VISUAL PHYSICS ONLINE

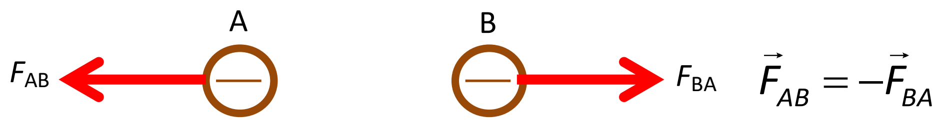
DYNAMICS

TYPES OF FORCES 1

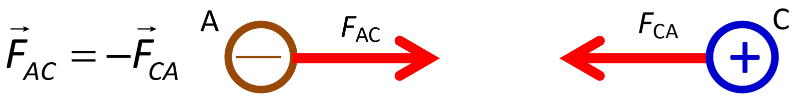
Weight: kilograms or newtons?

Electrostatic force

Force mediated by a field - long range: action at a distance: The attractive or repulsion between two stationary charged objects.



repulsion between two negatively charged objects



attraction between a negative charge and a positive charge

Gravitational force

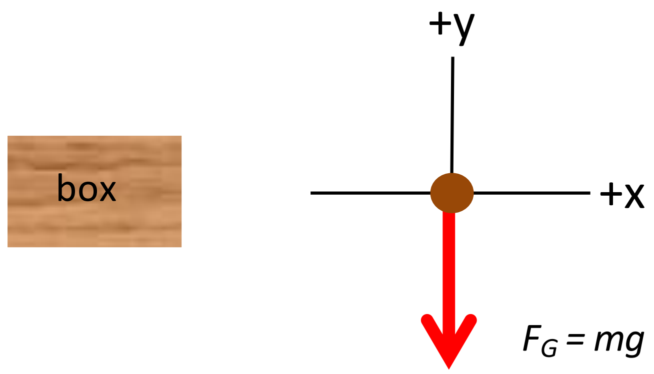
Force mediated by a field: Long range: action at a distance: attraction between two objects because of their mass.

Weight

Force mediated by a field - long range: action at a distance: The gravitational force acting on an object due to its attraction to the Earth. Near the Earth's surface the weight of an object is

(4) $F_G = m\,g$ weight of an object near Earth's surface

where m is the mass of the object and g is the local acceleration due to gravity at the Earth's surface.



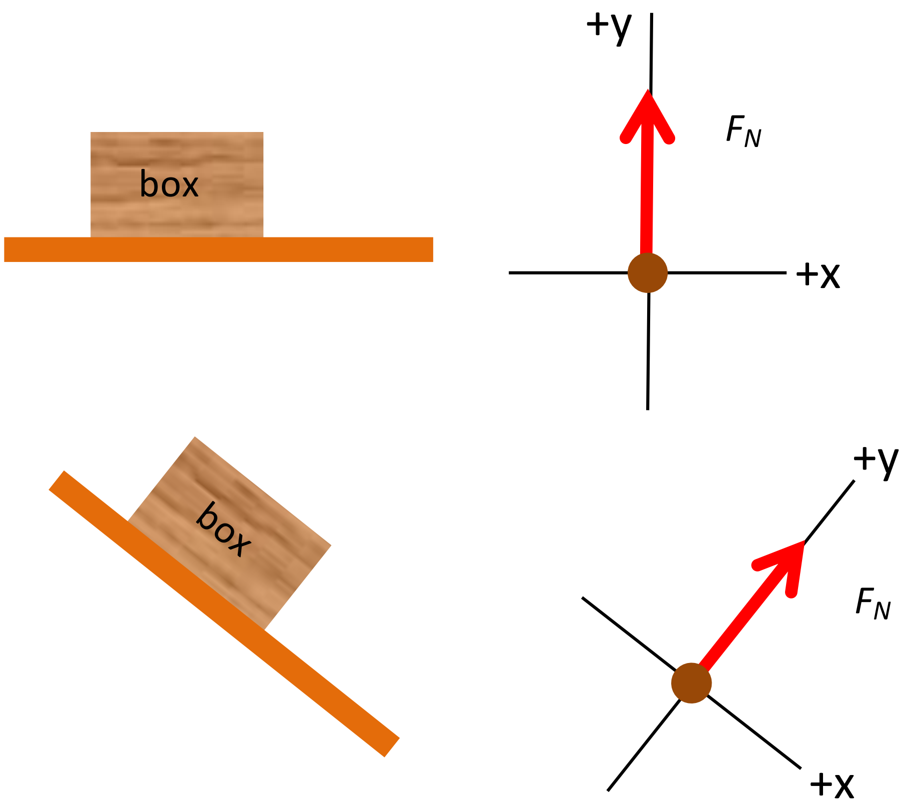
Beware: there are other definitions of weight.

