Problems for the Workshop

I have divided the problems into three different sections:

Enrichment – easy problems to help understand the theory by applying the equations and concepts involved
Extension – more difficult problems in which the equations need to be adapted to solve the problem and use a little more mathematics.
Challenge – difficult problems that will require a deeper understanding, sometime beyond the CAPS document, of the concepts involved and solving more difficult equations.

1 Enrichment Problems

1.1 A body of weight **W** rests on a plane inclined at an angle of 30º to the horizontal. What is the magnitude of the frictional force which prevents the body from moving down the incline?

1.2 A 1 000 kg car collides head-on with a 2500 kg bus. They stop instantly on collision. If before the impact the car was travelling at 20 ms^{-1}, what was the speed of the bus after the collision?

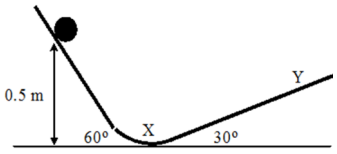
1.3 A car travels 3 km north, turns and travels a further 6 km east. Represent these displacements graphically and find the resultant:
i) graphically (by scale drawing)
ii) by calculation.

1.4 In question 1.3 above, how far has the car driven?

1.5 A constant horizontal force of 10 N is required to drag an object across a rough surface at a constant speed of 5 $m.s^{-1}$. What power is being expended ?

1.6 A 50 g bullet travelling at 40 000 $cm.s^{-1}$ is stopped by a steel plate. How much heat is generated on the assumption that all the energy is completely converted into heat.

1.7 A ball of mass 2 kg is held on a slope of 60º, half a metre above a horizontal surface. How far along the slope (distance XY) does the ball roll after being released? (You may assume that the ball loses no energy when it rolls and take g = 10 $m.s^{-2}$.)



1.8 Show that vector addition is commutative, i.e. that **A + B = B + A**

1.9 A ticker-timer is used to find the acceleration of an object. Use the information in the table on the right to:
a) find the average velocity for each section
b) find the acceleration of the object.

Section of Tape	Time at Start (s)	Time Interval (s)	Length of section (cm)
1	0.0	0.1	5.2
2	0.1	0.1	9.8
3	0.2	0.1	14.5

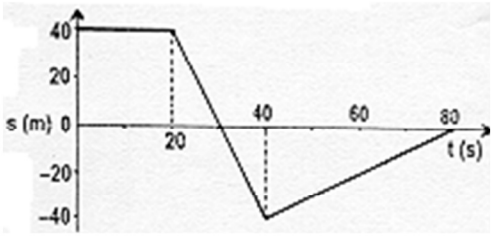
1.10 A body starts from rest and reaches a velocity of 15 $m.s^{-1}$ after 5 s. What is the body's acceleration?

1.11 The velocity of a car increases from 10 $m.s^{-1}$ to 20 $m.s^{-1}$ over a distance of 50 m.
a) What is the acceleration of the car?
b) how long did this take?

1.12 A car has a maximum acceleration of 2.5 $m.s^{-2}$. What is the minimum length of time for it to reach 90 $km.h^{-1}$ if it starts from rest?

1.13 A car accelerates from rest with an acceleration of 2 $m.s^{-2}$ for 20 s. If the car continues at this speed for a further 60 s and then brakes, and comes uniformly to rest 8 s later.
a) Sketch the velocity-time and displacement time graphs for the entire motion.
b) Calculate the car's speed after 25 s,
c) Calculate the car's final acceleration,
d) What was the total distance travelled by the car

1.14 The displacement – time graph shows the position of a car during a time interval of 80 seconds. What is the car's average velocity, in $m.s^{-1}$ during the 80 seconds?



1.15 On a motorway a car is travelling at 50 $m.s^{-1}$ and stops in a distance of 200 m.
a) what is the car's speed in $km.h^{-1}$
b) what is the car's acceleration?
c) how long does it take to stop?

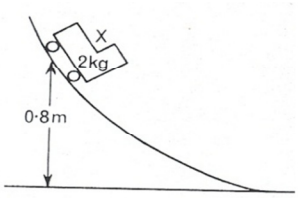
1.16 Galileo allegedly dropped two cannonballs from the Leaning Tower of Pisa to show that the acceleration due to gravity was independent of an object mass. In other words to dispel the myth that heavies objects fall faster than light ones. Use Newton's Universal Law of Gravitation to show that Galileo was right.

2 Extension Problems

2.1 A lift is accelerating upwards at 2 $m.s^{-2}$. A ball is held 3 m above the floor of the lift and then released. How long before it hits the floor?

