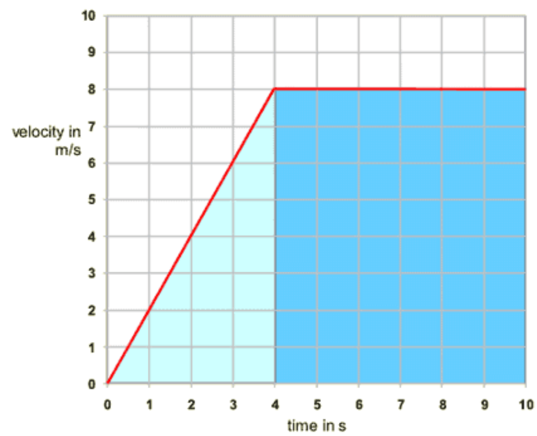
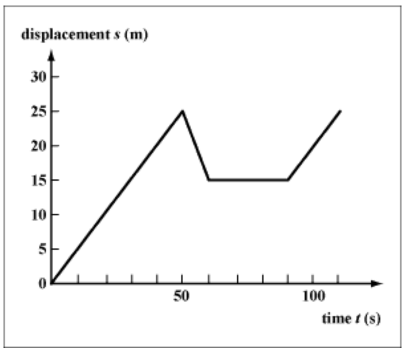
02 Mechanics review answers

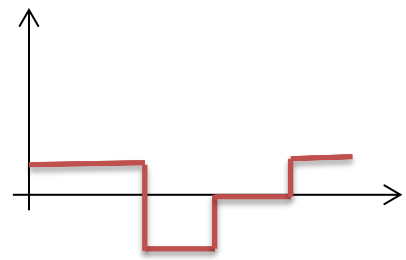


Part A: Kinematics:

1. For the graph on the right state:
   a. The instantaneous velocity at t=3seconds: **$6ms^{-1}$**
   b. The average v first 4s: **$(u+v)/2 = 8/2 = 4ms^{-1}$**
   c. a during the first 4s: **$=$ gradient $=(v-u)/t = 8/4 = 2ms^{-2}$**
   d. Total distance travelled: = area = **0.5*4*8+6*8=64m**



2. Velocity-time graph for the motion represented on the graph. The graph should be as shown:
Step changes in velocity from +0.5 to -1.0, to 0.0 to +0.5 ms^{-1}



3. The graph you have drawn for question 5 is a simplification. **Step (instantaneous) changes in v are not possible because infinite acceleration is not possible.**
4. State what the area under an acceleration-time graph represents. **<u>Change</u> in velocity**
5. State the condition under which the equation ***s = (u+v)t/2*** is valid. **Constant acceleration**

6. A ball is dropped near the surface of the Earth and if air resistance is negligible it would hit the ground 3 seconds later.
   a) Ball speed when it hits the ground? **$\Delta v = at = gx3 = 29.4\ ms^{-1}$**
   b) How far will the ball have travelled and what is its average speed?

$s = (u+v)t/2 = (0+29.4)x3/2=44.1m$, average velocity = $14.7\ ms^{-1}$

   c) After how long did it take the ball to travel 9.81 metres?

$s = ut + 0.5at^2$, $u=0$ so $t^2=s/0.5g = 9.81/(0.5*9.81) = 2$, $t=1.41s$

   d) How fast was the ball travelling after it had fallen 19.62 metres?

$v^2 = u^2 + 2as$, $u=0$ so $v = \sqrt{(2 \times 9.81 \times 19.62)} = 19.62\ ms^{-1}$

7. For the ball in question 6 air resistance is not, in fact negligible.
   a) How will this affect your answers to c) and d)?
   As the velocity increases air resistance will reduce the acceleration so the ball will take longer to drop. It will also be travelling slower.
   b) Will air resistance change the answer to c) or d) more? Explain.

Air resistance will affect d more as air resistance reduces the velocity more as the object falls eventually limiting it to terminal velocity.

Part B: Forces and Dynamics

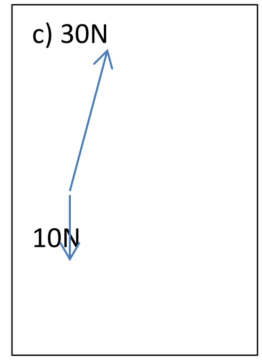
1. A 1kg block is sliding along a table. There is no force pushing it.
   a. Draw a force diagram for the block, labeling the forces and describe its motion.

