****

**UNUSED ORIGINAL**

**Answer ALL questions. Write your answers in the spaces provided.**

**1** A van of mass 750 kg is moving up a straight road inclined at an angle *β* to the

horizontal, where sin *β* = . At the instant when the speed of the van is *v* m s–1, the

resistance to the motion of the van from non‑gravitational forces is modelled as a force

of magnitude *λv* newtons, where *λ* is a constant. When the engine of the van is working

at a constant rate of 13 kW, the van moves up the road at a constant speed of 20 m s–1.

(*a*) Show that *λ* = 15

**(4)**

Later on, the van is moving along a straight horizontal road. At the instant when the

speed of the van is *v* m s–1, the resistance to the motion of the van is modelled as a force

of magnitude 15*v* newtons. When the engine of the van is working at a constant rate

of 11.25 kW, the speed of the van is *U* m s–1 and the acceleration of the van is 0.1 m s–2.

(*b*) Find the value of *U*.

**(4)**

**(Total for Question 1 is 8 marks)**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**2** A small box is projected with speed 7 m s–1 from a point *O* on a fixed rough inclined plane. The

plane is inclined to the horizontal at an angle *α*, where tan *α* = . The box moves up a line of

greatest slope of the plane and comes to instantaneous rest at the point *A*. The coefficient of

friction between the box and the plane is . In a model of the motion, the box is modelled

as a particle.

(*a*) Show that, after coming to rest at *A*, the box immediately slides back down the plane.

**(2)**

The speed of the box at the instant when it returns to *O* is *V* m s–1.

Given that *OA* = m,

(*b*) use the work‑energy principle to find the value of *V*.

**(4)**

(*c*) Suggest one way in which the model can be refined to make it more realistic.

**(1)**

**(Total for Question 2 is 7 marks)**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**3** A particle of mass 0.5 kg is moving with velocity (–**i** + 2**j**) m s–1 when it receives an

impulse **I** N s. As a result of the impulse, the kinetic energy of the particle increases by 12 J.

Given that **I** acts in the direction of (2**i** – **j**), find **I**.

**(7)**

**(Total for Question 3 is 7 marks)**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**4** Two smooth spheres, *A* and *B*, of the same radius, have masses 2*m* and 3*m* respectively.

The spheres are at rest on a smooth horizontal plane. Sphere *A* is projected towards *B* with

speed *u* and collides directly with *B*. The coefficient of restitution between the spheres is *e*,

where *e* > 

(*a*) Find, in terms of *u* and *e*,

 (i) the speed of *A* immediately after the collision,

 (ii) the speed of *B* immediately after the collision.

**(7)**

(*b*) Describe the direction of motion of *A* immediately after the collision, justifying your

 answer.

**(1)**

Given that *e* = 

(*c*) find the total kinetic energy lost in the collision between *A* and *B*.

**(4)**

**(Total for Question 4 is 12 marks)**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**5**

****

Two smooth uniform spheres, *P* and *Q*, with equal radii, are moving on a smooth

horizontal plane when they collide. Sphere *P* has mass 4*m* and sphere *Q* has mass

5*m*. Immediately before they collide, both spheres are moving with the same speed

at an angle *α*, 0° < *α* < 90°, to the line joining their centres. Immediately after they

collide, *Q* moves at an angle *θ* to the line joining their centres, as shown in Figure 1.

The coefficient of restitution between the spheres is *e*.

(*a*) Show that



**(10)**

Given that immediately after the collision, *Q* moves in a direction that is perpendicular to

the line of centres and that *α* = 45°

(*b*) (i) find the value of *e*,

 (ii) find the direction of motion of *P* immediately after the collision.

**(4)**

(*c*) Explain how you have used the fact that the two spheres have equal radii in your

 solution to part (*a*).

**(1)**

**(Total for Question 5 is 15 marks)**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**6** Two fixed points, *A* and *B*, lie on a horizontal ceiling with *AB* = 6*a*. A light elastic string

of modulus of elasticity has one end attached to *A* and the other end attached to *B*.

A particle *P* of mass 4*m* is attached to the midpoint of the string and *P* hangs in equilibrium

at a distance 4*a* below *AB*.

(*a*) Show that the natural length of the string is 4*a*.

**(5)**

The particle *P* is now held at the midpoint of *AB* and released from rest.

(*b*) Find the maximum speed of *P* as it falls.

**(6)**

**(Total for Question 6 is 11 marks)**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**7** A small ball is projected with speed 14 m s–1 from a point *O* on the ground. The ball is

projected at an angle *α* to the ground, where tan *α* = . The ball bounces on the ground

for the first time at the point *A*1. The coefficient of restitution between the ball and

the ground is . The ball is modelled as a particle moving freely under gravity from

*O* to *A*1 and between bounces. The ground is modelled as a smooth horizontal plane.

(*a*) Find the size of the angle between the direction of motion of the ball and the ground

 immediately after the ball bounces on the ground at *A*1

**(4)**

(*b*) Explain how, in your calculation, you have used the fact that the ball is moving freely

 under gravity from *O* to *A*1

**(1)**

The ball bounces on the ground for the second time at the point *A2*

(*c*) Find the total time taken by the ball to travel from *O* to *A*2

**(4)**

The ball bounces on the ground for the *n*th time at the point *An*

Immediately after the ball bounces at *An*, the angle between the direction of motion of the

ball and the ground is *ϕ*.

(*d*) Find, in terms of *n* only, an expression for tan *ϕ*.

**(3)**

(*e*) Describe, according to the model, the subsequent motion of the ball after it has

 bounced on the ground at *A*2

**(1)**

Given instead that the coefficient of restitution between the ball and the ground is 0

(*f*) describe fully the motion of the ball from the instant when it is projected from *O*.

**(2)**

**(Total for Question 7 is 15 marks)**

**TOTAL FOR PAPER IS 75 MARKS**