

1. [In this question, the unit vectors \mathbf{i} and \mathbf{j} are horizontal vectors due east and north respectively.]

At time $t = 0$, a football player kicks a ball from the point A with position vector $(2\mathbf{i} + \mathbf{j})$ m on a horizontal football field. The motion of the ball is modelled as that of a particle moving horizontally with constant velocity $(5\mathbf{i} + 8\mathbf{j})$ m s⁻¹. Find

(a) the speed of the ball, (2)

(b) the position vector of the ball after t seconds. (2)

The point B on the field has position vector $(10\mathbf{i} + 7\mathbf{j})$ m.

(c) Find the time when the ball is due north of B . (2)

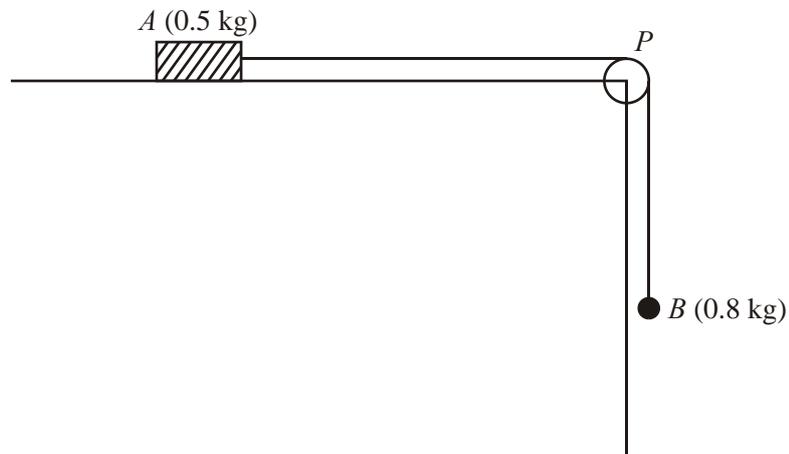
At time $t = 0$, another player starts running due north from B and moves with constant speed v m s⁻¹. Given that he intercepts the ball,

(d) find the value of v . (6)

(e) State one physical factor, other than air resistance, which would be needed in a refinement of the model of the ball's motion to make the model more realistic. (1)

(Total 13 marks)

2.

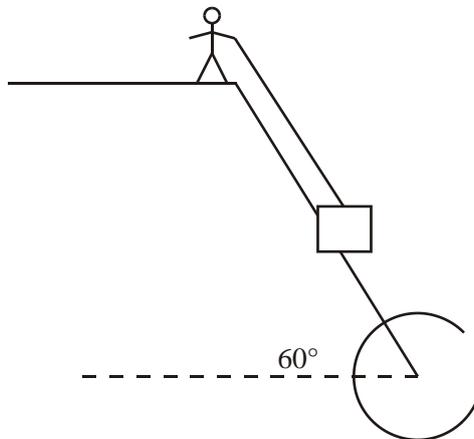


A block of wood A of mass 0.5 kg rests on a rough horizontal table and is attached to one end of a light inextensible string. The string passes over a small smooth pulley P fixed at the edge of the table. The other end of the string is attached to a ball B of mass 0.8 kg which hangs freely below the pulley, as shown in the diagram above. The coefficient of friction between A and the table is μ . The system is released from rest with the string taut. After release, B descends a distance of 0.4 m in 0.5 s . Modelling A and B as particles, calculate

- (a) the acceleration of B , (3)
- (b) the tension in the string, (4)
- (c) the value of μ . (5)
- (d) State how in your calculations you have used the information that the string is inextensible. (1)

(Total 13 marks)

3.



A heavy package is held in equilibrium on a slope by a rope. The package is attached to one end of the rope, the other end being held by a man standing at the top of the slope. The package is modelled as a particle of mass 20 kg. The slope is modelled as a rough plane inclined at 60° to the horizontal and the rope as a light inextensible string. The string is assumed to be parallel to a line of greatest slope of the plane, as shown in the diagram above. At the contact between the package and the slope, the coefficient of friction is 0.4.

