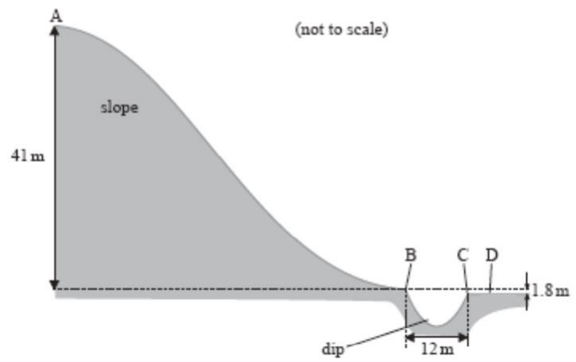
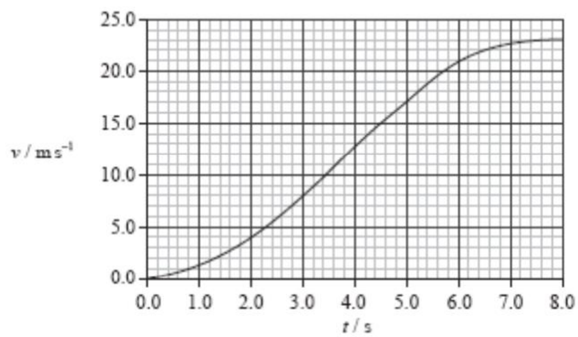
IBDP – Physics – A – sheet 1

Question 1 – 20 marks

At a sports event, a skier descends a slope AB. At B there is a dip BC of width 12m. The slope and the dip are shown in the diagram below. The vertical height of the slope is 41m. The graph adjacent shows the variation with time t of the speed v down the slope of the skier.





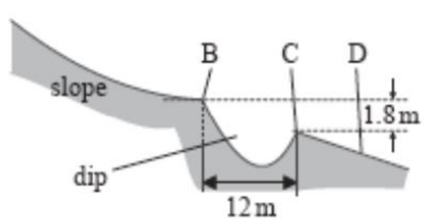
The skier of mass 72 kg, takes 8.0 s to ski, from rest, down the slope AB of the slope.

a. Use the graph to,
   1. Calculate the kinetic energy E_k of the skier at point B. [2]
   2. Determine the length of the slope. [4]

b. 1. Calculate the change ΔE_P in gravitational potential energy of the skier between point A and point B. [2]
   2. Use your answer a and b (1) to determine the average retarding force on the skier between points A and B [3]
   3. Suggest two causes of the retarding forces in b (2) [2]

c. At point B of the slope, the skier leaves the ground. He flies across the dip and lands on the lower side at point D. The lower side C of the dip is 1.8m below the upper side B. Determine the distance CD of the point D from the edge C of the dip. Air resistance may be assumed to be negligible. [4]

d. The lower side of the dip is altered, so that it is inclined to the horizontal as shown in diagram.



   1. State the effect of this on the landing position D. [1]
   2. Suggest the effect of the change on the impact felt by the skier on landing. [2]

a/i $E_K = \frac{1}{2}mv^2$
$= \frac{1}{2} \times 72 \times 23^2$
$= 1.9 \times 10^4$ J

a/ii using area under the curve.
approximating to Δ
distance $= \frac{1}{2} \times b \times h$
$= \frac{1}{2} \times 25 \times 8$
≈ 100 m

b/i $\Delta E_P = mgh$
$= 72 \times 9.8 \times 41$
$= 2.9 \times 10^4$ J

b/ii change in Energy ΔE between A and B
$= 2.9 \times 10^4 - 1.9 \times 10^4$
$= 1.0 \times 10^4$ J
$WD = F \times d \Rightarrow F = \frac{WD}{d} = \frac{1.0 \times 10^4}{100}$
$= 100$ N

b/iii • air resistance
• friction between the skies and slope material.

c $s = ut + \frac{1}{2}gt^2$
$1.8 = 0 + 0.5 \times 9.81 \times t^2$
[vertical speed is zero at B).
$\Rightarrow t = 0.61$ s.

