s^2

Extension: Flying a helicopter on Mars
https://www.sciencenewsforstudents.org/article/nasa-ingenuity-helicopter-first-flight-mars-perseverance-rover