2.2 A Formula 1 racing car has momentum ***P*** and kinetic energy ***T*** when it crashes into a tyre wall. It comes to rest after travelling a distance of ***d*** metres in ***t*** seconds. What is the force exerted on the car during the crash?

2.3 A trolley X of mass 2.0 kg rolls down a frictionless track from a vertical height of 0.8 m, as shown. What is the velocity of X in ms^{-1} when it reaches the bottom?



2.4 If a runner doubles her speed, what is the ratio of her new kinetic energy to her original kinetic energy?

2.5 A machinegun fires bullets into a wall at a rate of 100 bullets per minute. Each bullet has amass of 4 g and is fired at a speed of 450 $m \cdot s^{-1}$. Assume that all the momentum of the bullets is transferred to the wall. What is the average force exerted by the bullets on the wall?

2.6 When a spring is stretched by 2 cm, its potential energy is U. What is the elastic PE if the spring is stretched by 10 cm?

2.7 A, B, C and D are four points on the same vertical line such that AB = BC = CD. If a particle falls freely from rest at A, What is the ration the times taken by it to describe AB, BC and CD?

2.8 A train 100 m long travelling at 40 m/s overtakes another train 200 m long travelling at 30 m/s. What is the time taken by the first train to pass the second?

2.9 An object of mass 5 kg, falls from rest, a vertical distance of 20 m in air and reaches a velocity of 10 m/s. How much work is done by the air on the object? (Take g = 10 m/s)

2.10 A truck of mass 10 000 kg travelling due east at 15m/s collides with a car of mass 1 500 kg travelling north at 25m/s. The wrecked vehicles tangle together after collision. What is the velocity of the wreckage after collision?

2.11 A car covers half distance between two points at 20 km/h and the remaining half at 30 km/h. What is the average speed of the car?

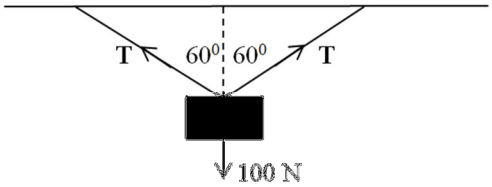
2.12 Two vehicles X and Y are on the same road. X is moving at a constant velocity of 30 $m.s^{-1}$ and Y is at rest and starts with an acceleration of 5 $m.s^{-2}$ as X passes it. How far has X travelled when Y overtakes X? Can be done graphically and by calculation.

2.13 Dale Steyn bowls a standard cricket ball of mass 160g at Ian Bell at a speed of 144 kph. Bell smashes it straight back past Steyn at 108 kph. If the ball is in contact with the bat for 10 ms, what force does Bell's bat exert on the ball?

2.14 A man weighs 1 000 N on the surface of the Earth. What would his weight be on a planet that has half the radius and half the mass as the Earth?

2.15 Two bodies A and B attract each other with a gravitational force of *F* newtons when they are a distance *R* apart. If the mass of A is doubled, the mass of B is tripled and distance between them is doubled, what will the force between A and B now be?

2.16 A 100 N weight is suspended from the centre of a rope as shown below. What is the tension in the rope?



2.17 A ship heads out to sea in still water for a distance of 40 km on a bearing of 90^0. However the captain finds that there is an unknown current that pushes his ship a distance of 30 km on a bearing of 180^0. What is the final displacement of the ship?

2.18 Explain how you can walk a distance of 100 m and have zero displacement when you finish walking?

2.19 A truck is moving at a constant speed of 90 $km{\cdot}h^{-1}$ when it passes a traffic officer, who starts off immediately, from rest, with an acceleration of 4 $m{\cdot}s^{-2}$ to chase the truck. After how long will he catch-up with the truck? How fast is the traffic officer then travelling?

2.20 A stone is dropped into a well in which the water level is h m below the top. If the speed of sound is c and the acceleration due to gravity is g. Show that the time to hear the splash of the stone hitting the water is $T = h\left[\sqrt{\frac{2}{gh}} + \frac{1}{c}\right]$

2.21 Two objects of mass *M* and *m* experience a force of *F* when they are a distance *R* apart. What is the force between them when the mass of both is doubled and the distance is:

a) doubled, and

b) halved?

3 Challenge Problems

3.1 An object of mass **m** is projected downwards with a velocity **u**. It then reaches a velocity v after **t** seconds and a height **h** above the Earth's surface. What is the kinetic energy of the body at this point?