Horizontal speed $= \sqrt{\frac{KE \times 2}{m}}$
$= \sqrt{\frac{1.9 \times 10^4 \times 2}{72}} = 22.97$
distance = speed (Horizonta) × time
$= 22.97 \times 0.61$
$= 14$m
$\therefore$ CD $= 14 - 12 = 2.0$m

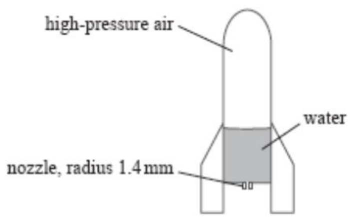
d/i s will be more than 1.8, so t will be more, so range will be more. so D is further from C.

d/ii velocity is not normal to ground, so impact will be less.

Question 2 – 7 marks

a. State the law of conservation of linear momentum. [2]

b. A toy rocket of mass 0.12 kg contains 0.59 kg of water as shown in the diagram below.



The space above the water contains high pressure air. The nozzle of the rocket has a circular cross section of radius 1.4 mm. When the nozzle is opened, water emerges from the nozzle at a constant speed of 18 ms^{-1}. The density of water is 1000 Kgm^{-3}.

1. Deduce that the volume of water ejected per second through the nozzle is 1.1×10^{-4} m^3. [2]
2. Deduce that the upward force that the ejected water exerts on the rocket is approximately 2.0N. Explain your working by reference to Newton's Laws of motion. [4]
3. State why the rocket does not lift off at the instant that the nozzle is opened. [1]

a) The momentum of a system of interacting particles is zero, if the net force acting on the system is zero.

b) i Volume / Second = Cross section area × speed

$= \pi \times (1.4 \times 10^{-3})^2 \times 18$

$= 1.1 \times 10^{-4}$ m^3/s.

b) ii upward force exerted = downward force (as per Newton's 3rd law)

$=$ change in momentum

$= mv$

$= \rho \times V \times 18$

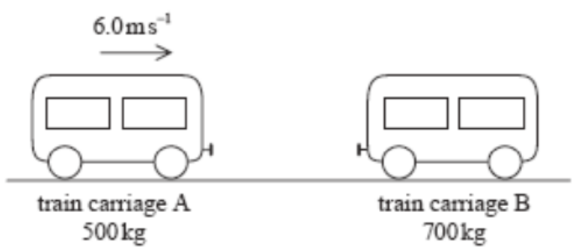
$= 1000 \times 1.1 \times 10^{-4} \times 18$

$= 1.98 \approx 2N$.

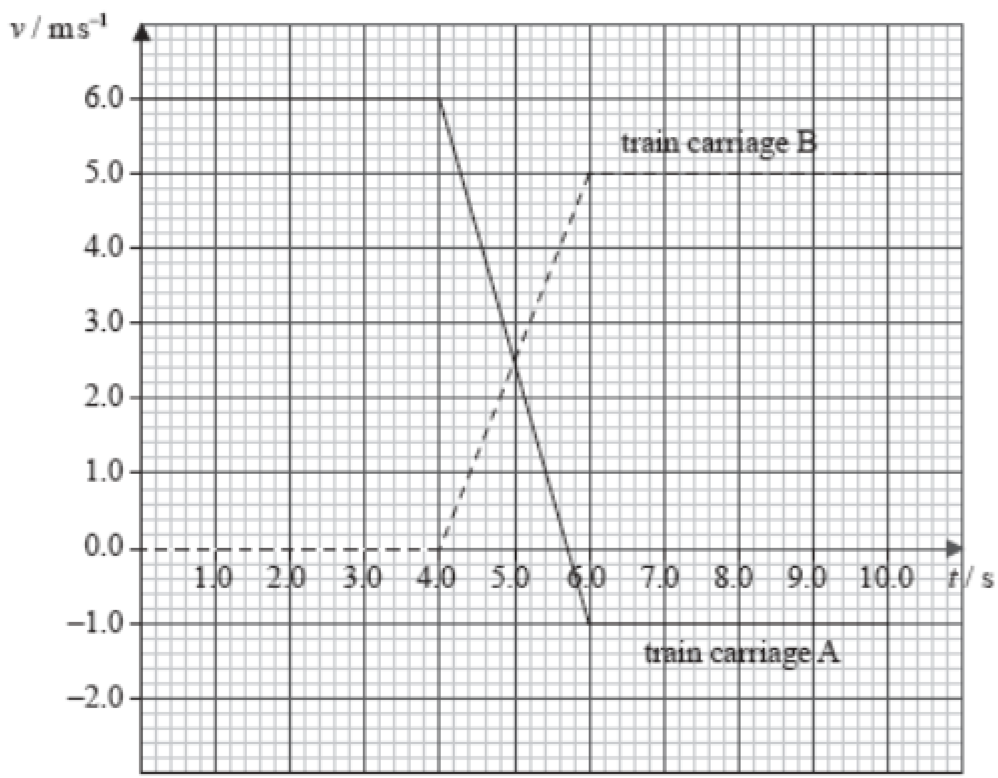
b) iii Weight of rocket and water is more than upward force.