10N Weight(mg) down, 10N Normal (upthrust) up, Friction acting against motion. Decelerating

   b. The block falls off the edge of the table, draw a force diagram for the block now.

10N Weight(mg) only

   c. The block is caught and during the catch max force on the ball was 30N, 10^0 to the vertical. Draw the force diagram now and calculate the acceleration.

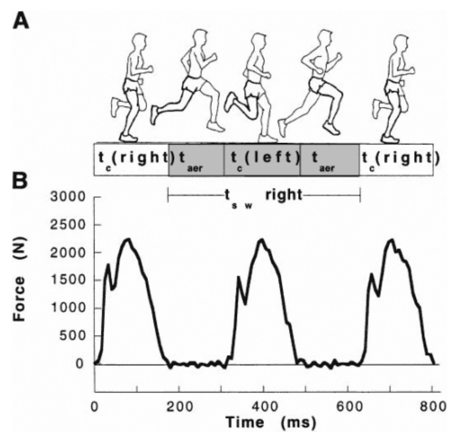


Resultant force is 30sin(10)=5.2N horizontal and 30cos(10)–10=19.5N vertical.
Magnitude = √(19.52+5.22) = 20.2, direction tan-1(5.2/19.5)=15O from vertical.
Acceleration = Force/Mass, Mass=1 so 20.2ms^{-2} at 15^O from vertical

2. For conservation of linear momentum….. **No external forces**

3. A rifle can shoot a 4.20 g bullet at a speed of 965 ms^{-1}. The bullet is fired into a 50.0 kg torso with vest of 2.5kg.
   $P_{before} = P_{after}$
   0.0042 x 965 = v x (50+2.5+0.0042) so v = 0.077ms^{-1}

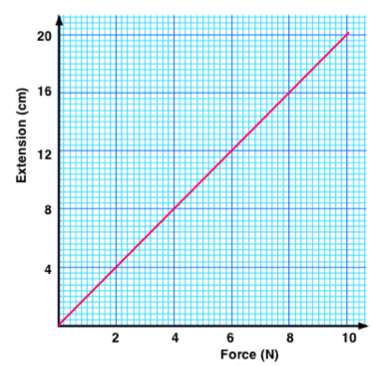
4. Estimate the (vertical) impulse from the graph opposite.
   Impulse = FΔt = 1700x170x10^{-3}s = 289Ns
   The 70kg person will change velocity by 289/70 = 4ms-1 but the ground will be almost unaffected. Apart from a mini-seismic wave travelling out from the impulse.



Part C: Work, Energy and Power

1) Sledge pulled with 10N at an angle of 30^o for 30m how much work is done?
   W=Fscosθ = 10x30xcos(30) = 260J

2) a) How much work is done stretching spring 0.2m?
   W for 0.2m stretch = Fs (using average F) = 10x10=100J
   Or by area under graph = 0.5x10x20 = 100J
   b) What type of energy is transferred to the spring? **E_p**



3) A 1100kg lorry travelling at 24ms^{-1} collides with a 600kg car travelling at 19ms^{-1} in the same direction.
   a) After the collision the new speed of the car is 23m/s what is the new velocity of the lorry?
   $P_{before} = P_{after}$ so….1100x24 + 600x19 =1100v + 600x23
   V = (1100x24 + 600x19 - 600x23)/1100 so v = 21.8ms^{-1}

   b) Calculate the total amount of kinetic energy before and after the collision.

$E_k = ½ mv^2$ ➔before = 316800+108300 = 425,000J, after = 261382+158700 = 420,000J (NB 3 s.f.)

4) An 80kg skier starts from a velocity of 0.5ms^{-1} at the top of a slope 35m high. The average force of friction on the skier is 20N and the slope is 200m long.

a) How fast is the skier travelling at the bottom of the slope?