3.2 A, B, C and D are four points on the same vertical line such that AB = BC = CD. If a particle falls freely from rest at A, what is the ratio time taken by it to describe AB, BC and CD?

3.3 The net work done on a car to increase its speed from 0 to *v,* is *W*. What is the net work needed to increase its speed from *v* to 3*v*?

3.4 Two objects, P and Q, have equal momentum. Object P has a mass of 1 kg and object Q has a mass of 4 kg. What is the ratio of their kinetic energies?

3.5 Two bodies of mass M and 4M are moving in a straight line, each with kinetic energy E. What is the ratio of their momenta?

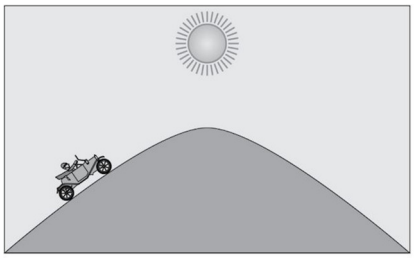
3.6 An object of mass **m** is projected downwards with a velocity *u*. It then reaches a velocity **v** after **t** seconds and a height h above the Earth's surface. What is the kinetic energy of the body at this point?

3.7 Using the principle of conservation of mechanical energy find the velocity with which a body must be projected, vertically upwards, from the Earth's surface, to reach a height of *R* above the Earth's surface. Assume the Earth's mass is *M* and its radius *R*. Neglect air resistance

3.8 A heavy particle of mass M collides elastically with a light particle of mass m. The initial velocity of the heavy particle is *u* and the final velocity is *v*. The light particle is initially at rest. After the collision the light particle goes off in the forward direction with velocity *V*, what fraction of the energy of the heavy particle is lost in the collision?

3.9 A light body and a heavy body have the same momentum. Which one has more kinetic energy?

3.10 This problem was adapted from one sent by Max Wertheimer to his friend Albert Einstein in 1934 – who couldn't do it! An old clattery car is to drive a stretch of 2 km, up and down a hill. Because it is so old, it cannot drive the first km (the ascent) faster than with an average speed of 30 km/h. Question: How fast does it have to drive down the second km to obtain an average speed of 60 km/h for the whole distance? Going down it can go faster of course.

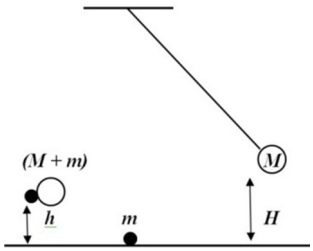


3.11 Two villages "A" and "B", are separated by a mountain and joined by a narrow path. Sipho leaves A at 06:00 and arrives at B at 18:00. The next day he walks back along the same path leaving at 06:00 and arrives at home in village A at 18:00. For both trips he walks at different speeds depending on the terrain. Show there is one place where he is at the same time on the second day as he was on the first.

3.12 A boy drops a rubber ball from a height of 1 m and lets it bounce. If the ball loses 10% of its energy during the bounce, how many bounces will it take before the ball will only rise 0.5 m above the ground?

3.13 A particle is projected vertically upwards at a speed u. It is at a height h after time t and again after time T. Show that the speed u = ½ g (t – T)

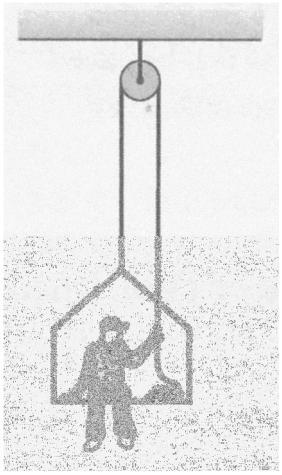
3.14 A pendulum with a bob of mass M is raised to a height H and released. At the bottom of its swing, it picks up a piece of putty whose mass is m. To what height h will the combination $(M + m)$ rise?



3.15 A car of mass 1 200 kg is freewheeling down a road sloping at 30^o to the horizontal and reaches a steady speed of 54 km/h. What is the power of the car's engine if it is travelling along a horizontal road at the same speed and all other conditions are unchanged?

3.16 A stone, of mass m, is thrown from the top of a cliff H metres above a lake at an initial speed of u $m.s^{-1}$ At what angle must it be thrown so that it hits the water at the maximum speed?

3.17 A painter of mass 85 kg is working in a Bosun's Chair, of mass 30 kg, hanging down the side of a tall building, and desires to move up. He pulls down on the rope with such a force that he presses against the chair with a force of 400 N.



a) what is the acceleration of the painter and chair?
b) What is the total force on the pulley?

Richard Feynman