Question 3 – 7 marks

A train carriage A of mass 500 kg is moving horizontally at 6.0 ms^{-1}. It collides with another train carriage B of mass 700 kg that is initially at rest, as shown in the diagram below.



The graph below shows the variation with time t of the velocity of two train carriages, before, during and after the collisions.



a. Use the graph to deduce that

1. The total momentum of the system is conserved in the collision. [2]
2. The collision is elastic. [2]

b. Calculate the magnitude of the average force experienced by train carriage B. [3]

a) i Momentum before collision = $500 \times 6 = 3000 \ kgms^{-1}$

Momentum after the collision = $500 \times (-1) + 700(5)$.

$= 3500 - 500 = 3000 \ kgms^{-1}$

a) ii KE before = $\frac{1}{2}mv^2 = \frac{1}{2} \times 500 \times 6^2 = 9000 \ J$

KE after = $\frac{1}{2} 500 (1)^2 + \frac{1}{2}(700)(5^2) = 9000 \ J$

elastic

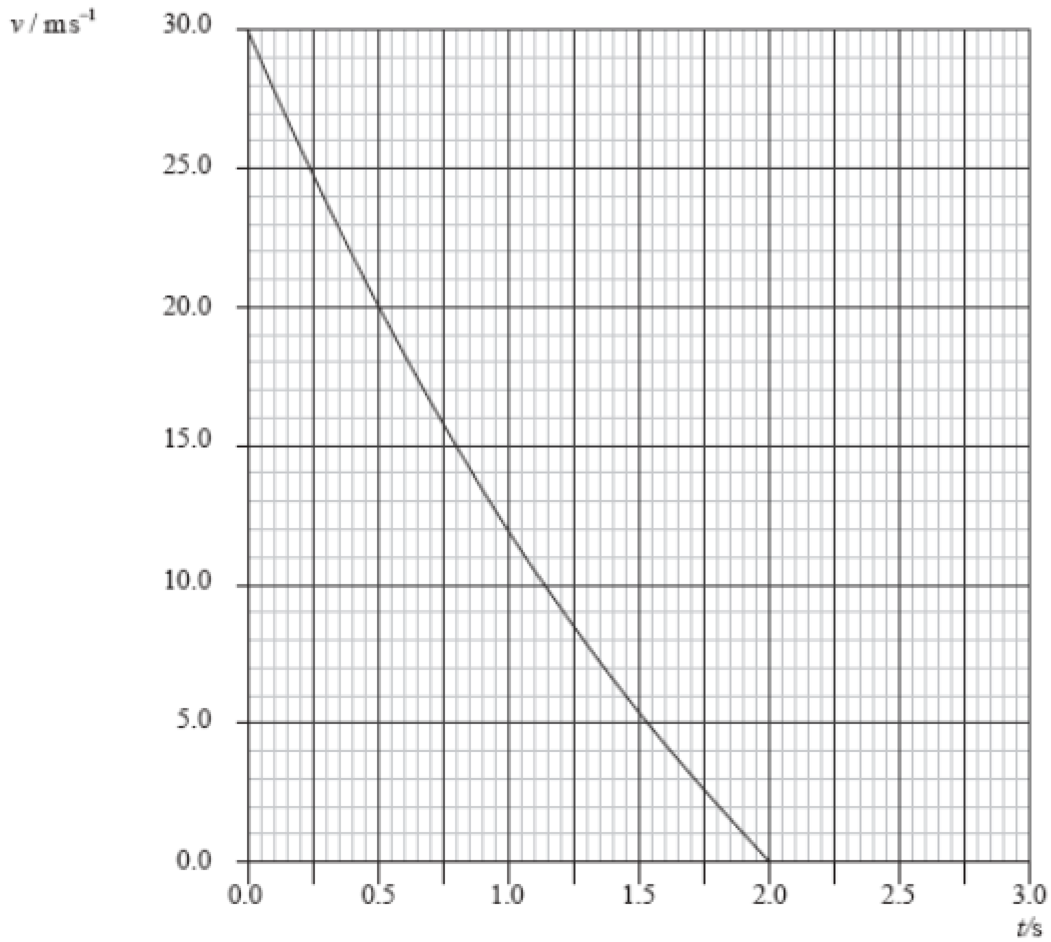
b) Force = $\frac{\Delta p}{t} = \frac{700 \times 5}{2} = 1750 \ N$

