



# VCE PHYSICS UNITS 3&4 [2020]

Unit 3 AOS 3 - How fast can things go? - Topic Exam 1

**YOUR NAME:** Vishnu Prasad Sivakumar

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## STRUCTURE OF EXAM

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Section A - Short Answer

10 questions

39 marks

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**39 marks**

## WHEN YOU FINISH

Get your marks, and view solution videos that explain the answer to each question at:

**[edrolo.com.au/e2815](https://edrolo.com.au/e2815)**

**SECTION A – SHORT ANSWER****Question 1** (4 marks)

A package of mass  $1.2\text{ kg}$  is sliding down an initially smooth slope angled at  $35^\circ$  to the horizontal. It encounters a rough surface on the slope which provides a constant friction force of  $10\text{ N}$  until the package stops. Assume that there is no air resistance.

**Question 1.a**

2 marks

Calculate the size of the net force acting on the package on the rough surface.

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**Question 1.b**

2 marks

How far will the package slide on the rough surface if the speed at which it first meets it is  $14\text{ m/s}$ ?

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**Question 2**

3 marks

In the diagram below  $m_1$  has been pushed and then released so that it is moving at  $4\text{ m/s}$  to the right. The moment of release is  $t = 0$ . At what time will the block  $m_1$  return to the same location as it started, assuming no air resistance and that the surface is smooth.



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**Question 3** (4 marks)

Engineers are designing a curve on a high-speed railway track. To prevent excessive wear and for the comfort of passengers, it is important that the track be correctly banked so that there are no sideways forces between the rail and the wheel of the train. This is shown in Figures 4a and 4b.

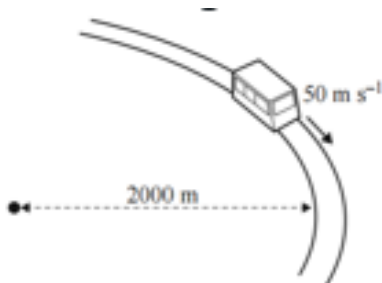


Figure 4a



Figure 4b

The radius of the curve is 2000 m and the speed of the train is a constant  $50 \text{ m s}^{-1}$ .

**Question 3.a**

2 marks

On Figure 4b, draw two arrows to show external forces acting on the train and a third arrow, marked  $F_{\text{net}}$ , to show the net force on the train.

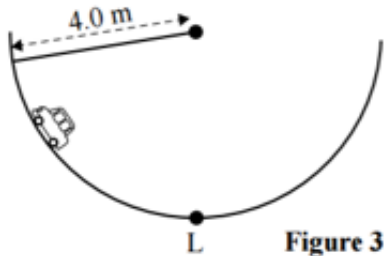
**Question 3.b**

2 marks

Calculate the correct angle of bank ( $\theta$ ) for the track to the horizontal for there to be no sideways force on the wheels by the track. Show the steps of your working

**Question 4** (3 marks)

A model car of mass  $2.0\text{ kg}$  is on a track that is part of a vertical circle of radius  $4.0\text{ m}$ , as shown in Figure 3. At the lowest point, L, the car is moving at  $6.0\text{ m s}^{-1}$ . Ignore friction.

**Figure 3****Question 4.a**

1 mark

At the lowest point (L), draw the resultant force acting on the car as an arrow attached to the car, labelled  $F_R$ .

**Question 4.b**

2 marks

Calculate the magnitude of the force exerted by the track on the car at its lowest point (L). Show your working.

**Question 5** (5 marks)

Figure 3 shows an experiment in which a frictionless trolley,  $m_1$ , of mass  $2.0\text{ kg}$ , moving to the right at  $6.0\text{ m s}^{-1}$ , collides with and sticks to an initially stationary trolley,  $m_2$ , of mass  $4.0\text{ kg}$  and also frictionless.

**Figure 3**

**Question 5.a**

1 mark

Calculate the magnitude of the total momentum of the two trolleys when they stick together after the collision

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**Question 5.b**

2 marks

Determine, by using calculations, whether this collision is elastic or inelastic

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**Question 5.c**

2 marks

Calculate the magnitude and direction of the impulse exerted on  $m_1$  by  $m_2$  during the collision.

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**Question 6** (3 marks)

A hunter sets up a target at the same height as her firing position 200 metres away. This target is an iron can attached to an electromagnet. The electromagnet is designed so that as soon as the round is fired it will release the iron can which will then fall vertically.