Contact forces

Contact force occur when two objects are in direct contact with each other. Three examples of contact forces are: normal force, friction and tension.

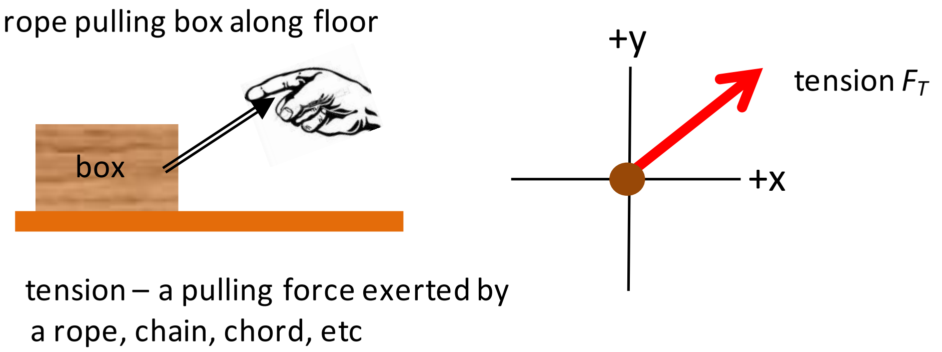
Normal force

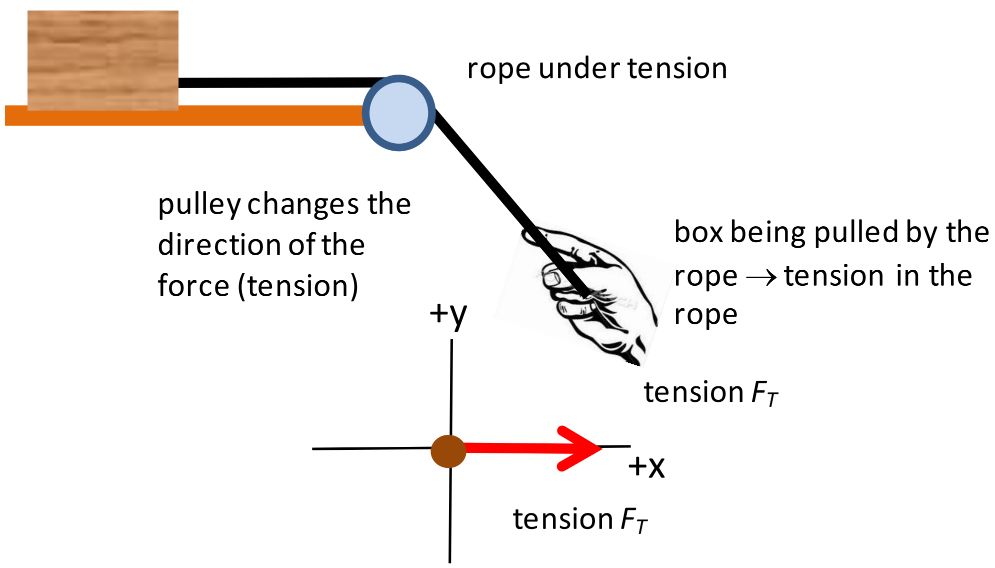
Normal force acting on an object in contact with a surface which acts in a direction at **right angles** to the surface (perpendicular).



Tension

Tension is the force acting along a stretched rope which is connected to an object.

