Weight and Tension (Lab)

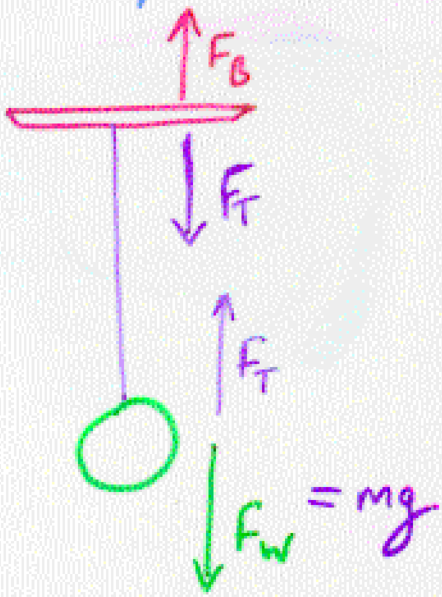
If any object, mass m is accelerated to earth by amount g ($= 9.81\,m/s^2$) then

Force of gravity F_W = mass x accel = mg

– this is the weight of the object (Newtons)

Note: Mass does not change on Mars etc., weight does.

Now suspend mass on string:



At bottom of string.....

- No net motion as F_W is balanced by tensile force F_T i.e. $F_T = mg$.

At top of string .....

- F_T acts away from end towards center
- Support beam provides reaction force $F_B = F_T = mg$.

i.e. String tension transmits point of application of force from one end to the other.

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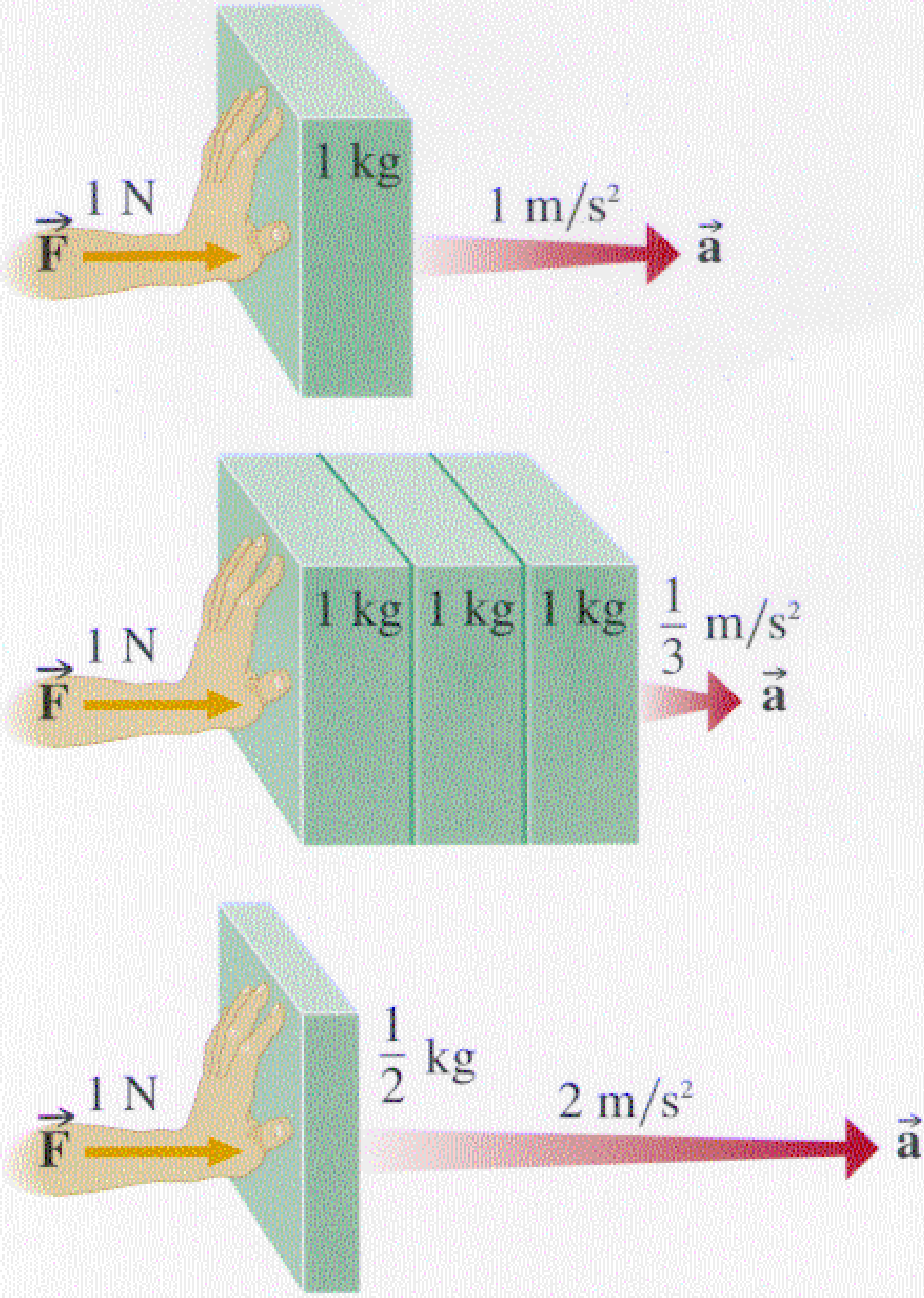
Figure 4.10