$\approx 1800 \ N$ (2sf)

Question 4 – 15 marks

A ball of mass 0.25 kg is projected vertically upwards from the ground with an initial velocity of $30 ms^{-1}$. The acceleration of free fall is $10 \ ms^{-2}$, but air resistance cannot be neglected.

The graph below shows the variation with time t of the velocity v of this ball for the upward part of the motion.



a. State what the area under the graph represents. [1]

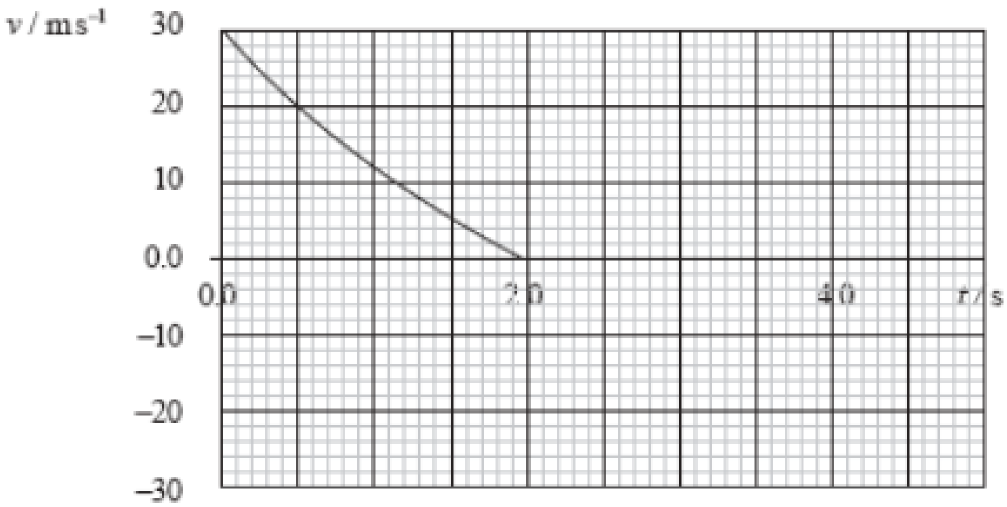
b. Estimate the maximum height reached by the ball. [1]

c. Determine, for the ball at t = 1.0 s,

   1. The acceleration. [3]
   2. The magnitude of the force of air resistance. [2]

d. Use the graph to explain, without further calculation, that the force of air resistance is decreasing in magnitude as the ball moves upward. [2]

e. The diagram below is a sketch of the upward motion of the ball.
   Draw a line to indicate the downward motion of the ball. The line should indicate the motion from the maximum height of the ball until just before it hits the ground. [2]



f. State and explain, by reference to energy transformations, whether the speed with h the ball hits the ground is equal to 30 ms^{-1} [2]