**Question 6.a** (1 mark)

Ignoring the effects of air resistance, select the best response from the options below as to where the hunter should aim.

- A** Slightly above the can
- B** Directly at the can
- C** Slightly below the can

**Question 6.b**

2 marks

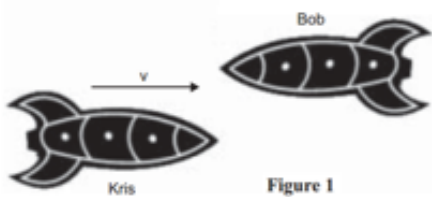
Explain your answer to part a.

**Question 7**

2 marks

Two space travellers, Kris and Bob, are in rocket ships that are travelling towards each other with a relative velocity,  $v$ , that is close to the speed of light.

They agree to measure the length of Kris's rocket ship using two different methods. Kris measures her ship with a metre stick, and gets a value of  $L$ .



Bob starts his watch as the front of Kris's rocket ship reaches him, and stops it as the rear passes him. The time interval he measures is  $\Delta t$ . He calculates the length of Kris's rocket ship as  $L' = v \Delta t$ . Although both measurements  $L$  and  $L'$  are correct, one of them is known as the 'proper' length.

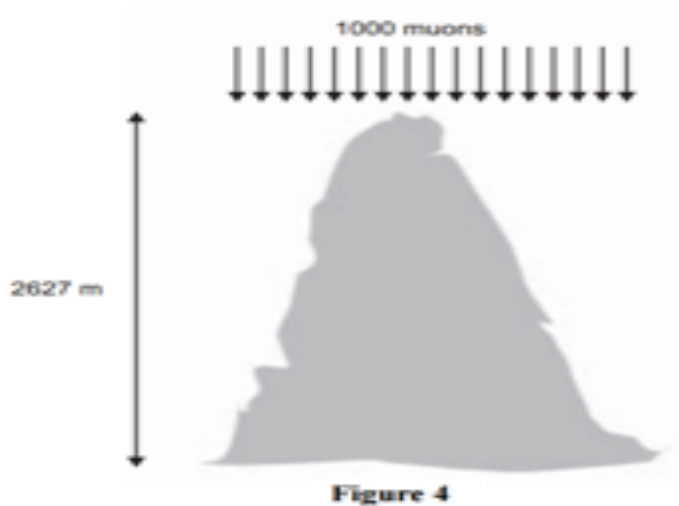
In the space below indicate which one is the proper length, and explain why this is so.

**Question 8** (7 marks)

Muons are elementary particles created in the upper atmosphere by cosmic rays. They are unstable, and decay with a half-life of  $2.2\ \mu\text{s}$  ( $2.2 \times 10^{-6}\ \text{s}$ ) when measured at rest. This means that in the reference frame of the muons, half of them decay in each time interval of  $2.2\ \mu\text{s}$ .

In an experiment, 1000 muons with a velocity of  $0.995c$  were observed to pass the top of a mountain of height 2627 m. Experimenters measured the number of these reaching ground level.

The experimenters calculated the time that a muon would take to travel from the top of the mountain to the ground. The calculated value was much longer than the muon half-life.



Thus the experimenters expected that only a few muons should reach the ground. In fact they detected many more than expected. The reason for the difference is that, relative to the experimenters, the muons were moving at close to the speed of light, and their half-life, as measured by the experimenters, increased.

From their reference frame, the muons see the ground rushing upwards at a speed of  $0.995c$ .

**Question 8.a**

2 marks

Calculate the lifetime of the moving muons, as measured from the ground.

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**Question 8.b**

3 marks

What would be the height of the mountain as measured by the muons?

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**Question 8.c**

2 marks

At what speed would an object have to be moving for a change of 1% in its length to be observed?

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**Question 9** (5 marks)

In a toy rifle, a ball is forced to compress a spring by 8 cm and then released when the trigger is pulled. This ball has a mass of 15 g and leaves the spring as the gun is fired at a speed of 26 m/s.

**Question 9.a**

3 marks

Assuming all of the energy stored in the spring is transferred into the kinetic energy of the ball, calculate the spring constant of the spring.

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**Question 9.b**

2 marks

If this ball was fired horizontally from a height of 7.5 m and air resistance was ignored, at what speed would the ball strike the ground?

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**Question 10**

3 marks

A rocket is travelling extremely quickly in the upper atmosphere. If it has a rest mass of 130 kg and travels at a speed of  $2.72 \times 10^8$  m/s, calculate the total 'mass-energy' of the rocket.

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