Examples of how $\vec{F}=m\vec{a}$ works



Forces change Momentum over time (and distance)

e.g. A rocket motor provides thrust force of 3000N (rocket mass = 20kg). Motor burns for 10s

Note: Constant $\vec{F} \Rightarrow$ constant $|\vec{a}| = \frac{F}{m} = \frac{3000}{20} = 150\,m/s^2$

So after 10s, $v = v_0 + at = 0 + 150 \times 10 = 1500\,m/s$

OR Total change in momentum from $F = \frac{dp}{dt}$

is $\Delta p = \int_0^t F\,dt$, i.e. $m(v - v_0) = 3000N \times t$

Over distance (c.f. lab) .....

If force constant, then $|\vec{a}|$ constant and over distance $(x - x_0)$: $v^2 = v_0^2 + 2a(x - x_0)$

e.g. if dart with m = 10g exits 5cm blowpipe at 2m/s:

We have $(2m/s)^2 = 0 + 2a \times 5cm$

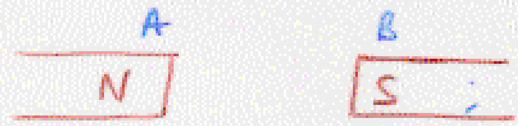
$\Rightarrow$ accel. $a = 0.4\,m/s^2$

blowing force $F = ma = 0.01kg \times 4m/s^2 = 0.04N$

Newton's 3rd Law: Interaction

When two bodies "interact" (e.g. collide) both are affected:

Both green + purple ball undergo change in momentum.



magnet poles attract/repel without touching – each feels same force.

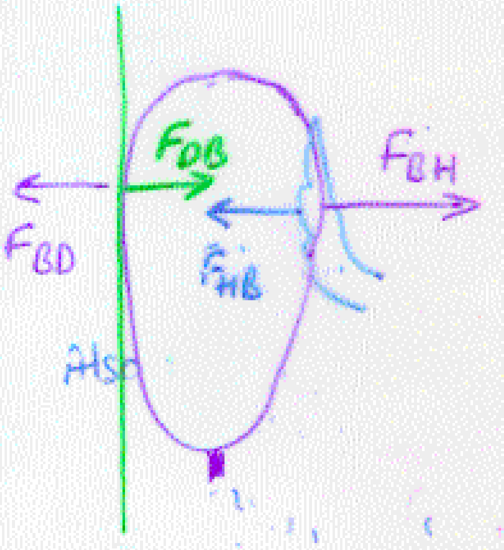
"To every action, there is an equal and opposite reaction". – Newton's 3rd Law.

i.e. if A pushes on B, B pushes back on A with equal and opposite effort.