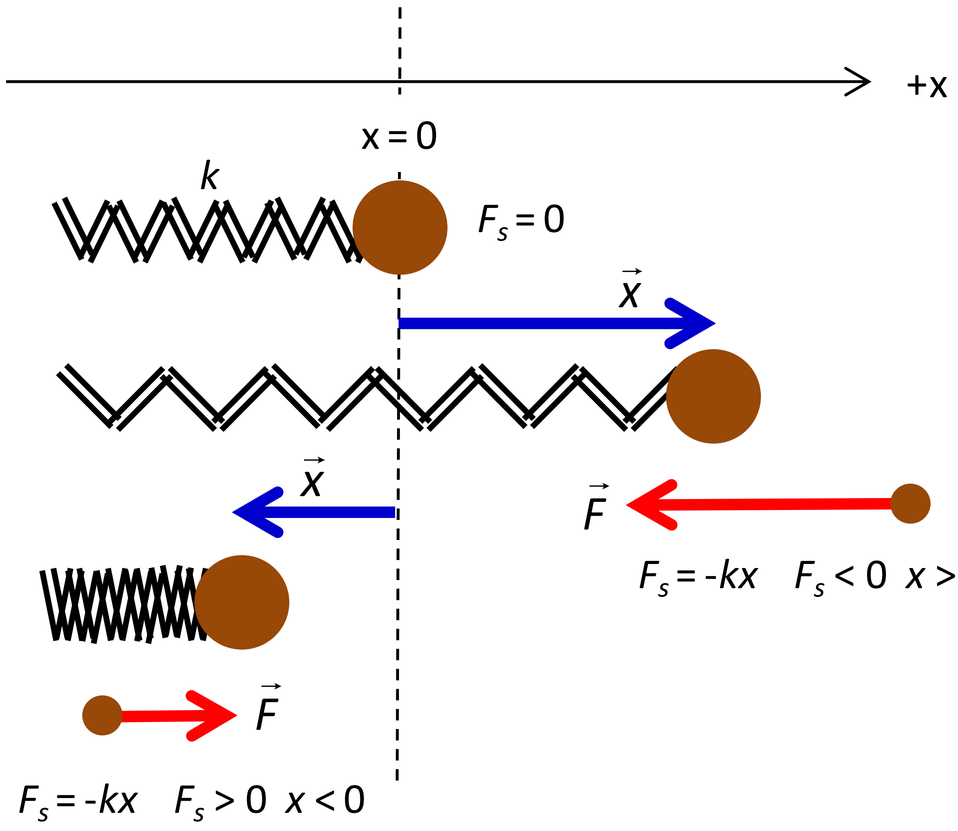




Springs

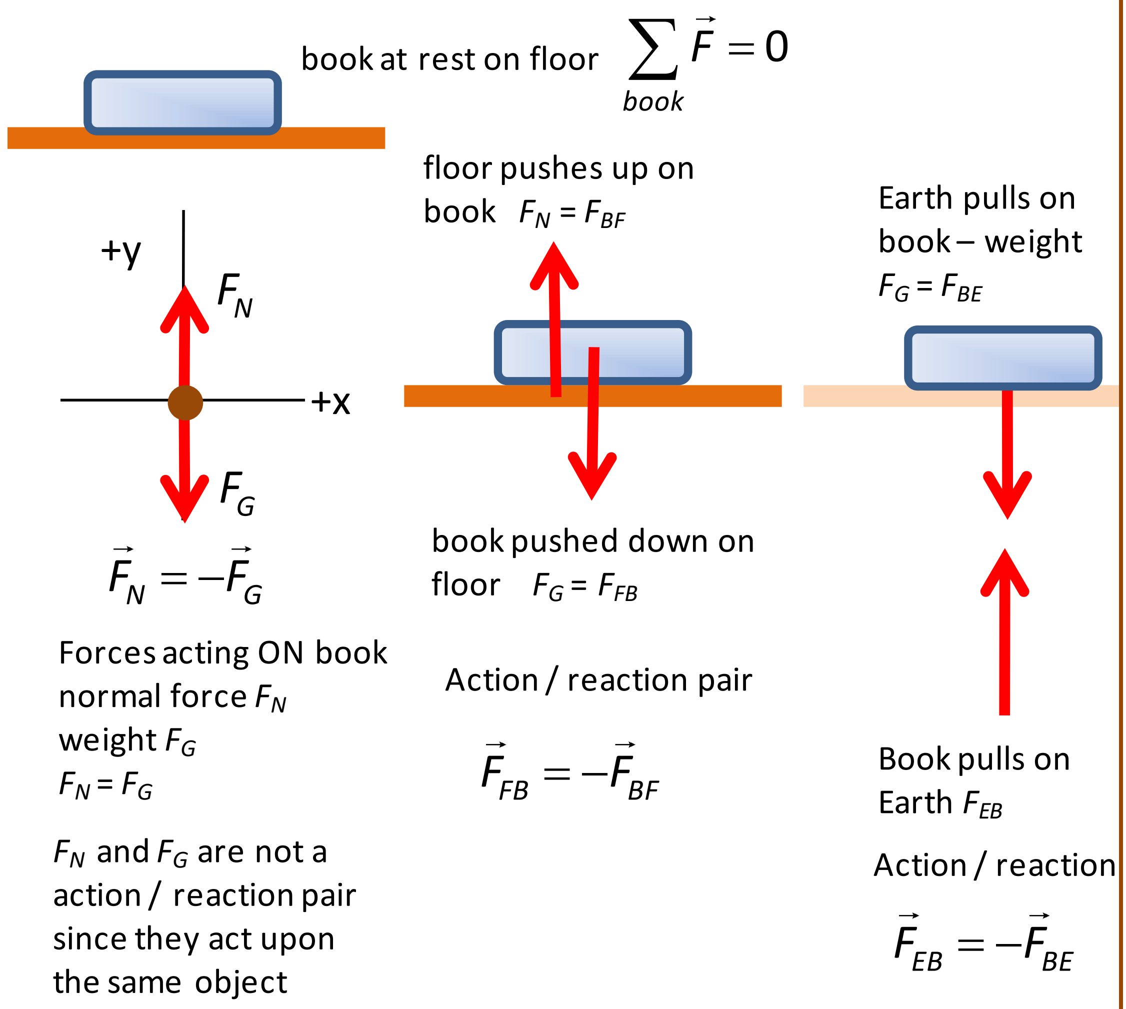
A common instrument for measuring force magnitudes is the spring balance. When an object is connected to a spring it will experience a force when the spring is compressed or extended. A simple model for a spring is that the force F_s exerted on the object is proportional to the compression or extension x of the string from its natural length. This force is known as the **elastic restoring force**. The constant of proportionality is the **spring constant** k. This relationship is known as **Hooke's Law**