- (a) Find the minimum tension in the rope for the package to stay in equilibrium on the slope.

(8)

The man now pulls the package up the slope. Given that the package moves at constant speed,

- (b) find the tension in the rope.

(4)

- (c) State how you have used, in your answer to part (b), the fact that the package moves

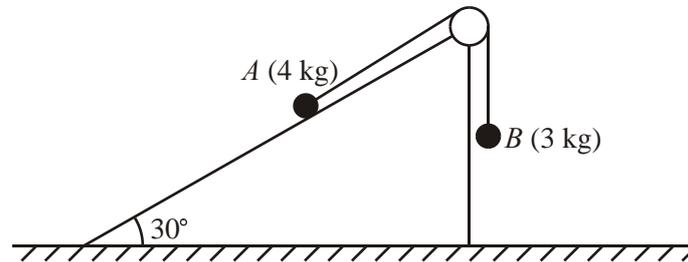
(i) up the slope,

(ii) at constant speed.

(2)

(Total 14 marks)

4.



A particle A of mass 4 kg moves on the inclined face of a smooth wedge. This face is inclined at 30° to the horizontal. The wedge is fixed on horizontal ground. Particle A is connected to a particle B , of mass 3 kg , by a light inextensible string. The string passes over a small light smooth pulley which is fixed at the top of the plane. The section of the string from A to the pulley lies in a line of greatest slope of the wedge. The particle B hangs freely below the pulley, as shown in the diagram above. The system is released from rest with the string taut. For the motion before A reaches the pulley and before B hits the ground, find

- (a) the tension in the string, (6)
- (b) the magnitude of the resultant force exerted by the string on the pulley. (3)
- (c) The string in this question is described as being 'light'.
- (i) Write down what you understand by this description.
- (ii) State how you have used the fact that the string is light in your answer to part (a). (2)

(Total 11 marks)

5. A competitor makes a dive from a high springboard into a diving pool. She leaves the springboard vertically with a speed of 4 m s^{-1} upwards. When she leaves the springboard, she is 5 m above the surface of the pool. The diver is modelled as a particle moving vertically under gravity alone and it is assumed that she does not hit the springboard as she descends. Find

(a) her speed when she reaches the surface of the pool,

(3)

(b) the time taken to reach the surface of the pool.

(3)

(c) State two physical factors which have been ignored in the model.

(2)

(Total 8 marks)

6. A ball is projected vertically upwards with a speed $u \text{ m s}^{-1}$ from a point A which is 1.5 m above the ground. The ball moves freely under gravity until it reaches the ground. The greatest height attained by the ball is 25.6 m above A .

(a) Show that $u = 22.4$.

(3)

The ball reaches the ground T seconds after it has been projected from A .

(b) Find, to 2 decimal places, the value of T .

(4)

The ground is soft and the ball sinks 2.5 cm into the ground before coming to rest. The mass of the ball is 0.6 kg. The ground is assumed to exert a constant resistive force of magnitude F newtons.

(c) Find, to 3 significant figures, the value of F .

(6)

(d) State one physical factor which could be taken into account to make the model used in this question more realistic.

(1)

(Total 14 marks)

7.



A plank AB has length 4 m. It lies on a horizontal platform, with the end A lying on the platform and the end B projecting over the edge, as shown above. The edge of the platform is at the point C .

Jack and Jill are experimenting with the plank. Jack has mass 40 kg and Jill has mass 25 kg. They discover that, if Jack stands at B and Jill stands at A and $BC = 1.6$ m, the plank is in equilibrium and on the point of tilting about C . By modelling the plank as a uniform rod, and Jack and Jill as particles,

(a) Find the mass of the plank.

(3)

They now alter the position of the plank in relation to the platform so that, when Jill stands at B and Jack stands at A , the plank is again in equilibrium and on the point of tilting about C .