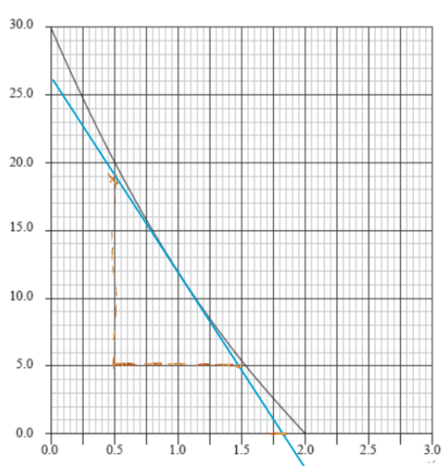
g. Use your answer in (f) to state and explain whether the ball takes 2.0 s to move from its maximum height to the ground. [2]

a| The maximum height reached by the ball.

b) Area of 1 big rectangle = $0.25 \times 5 = 1.25$

∴ Total area = $20 \times 1.25 = 25$ m

c)



i) Slope = $\dfrac{19 - 5}{1.45 - 0.5} = 14.73\ \text{m s}^{-2}$

ii) Fnet, Fair, W

$F_{net} = F_{air} + W$

$ma = F_{air} + mg$.

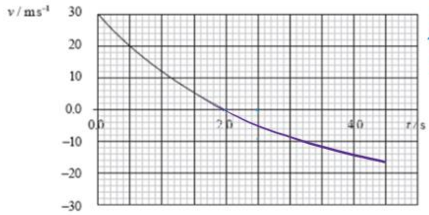
$F_{air} = ma - mg$

$= 0.25(4.73)$

$= 1.18$

≈ 1.2 N.

d) slope is decreasing so the air resistance must decrease e



f It will be less because kinetic energy is being converted into thermal energy of particles of air.

g the average speed on the way down is less hence time will be more.

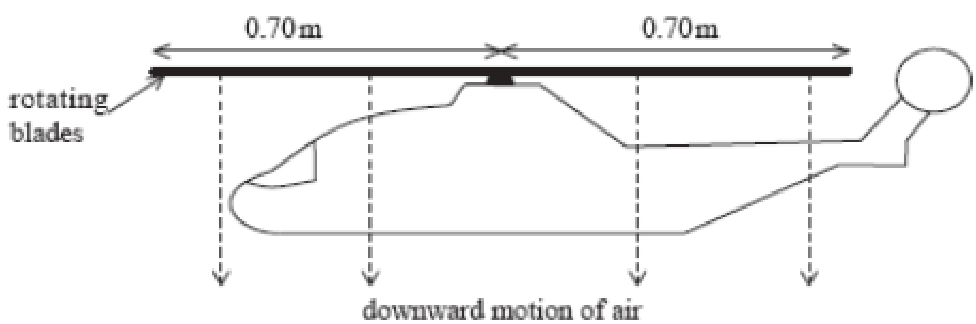
or

area under the graph for upward and downward curve must be same, from the curve shape, it follows that time must be more

Question 5 – 24 marks

a. Explain how Newton's third law leads to the conservation of momentum in the collision between two objects in an isolated system. [4]

b. The diagram illustrates a model helicopter that is hovering in a stationary position.



The rotating blades of the helicopte force a column of air to move downwards. Explain how this may enable the helicopter to remain stationary. [3]

c. The length of each blade of the helicopter in (b) is 0.70m. Deduce that the area that the blades sweep out as they rotate is 1.5 m^2. (Area of a circle = Πr^2) [1]

d. For the hovering helicopter in (b), it is assumed that air beneath the blades is pushed vertically dwnwards with the same speed of 4.0 ms^{-1}. No other air is disturbed.
The density of the air is 1.2 $kgm^{-3.}$
Calculate, for the air moved downwards by the rotating blades,
1. The mass per second. [2]

2. The rate of change of momentum. [1]

e. State the magnitude of the force that the air beneath the blades exerts on the blades. [1]

f. Calculate the mass of the helicopter and its load. [2]

g. In order to move forward, the helicopter blades are made to incline at an angle θ to the horizontal as shown schematically below.