(6) $F_s = -k\,x$ Hooke's law – elastic springs



Example 1

We will consider the forces acting on a stationary book on a floor and the reaction forces. The book is at rest, therefore, from Newton's 1st Law the sum of all the forces acting on the book must be zero. The book pushes down on the floor due to its weight F_{FB} and the floor deflects slightly pushing back on the book F_{BF}. The book is attracted towards the centre of the Earth with a force F_{BE} and the Earth is pulled by the book with a force F_{EB}.



Forces involved in a book resting on a floor.

Predict Observe Explain

Image that you are standing on a set of bathroom scales in an elevator (lift). **Predict** how the scale reading changes when the elevator accelerates upwards, downwards and travels with a constant velocity. Write down your predictions and justify them. **Observe**: Work through Example 5. **Explain** any discrepancies between the answers given in Example 5 and your prediction.

Example 2

A 60 kg person stands on a bathroom scale while riding an elevator. What is the reading on the scale in the following cases:

(1) The elevator is at rest.

(2) The elevator is going up at 2.0 $m.s^{-1}$.

(3) The elevator is going up at 4.0 $m.s^{-1}$.

(4) The elevator is going down at 2.0 $m.s^{-1}$.

(5) The elevator starts from rest and goes up reaching a speed of 2.0 $m.s^{-1}$ in 1.8 s.

(6) The elevator is moving up and accelerates from 2.0 $m.s^{-1}$ to 4.0 $m.s^{-1}$ in 1.8 s.

(7) The elevator starts from rest and goes down reaching a speed of 2.0 $m.s^{-1}$ in 1.8 s.

(8) The elevator is moving down and accelerates from 2.0 $m.s^{-1}$ to 4.0 $m.s^{-1}$ in 1.8 s.

(9) The elevator is moving up and slows from 4.0 $m.s^{-1}$ to 2.0 $m.s^{-1}$ in 1.8 s.