(b) Find the distance BC in this position.

(5)

(c) State how you have used the modelling assumptions that

- (i) the plank is uniform,
- (ii) the plank is a rod,
- (iii) Jack and Jill are particles.

(3)

(Total 11 marks)

1. (a) Speed of ball = $\sqrt{(5^2 + 8^2)} \approx \underline{9.43 \text{ m s}^{-1}}$ M1 A1 2
M1 Valid attempt at speed (square, add and squ. root cpts)
- (b) p.v. of ball = $(2\mathbf{i} + \mathbf{j}) + (5\mathbf{i} + 8\mathbf{j})t$ M1 A1 2
M1 needs non-zero p.v. + (attempt at veloc vector) x t. Must be vector
- (c) North of B when \mathbf{i} components same, i.e. $2 + 5t = 10$ M1
 $t = \underline{1.6 \text{ s}}$ A1 2
- (d) When $t = 1.6$, p.v. of ball = $10\mathbf{i} + 13.8\mathbf{j}$ (or \mathbf{j} component = 13.8) M1 A1
 \downarrow
 Distance travelled by 2nd player = $13.8 - 6 = 6.8$ M1 A1
 \downarrow
 Speed = $6.8 \div 1.6 = \underline{4.25 \text{ m s}^{-1}}$ M1 A1 6
 or $[(2 + 5t)\mathbf{i} + (1 + 8t)\mathbf{j}] = [10\mathbf{i} + (7 + vt)\mathbf{j}]$ M1 A1
(pv's or j components same)
 \downarrow
 Using $t = 1.6$: $1 + 12.8 = 7 + 1.6v$ (equn in v only) M1 A1
 \downarrow
 $v = \underline{4.25 \text{ m s}^{-1}}$ M1 A1
2nd M1 – allow if finding displacement vector (e.g. if using wrong time)
3rd M1 for getting speed as a scalar (and final answer must be as a scalar). But if they get e.g. '4.25j', allow M1 A0
- (e) Allow for friction on field (i.e. velocity of ball not constant) B1 1
 or allow for vertical component of motion of ball
Allow 'wind', 'spin', 'time for player to accelerate', size of ball
Do not allow on their own 'swerve', 'weight of ball'.

[13]

2. (a) ' $s = ut + \frac{1}{2}at^2$ ' for B: $0.4 = \frac{1}{2}a(0.5)^2$ M1 A1
 $a = \underline{3.2 \text{ m s}^{-2}}$ A1 3
- (b) N2L for B: $0.8g - T = 0.8 \times 3.2$ M1 A1ft
 \downarrow
 $T = \underline{5.28 \text{ or } 5.3 \text{ N}}$ M1 A1 4
- (c) A: $F = \mu \times 0.5g$ B1

N2L for A: $T - F = 0.5a$

Sub and solve $\mu = \underline{0.75 \text{ or } 0.751}$

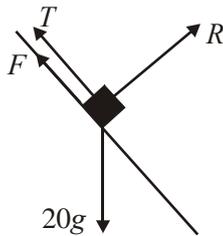
M1 A1
↓
M1 A1 5

(d) Same acceleration for A and B.

B1 1

[13]

3. (a)



R(perp. to slope): $R = 20g \cos 60 (= 10g = 98 \text{ N})$

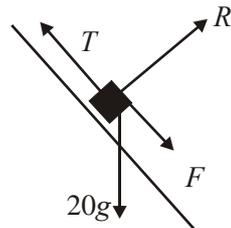
$F = 0.4R$ (used)

R(parallel to slope): $T + F = 20g \cos 30$

$T = 10\sqrt{3}g - 4g \approx \underline{131 \text{ or } 130 \text{ N}}$

M1 A1
B1
M1 A2, 1, 0
↓
M1 A1 8

(b)



$R = 10g$ as before

$T - 0.4R = 20g \cos 30$

$T = 10\sqrt{3}g + 4g \approx \underline{209 \text{ or } 210 \text{ N}}$

B1 ft
M1 A1
A1 4

(c) (i) Friction acts down slope (and has magnitude $0.4R$)