While moving forward , the helicopter does not move vertically up or down. In the space provided below, draw a free body force diagram that shows the forces acting on the helicopter blades at the moment that the helicopter starts to move forward. On your diagram, label the angle θ. [4]

h. Use your diagram in (g) to explain why a forward force F now acts on the helicopter and deduce that the initial acceleration a of the helicopter is given by : a = g tan θ. [5]

i. The helicopter is driven by an engine that has a useful power output of 9.0×10^2 W. The engine makes 300 revolutions per second. Deduce that the work done in one cycle is 3.0 J. [1]

a) In an isolated system, According to Newton's third law. forces they exert during collision is equal in magnitude and opposite in direction

$\Rightarrow F_1 = -F_2$.

$\Rightarrow \frac{\Delta p_1}{\Delta t} = \frac{-\Delta p_2}{\Delta t}$

$\Rightarrow \Delta p_1 + \Delta p_2 = 0$.

b) According to Newton's law, there will be equal and opposite force in upward direction against the downward force exerted by air.

This upward force will balance the downward force due to weight which enables the helicopter to remain stationary.

c) area $= \pi r^2$
$= \pi (0.7)^2 = 1.5\ m^2$.

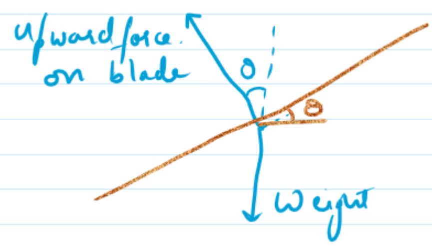
d i) mass per second $= 1.2 \times \dfrac{1.5 \times 4}{1\ \text{second}} = 7.2\ kg\ s^{-1}$
$\{\rho = \frac{m}{V},\ m = \rho \times V\}$

d ii) $\dfrac{\Delta p}{t} = \dfrac{7.2 \times 4}{1} = 29\ N$.

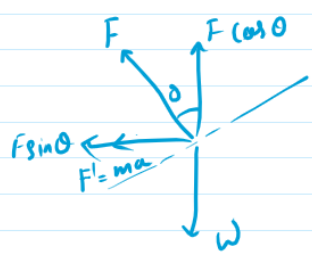
e $F = \dfrac{\Delta p}{\Delta t} = 29\ N$

f $F = mg \quad m = \dfrac{F}{g} = \dfrac{29}{9.81} = 2.95 \approx 3\ kg$.

g



h)



$W = F\cos\theta$
$mg = F\cos\theta \Rightarrow F = \dfrac{mg}{\cos\theta}$
$F' = ma = F\sin\theta$
$\Rightarrow ma = \dfrac{mg}{\cos\theta}\sin\theta$
$\Rightarrow a = g\tan\theta$

i $P = \dfrac{WD}{t}$ → in one cycle $t = T$.
$\Rightarrow P = \dfrac{WD}{T}$ → for T, $f = 300$ $T = \frac{1}{300}$
$\Rightarrow WD = P \times T = 9 \times 10^2 \times \dfrac{1}{300} = 3.0\ J$.

Question 6 – 9 marks

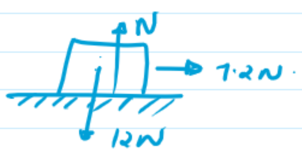
a. State two factors that affect the frictional force between surfaces in contact. [2]
b. Distinguish between static friction and dynamic friction. [3]
c. A block of wood of weight 12N is at rest on a flat, horizontal surface. The minimum horizontal force required to move the block is 7.2 N. Calculate the coefficient of static friction between the block and the surface. [1]
d. The force of 7.2 N is applied continuously to the block. Explain whether the block will accelerate or move with constant speed. [3]

a
- Nature of the surface.
- Relative motion between the surfaces.

b
Friction force is force between two objects. When the two objects are at rest, then friction force between them is static friction.

When the two objects are in relative motion with respect to each other, then the friction force between them is dynamic.

c



$f = \mu N$

$7.2 = \mu\, 12$

$\mu = \frac{7.2}{12} = 0.6$

d
Once the blocks starts moving, coefficient of dynamic friction comes into picture and $\mu_d < \mu_s$.

$\Rightarrow$ frictional force < 7.2

$\Rightarrow$ Net force greater than zero is acting on the block.

$\Rightarrow$ the block will accelerate.

References:

Physics course companion – Oxford

IB physics HL – Pearson