Newton's 3rd Law: Forces arise in "Interaction Pairs"

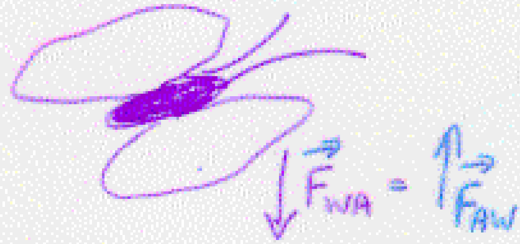
Statics:

Push Balloon into Door with Hand



Dynamics

Beating wings:



Wing pushes down on air

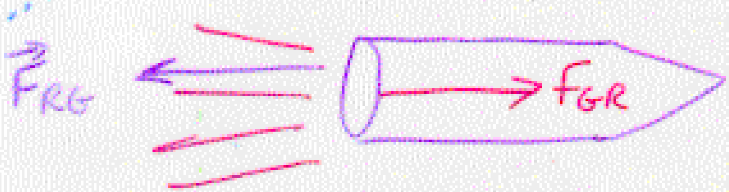
Air pushes back up on wing

⇒ lifts butterfly off ground when $F_{WA} > mg$

Rocket Propulsion

Expel gas from rocket with force F_{RG}

⇒ reaction force on rocket F_{GR}



e.g. Expel gas at 600 m/s at rate 10 kg/s

⇒ Momentum change of gas in 1s = Δmv = 6000 kg m/s

∴ Force on rocket $F_{GR} = \frac{dp}{dt} = \frac{\Delta mv}{1s} = 6000\,N$ (and $a = \frac{F}{M}$)

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Internal and External Forces

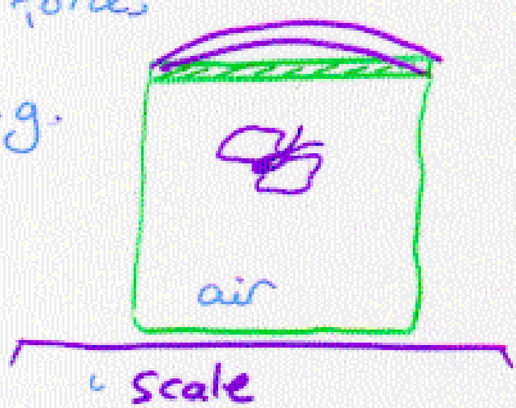
OR If bluebirds fly, why can't I ?

- Since forces occur in (equal + opposite) pairs
  - cannot lift oneself by belt ! $F_{BH} = -F_{HB}$
  - but can use a bar  $F_{BH} = -F_{HB}$

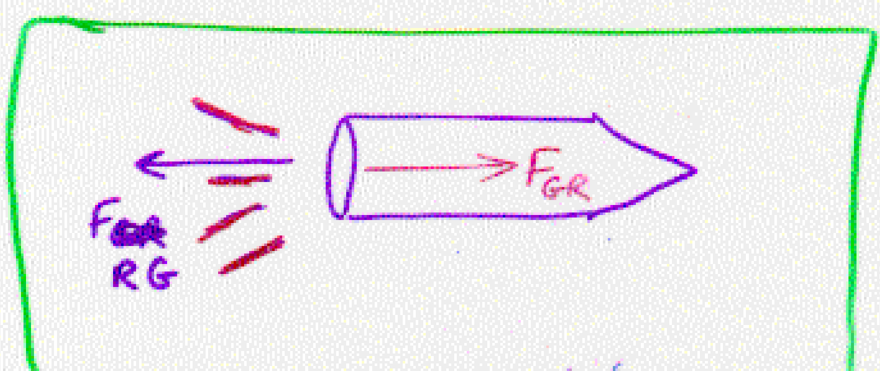
  (pull down on bar to lift yourself)

- In general, must consider entire 'closed system' of forces

e.g.



fly or bird can lift off jar bottom, but cannot lift whole jar. (In fact, scale reading stays constant!)



enclose rocket in a box. $\vec{F}_{GR} = -\vec{F}_{RG}$

No net external force ⇒ box does not move.

ANSWER: MAGNET CAR

The answer is: c. You could just dismiss the thing by saying that no work output will result from zero work input — or perpetual motion is impossible. Or you could invoke Newton's Third Law: the force on the car is equal and opposite to the force on the magnet — so they cancel out. But these formal explanations don't illustrate why it will not work.

To see intuitively why it will not work, improve the design by putting another magnet in front of the car. Then, to streamline things, put the magnets in the car. Then comes the question: which way will it go?