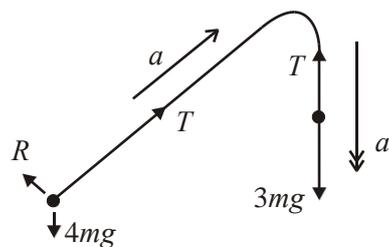
B1

(ii) Net force on package = 0 (or equivalent), or 'no acceleration'

B1 2

[14]

4. (a)



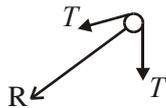
A: $T - 4g \sin 30 = 4a$

B: $3g - T = 3a$

$\Rightarrow T = \frac{18g}{7} = \underline{25.2 \text{ N}}$

M1 A1
M1 A1
M1 A1 6

(b)



$$R = 2T \cos 30$$

$$\approx \underline{44 \text{ or } 43.6 \text{ N}}$$

M1 A1
A1 3

(c) (i) String has no weight/mass

B1

(ii) Tension in string constant, i.e. same at A and B

B1 2

[11]

5. (a) “ $v^2 = u^2 + 2as$ ”: $v^2 = 4^2 + 2 \times g \times 5$
 $v \approx 10.7 \text{ m s}^{-1}$ (accept 11 m s^{-1})

M1 A1
A1 3

(b) “ $v = u + at$ ”: $-10.7 = 4 - gt$
 $t = \frac{14.7}{g} = 1.5 \text{ s}$

M1 A1 ft
A1 3

(c) Air resistance; ‘spin’; height of diver;
hit board again or horizontal component of velocity (any two)

B1 B1 2

[8]

6. (a) $v^2 = u^2 + 2as$: $0 = u^2 - 2 \times 9.8 \times 25.6$
 $u^2 = 501.76 \Rightarrow u = 22.4$ (*)

M1 A1
A1cso 3

(b) $-1.5 = 22.4T - 4.9T^2$
 $4.9T^2 - 22.4T - 1.5 = 0$
 $T = \frac{22.4 \pm \sqrt{22.4^2 + 4 \times 1. \times 4.9}}{9.8}$
 $= 4.64 \text{ s}$

M1 A1
M1
A1 4

(c) Speed at ground $v = 22.4 - 9.8 \times 4.64$
 $v = -23.07$
(or $v^2 = 22.4^2 + 2 \times 9.8 \times 1.5$, $v = 23.05$)
 $v^2 = u^2 + 2as$: $0 = 23.07^2 + 2 \times a \times 0.025$
($\rightarrow a = -10644.5$)
 $F - 0.6g = 0.6a$
 $F = 6390 \text{ N}$ (3 sf)

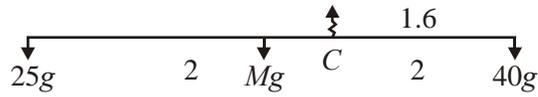
M1
A1
M1 A1 ft
M1
A1 6

(d) Air resistance; variable F ;

B1 1

[14]

7. (a)



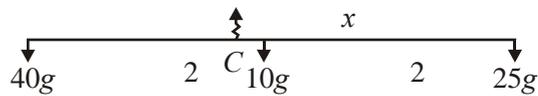
$$M(C) \quad 40g \cdot 1.6 = Mg \cdot 0.4 + 25g \cdot 2.4$$

$$\Rightarrow M = 10 \text{ kg}$$

M1 A1

A1 3

(b)



$$M(C) \quad 25g \cdot x + 10g \cdot (x - 2) = 40g \cdot (4 - x)$$

$$\Rightarrow 75x = 180$$

$$\Rightarrow x = 2.4 \text{ m}$$

M1 A1 A1

M1 A1 5

(c) (i) Weight acts at centre of plank

B1

(ii) Plank remains straight

B1

(iii) Weights act at the ends of the plank

B1 3

[11]

