**Candidates may use any calculator allowed by Pearson regulations.**

**Calculators must not have the facility for symbolic algebra**

**manipulation, differentiation and integration, or have retrievable**

**mathematical formulae stored in them.**

**Instructions**

* Use **black** ink or ball-point pen.
* If pencil is used for diagrams / sketches / graphs it must be dark (HB or B).
	+ **Fill in the boxes** at the top of this page with your name,

centre number and candidate number.

* Answer **all** questions and ensure that your answers to parts of questions are

clearly labelled.

* Answer the questions in the spaces provided
 *– there may be more space than you need.*
* You should show sufficient working to make your methods clear. Answers

without working may not gain full credit.

* Unless otherwise indicated, whenever a value of *g* is required, take *g* = 9.8 m s−2,

 and give your answer to either 2 significant figures or 3 significant figures.

**Information**

* A booklet ‘Mathematical Formulae and Statistical Tables’ is provided.
* The total mark for this part of the examination is 40. There are 4 questions.
* The marks for **each** question are shown in brackets
 *– use this as a guide as to how much time to spend on each question.*

**Advice**

* Read each question carefully before you start to answer it.
* Try to answer every question.
* Check your answers if you have time at the end.

**Answer ALL questions.**

**1.**

**Figure 1**

Figure 1 represents the plan of part of a smooth horizontal floor, where *W*1 and *W*2 are two fixed parallel vertical walls. The walls are 3 metres apart.

A particle lies at rest at a point *O* on the floor between the two walls, where the point *O* is *d*metres, 0 < *d* ≤ 3, from *W*1.

At time *t* = 0, the particle is projected from *O* towards *W*1 with speed *u* m s–1 in a direction perpendicular to the walls.

The coefficient of restitution between the particle and each wall is .

The particle returns to *O* at time *t* = *T* seconds, having bounced off each wall once.

(a) Show that *T* = .

**(6)**

The value of *u* is fixed, the particle still hits each wall once but the value of *d* can now vary.

(b) Find the least possible value of *T*, giving your answer in terms of *u*. You must give a reason for your answer.

**(2)**

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**2.**

**Figure 2**

Figure 2 represents the plan view of part of a horizontal floor, where *AB* and *BC* are fixed vertical walls with *AB* perpendicular to *BC*.

A small ball is projected along the floor towards AB with speed 6 m s–1 on a path that makes an angle *α* with *AB*, where tan *α* = . The ball hits *AB* and then hits *BC*.

Immediately after hitting *AB*, the ball is moving at an angle *β* to *AB*, where tan *β* = .

The coefficient of restitution between the ball and *AB* is *e*.

The coefficient of restitution between the ball and *BC* is .

By modelling the ball as a particle and the floor and walls as being smooth,

(a) show that the value of *e* = ,

**(5)**

(b) find the speed of the ball immediately after it hits *BC*.

**(4)**

(c) Suggest two ways in which the model could be refined to make it more realistic.

**(2)**

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**3.** A particle *P*, of mass 0.5 kg, is moving with velocity (4**i** + 4**j**) m s–1 when it receives an impulse **I** of magnitude 2.5 Ns.

As a result of the impulse, the direction of motion of *P* is deflected through an angle of 45°.

Given that **I** = (*λ***i** + *µ***j**) Ns, find all the possible pairs of values of *λ* and *µ*.

**(9)**

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**4.** A car of mass 600 kg pulls a trailer of mass 150 kg along a straight horizontal road. The trailer is connected to the car by a light inextensible towbar, which is parallel to the direction of motion of the car. The resistance to the motion of the trailer is modelled as a constant force of magnitude 200 N. At the instant when the speed of the car is *v* m s–1, the resistance to the motion of the car is modelled as a force of magnitude (200 + λ*v*) N, where is a constant.

When the engine of the car is working at a constant rate of 15 kW, the car is moving at a constant speed of 25 m s–1.

(a) Show that *λ* = 8.

**(4)**

Later on, the car is pulling the trailer up a straight road inclined at an angle *θ* to the horizontal, where sin *θ* = .

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 200 N at all times. At the instant when the speed of the car is *v*m s–1, the resistance to the motion of the car from non-gravitational forces is modelled as a force of magnitude (200 + 8*v*) N.

The engine of the car is again working at a constant rate of 15 kW. When *v* = 10, the towbar breaks. The trailer comes to instantaneous rest after moving a distance *d* metres up the road from the point where the towbar broke.

(b) Find the acceleration of the car immediately after the towbar breaks.

**(4)**

(c) Use the work-energy principle to find the value of *d*.

**(4)**

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**5.** A particle P of mass 3*m* and a particle *Q* of mass 2*m* are moving along the same straight line on a smooth horizontal plane. The particles are moving in opposite directions towards each other and collide directly.

Immediately before the collision the speed of *P* is *u* and the speed of *Q* is 2*u*.

Immediately after the collision *P* and *Q* are moving in opposite directions.

The coefficient of restitution between *P* and *Q* is *e*.

(a) Find the range of possible values of *e*, justifying your answer.

**(8)**

Given that *Q* loses 75% of its kinetic energy as a result of the collision,

(b) find the value of *e*.

**(3)**

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**6.** [*In this question* **i** *and* **j** *are perpendicular unit vectors in a horizontal plane*.]

A smooth uniform sphere *A* has mass 0.2 kg and another smooth uniform sphere *B*, with the same radius as *A*, has mass 0.4 kg.

The spheres are moving on a smooth horizontal surface when they collide obliquely. Immediately before the collision, the velocity of *A* is (3**i** + 2**j**) m s–1 and the velocity of *B* is (–4**i** – **j**) m s–1.

At the instant of collision, the line joining the centres of the spheres is parallel to **i**.

The coefficient of restitution between the spheres is .

(a) Find the velocity of *A* immediately after the collision.

**(7)**

(b) Find the magnitude of the impulse received by *A* in the collision.

**(2)**

(c) Find, to the nearest degree, the size of the angle through which the direction of motion of *A* is deflected as a result of the collision.

**(3)**

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**7.** A particle *P*, of mass *m*, is attached to one end of a light elastic spring of natural length *a* and modulus of elasticity *kmg*.

The other end of the spring is attached to a fixed point *O* on a ceiling.

The point *A* is vertically below *O* such that *OA* = 3*a*.

The point *B* is vertically below *O* such that *OB* = *a*.

The particle is held at rest at *A*, then released and first comes to instantaneous rest at the point *B*.

(a) Show that *k* = .

**(3)**

(b) Find, in terms of *g*, the acceleration of *P* immediately after it is released from rest at *A*.

**(3)**

(c) Find, in terms of *g* and *a*, the maximum speed attained by *P* as it moves from *A* to *B*.

**(6)**

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**TOTAL FOR PAPER IS 75 MARKS**