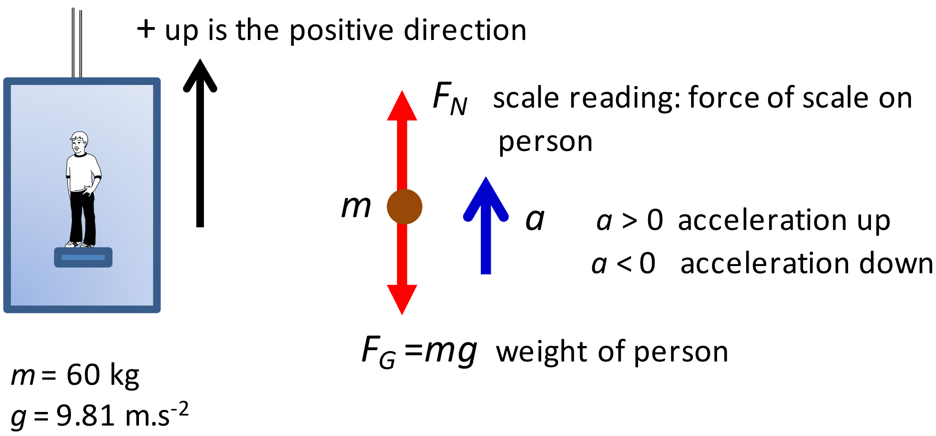
(10) The elevator is moving down and slows from 4.0 $m.s^{-1}$ to 2.0 $m.s^{-1}$ in 1.8 s.

Solution

How to approach the problem

Identify Setup Execute Evaluate

- Visualize the situation – write down all the given and unknown information. Draw a diagram of the physical situation showing the inertial frame of reference.
- Type of problem – forces and Newton's laws.
- Draw a free-body diagram showing all the forces acting on the person.
- Use Newton's 2nd law to give the relationship between the forces acting on the person and the acceleration of the person.
- Determine the acceleration of the person in each case.
- Solve for the unknown quantities.



The person exerts a force on the bathroom scales and the bathroom scales exerts a force on the person. This is an action / reaction pair. But, we are only interested in the forces acting on the person which are the weight and the normal force due to the scale on the person.

The scale reading F_N is found from Newton's 2nd law:

$$\sum F_y = F_N - F_G = F_N - m\,g = m\,a$$

$$F_N = m(g + a)$$

- acceleration due to gravity g = 9.8 m.s^{-2} (scalar quantity in this example)
- acceleration of person $a > 0$ if direction up and $a < 0$ if acceleration down

The weight of the person is $F_G = mg$ = (60)(9.81) N =588.6 N

We can assume when the velocity changes the acceleration a is constant and equal to the average acceleration

$$a = a_{avg} = \frac{\Delta v}{\Delta t}$$

In cases (1), (2), (3) and (4) there is no change in the velocity, hence

$$\Delta v = 0 \quad \Rightarrow \quad a = 0 \quad \Rightarrow \quad F_N = F_G = m\,g$$

Therefore, the scale reading is F_N = 588.6 N or 60 kg.

For cases (5), (6) and (10) $\quad \Delta t = 1.8\text{ s}$

case (5) $\quad \Delta v = (2-0)\text{ m.s}^{-1} = +2\text{ m.s}^{-1}$

case (6) $\quad \Delta v = (4-2)\text{ m.s}^{-1} = +2\text{ m.s}^{-1}$

case (10) $\quad \Delta v = (-2-(-4))\text{ m.s}^{-1} = +2\text{ m.s}^{-1}$

The acceleration is

$$a = \frac{\Delta v}{\Delta t} = \left(\frac{+2.0}{1.8}\right)\text{m.s}^{-2} = 1.11\text{ m.s}^{-2}$$

The scale reading is

$$F_N = m(g+a) = (60)(9.81+1.11)\text{ N} = 655\text{ N} \quad \text{or} \quad 67\text{ kg}$$

This scale reading is often called the person's **apparent weight**. The person feels the floor pushing up harder than when the elevator is stationary or moving with a constant velocity.