1. The question proved again to be a good discriminator. The calculations involved were relatively simple, though a correct solution did require a proper understanding of the physical situation. Part (a) was generally well done, though not universally: some evidently did not know the meaning of the word 'speed'. Part (b) was mostly correct. In part (c) a significant minority equated the \mathbf{j} components, rather than the \mathbf{i} components. In part (d), many got to the end result, apparently correctly, though the working presented often proved to be very challenging to decipher. Others used the wrong vectors or distances involved. In part (e) presentation was again somewhat inadequate, with some effectively stating one of the assumptions (e.g. the field being smooth), rather than saying that the opposite would be a factor needing to be taken into account (i.e. friction). Again some relevant responses were given, but also a number of irrelevant (or unclear) ones.
2. This question was generally well answered and it was pleasing to see candidates being able to write down equations of motion for the two particles separately. Mistakes from weaker candidates arose from sometime including the weight of A in the (horizontal) equation of motion for A , or confusing the two particles and the forces acting on them. Most realised that they had to use the given data to solve part (a) though a few launched straight into writing down the equations of motion and then floundering when they did not have enough information to solve these. Answers to part (d) were almost uniformly incorrect: the vast majority stated that the inextensibility of the string meant that the tensions were the same (or constant throughout the string).
3. This proved to be the most discriminating question on the paper and not so many fully correct answers were seen. A common mistake in part (a) was to assume that the friction was acting down, rather than up, the slope for the minimum force. Several then went on to repeat the same working in part (b) (which was of course then correct). Several too failed to round their answers to an appropriate degree of accuracy (having used g as 9.8, they should have given their answers to no more than 3 significant figures). Explanations in part (c) were fair, with answers to (ii) better than answers to (i). In the latter case, it was often not clear from the statement written what exactly was being asserted: a succinct statement is all that is required – but it must be clear!
4. This type of connected particle question seemed to be much more familiar to many, and hence part (a) was generally well done: most could write down two equations of motion and solve them successfully. Some however failed to realise that the weight of A needed resolving when considering the motion up/down the slope. Very few however realised what was required in part (b). Again the fact that the tensions at the different ends of the string were the same in magnitude did not seem to be appreciated, so that quite a few appeared to think that the resultant force on the pulley was made up of the components of the two weights; others simply assumed that the two tensions were acting perpendicular to each other. A number who realised what to do also lost a mark by failing to round their answer to no more than 3 significant figures. In part (c), most realised that a 'light' string is one that has no weight/mass; but very few realised what the implications of this were for the equations they had written down earlier, viz. that the tension in the string remained constant throughout its length.
5. The equations for constant acceleration were well known and generally applied appropriately.

Mistakes did however tend to arise with candidates failing to allow for the different directions of motion at different stages so that the sign used with the velocity had to be carefully taken into consideration. A significant number of candidates also insisted on making the question quite a lot longer than necessary by splitting the motion up into separate parts (e.g. to the highest point and then down) and doubling (or more) the number of calculations required. Some candidates also lost a mark by failing to round their answers 'appropriately', i.e. by giving their answer to 2 or 3 significant figures where they had used g as 9.8. In part (c) an appeal to air resistance was frequently correctly given, though quite a number also incorrectly stated that the mass/weight of the diver had been ignored in the model.

6. Part (a) was generally well done, though weaker candidates tended to make mistakes with the signs and then ended up having to take the square root of a negative number. In part (b), there were often sign errors and/or failure to appreciate the final vertical displacement from the initial position (some took this to be the total distance travelled, both up and down). Others split the motion up into two parts, finding the time to the highest point and then the time down. Some though simply found the time for one part of the motion only. Part (c) proved to be much more demanding. Several used the value 22.4 still for the initial speed in this part of the motion. A failure to convert 2.5 cm into metres was not uncommon; and almost all failed to take any account of the weight in writing down the equation of motion to find the resistive force.

7. No Report available for this question.