E_k gained = Ep – work done against friction = mgh – Fs = 80x9.81x35 – 20x200 = 23468J

½ mv^2 = 23468J so v = √(23468x2/80) = 24.2 ms^{-1}

b) If the skier uses a drag lift to get back up the slope how much work does the drag list do if the average frictional force remains 20N?

mgh + Fs = 80x9.81x35 + 20x200 = 31486J = 31500J

c) State the dynamic coefficient of friction for the skiis.

Normal force is almost exactly equal to mgh but not quite as there is a slope.

Angle of slope = y = sin^{-1}(35/200) = 10.1 degrees

Normal force = mgh x cos(y) = 773N

Dynamic coefficient of friction = friction/normal = 20/773 = 0.026

d) If the coefficient of static friction is 0.05 what is the maximum value of static friction? Explain why the static friction can be less that this value.

773 * 0.05 = 77.3N = 39N

The friction can be less than this because static friction is only produced is other forces on the skier are not balanced.

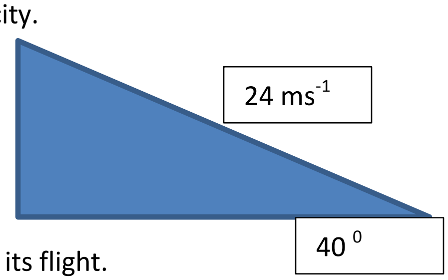
<u>Part A: Projectile motion:</u>

1. A stone is thrown from a hand at a velocity of 24ms^{-1} and an elevation of 40^0 to the horizontal. The stone is 2m above the ground when released. Ignore air resistance.

a. Calculate the horizontal and vertical components of velocity.

Horizontal: 24cos(40) = 18.4ms^{-1}

Vertical: 24sin(40) = 15.4ms^{-1}



Note that for the rest of the answers we are ignoring air resistance.

b. Calculate the time taken for the stone to reach the top of its flight.

This is the same as time taken to reach zero vertical velocity:

a = (v-u)/t so t = (v-u)/a = (0-15.4)/-9.81 = 1.57s

c. Calculate the total flight time for the stone.

There are a few ways to do this:

Easiest is to work out the height reached then the time to descend then add this to the 1.57s taken to go up.

Height reached = average velocity x time = (v+u)t/2 = (0+15.4)x1.57/2 = 12.1m

Height to fall = 14.1m

s = ut + 1/2at^2 with u=0 because vertical velocity is zero at the high point

s = 1/2at2 so t2 = 2s/a = 2x14.1/9.81 = 2.87 so time taken to fall is 1.70s

Flight time = 1.57 + 1.70 =3.27s

d. Calculate the horizontal distance travelled by the stone.

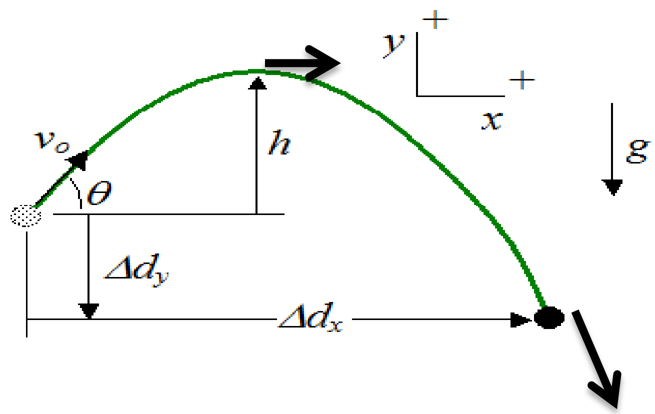
Horizontal velocity is constant so s=vt = 18.4x3.27=60m

e. Calculate the velocity of the stone just before landing.

Vertical velocity = u+at = 0 + 9.81 x 1.70 = 16.7 ms^{-1}

Horizontal velocity = 18.4 ms^{-1}. So v = 24.8 ms^{-1} at 42 degrees to horizontal.

f. Sketch the flight path of the stone with arrows drawn to scale to represent the velocity of the stone at the start, high point and landing.



2. A bullet is fired horizontally from a gun at 500ms-1 directly at a cross on a target. If the target is 200m away how far below the cross will the bullet hit?

Time taken to reach the target = 200/500 = 0.4s

Falling distance: s = ut + ½at^2 = 0 + 0.5x9.81x0.4^2 = 0.78m