For cases (7), (8) and (9) $\quad \Delta t = 1.8\text{ s}$

case (7) $\quad \Delta v = (-2-0)\text{ m.s}^{-1} = -2\text{ m.s}^{-1}$

case (8) $\quad \Delta v = (-4-(-2))\text{ m.s}^{-1} = -2\text{ m.s}^{-1}$

case (9) $\quad \Delta v = (2-4)\text{ m.s}^{-1} = -2\text{ m.s}^{-1}$

The acceleration is

$$a = \frac{\Delta v}{\Delta t} = \left(\frac{-2.0}{1.8}\right)\text{m.s}^{-2} = -1.11\,\text{m.s}^{-2}$$

The scale reading is

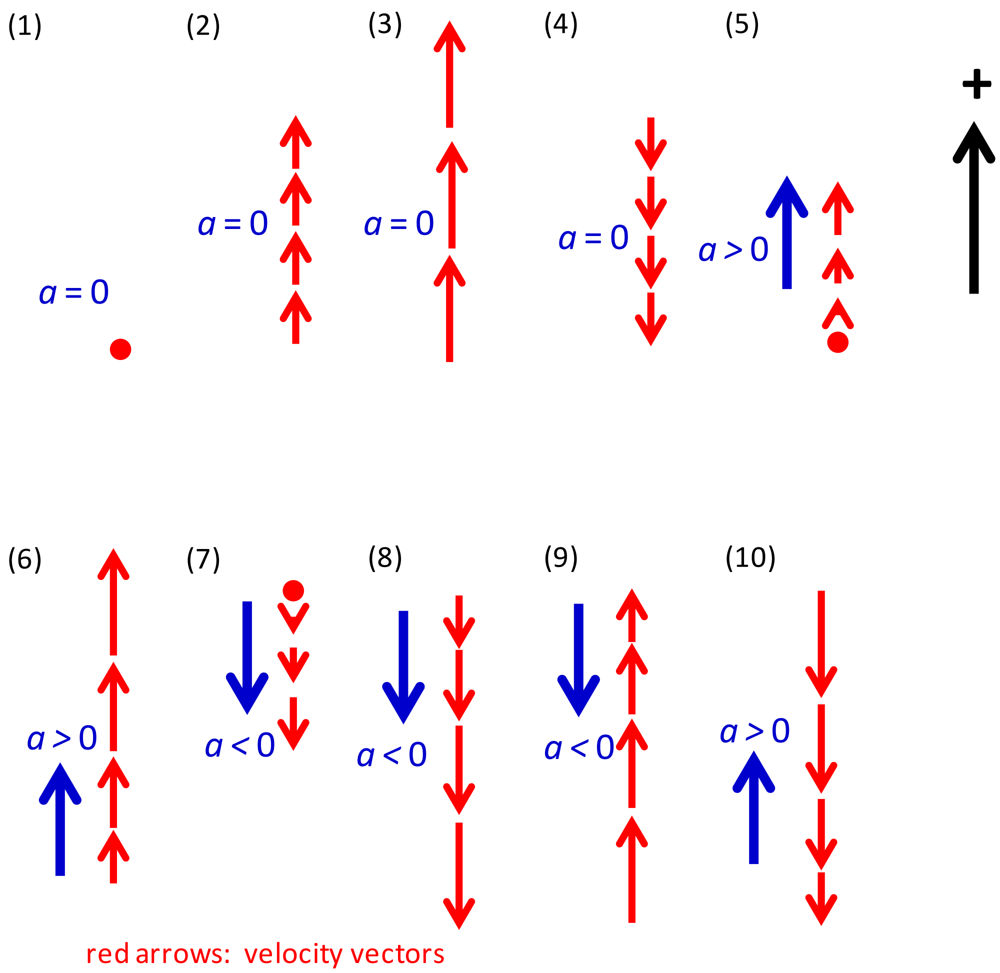
$$F_N = m\left(g + a\right) = \left(60\right)\left(9.81 - 1.11\right)\text{N} = 522\text{ N} \quad \text{or} \quad 53\text{ kg}$$

The person feels their weight has decreased.

In the extreme case when the cable breaks and the elevator and the person are in free-fall and the downward acceleration is $a = -g$. In this case the normal force of the scales on the person is $F_N = m(g - g) = 0$ N. The person seems to be weightless. This is the same as an astronaut orbiting the Earth in a spacecraft where they experience **apparent weightlessness**. The astronaut and spacecraft are in free-fall and there are zero normal forces acting on the person. The astronaut still has weight because of the gravitational force acting on them.

The acceleration does not depend upon the direction of the velocity. What is important is the change in the velocity.

A good way to understand this concept is to draw the appropriate motion maps



[VISUAL PHYSICS ONLINE]

If you have any feedback, comments, suggestions or corrections please email:

Ian Cooper School of Physics University of Sydney

ian.cooper@sydney.edu.au