A-level Physics (7407/7408)

Name:

Class:

Mechanics II progress test

Author:

Date:

Time: **55 minutes**

Marks: **45**

Comments:

Q1. A car exerts a driving force of 500 N when travelling at a constant speed of72 km h^{-1} on a level track. What is the work done in 5 minutes?

A 3.0×10^6 J ☐

B 2.0×10^6 J ☐

C 2.0×10^5 J ☐

D 1.1×10^5 J ☐

(Total 1 mark)

Q2. Which of the following statements is correct?

The force acting on an object is equivalent to

A its change of momentum. ☐

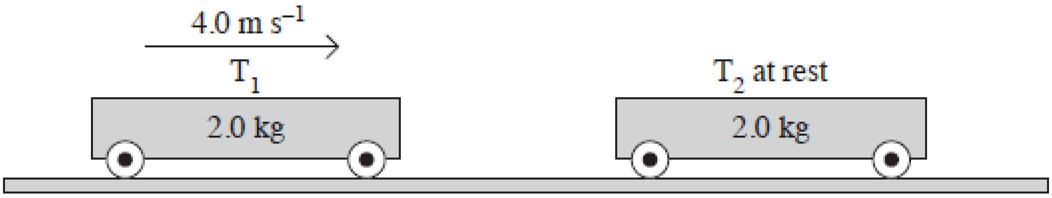
B the impulse it receives per second. ☐

C the energy it gains per second. ☐

D its acceleration per metre. ☐

(Total 1 mark)

Q3. Trolley T_1, of mass 2.0 kg, collides on a horizontal surface with trolley T_2, which is also of mass 2.0 kg. The collision is elastic. Before the collision T_1 was moving at 4.0 m s^{-1} and T_2 was at rest.



Which one of the following statements is correct?

Immediately after the collision

A T_1 is at rest and T_2 moves at 4.0 m s^{-1}.

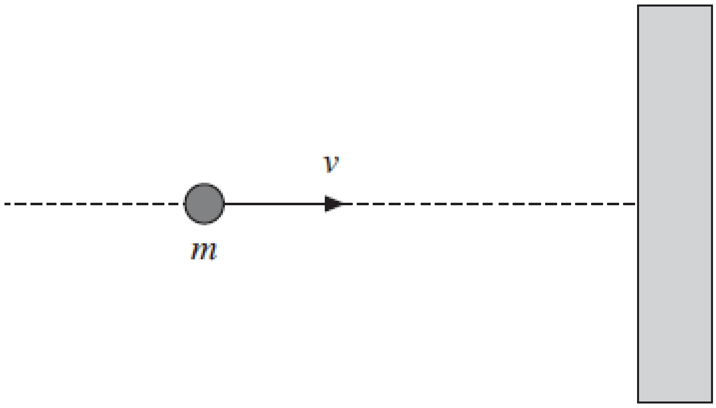
B T_1 will rebound from T_2 at 4.0 m s^{-1}.

C T_1 and T_2 will both move at 2.8 m s^{-1}.

D T_1 and T_2 will both move at 1.4 m s^{-1}.

(Total 1 mark)

Q4. A ball of mass *m* travelling at velocity *v* collides normally with a smooth wall, as shown in the diagram, and rebounds elastically.



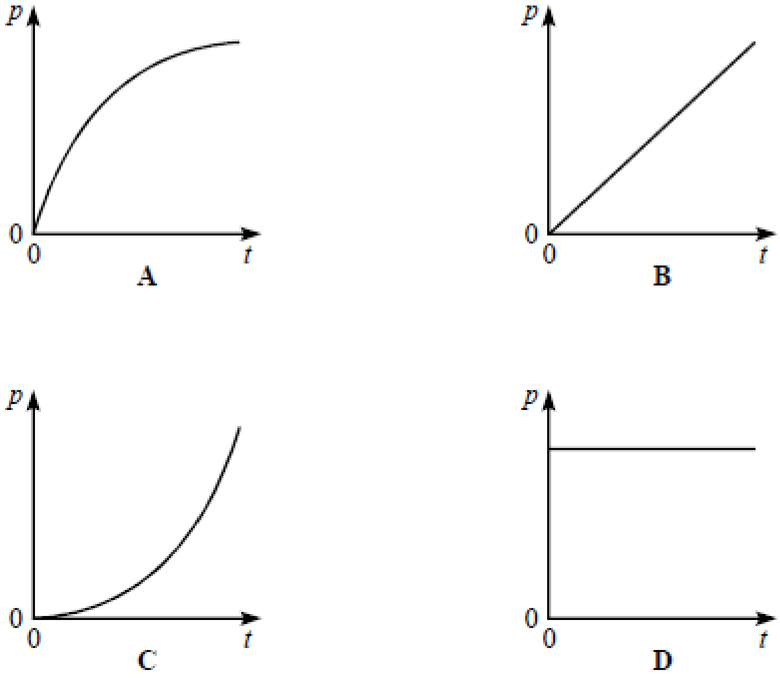
Which line, **A** to **D**, in the table, gives the correct expressions for the magnitude of the change of momentum, and the change of kinetic energy, of the ball?

	magnitude of change of momentum	**change of kinetic energy**
A	$2mv$	0
B	$2mv$	mv^2
C	0	0
D	0	mv^2

(Total 1 mark)

Q5. A body is accelerated from rest by a constant force.

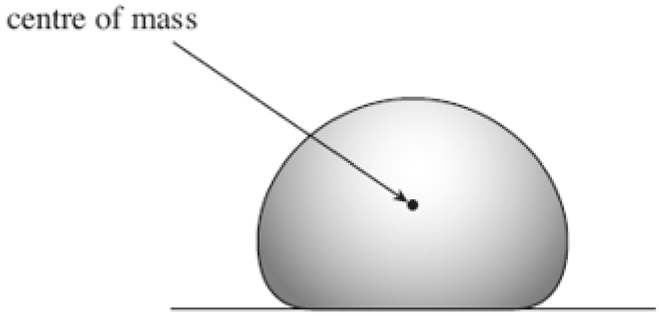
Which one of the following graphs best represents the variation of the body's momentum p with time t?



(Total 1 mark)

Q6. A boy throws a ball vertically upwards and lets it fall to the ground.
Figure 1 shows the ball deforming as it contacts the ground, just at the point where it is stationary for an instant and has reached maximum deformation.

Figure 1



(i) Explain how Newton's third law of motion applies to **Figure 1**.

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(2)

(ii) Explain why there is a resultant upward force on the ball in **Figure 1**.

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(2)
(Total 4 marks)

Q7.(a) Collisions can be described as *elastic* or *inelastic*. State what is meant by an inelastic collision.

....

....

(1)

(b) A ball of mass 0.12 kg strikes a stationary cricket bat with a speed of 18 m s^{-1}. The ball is in contact with the bat for 0.14 s and returns along its original path with a speed of 15 m s^{-1}.

Calculate

(i) the momentum of the ball before the collision,

....

....

(ii) the momentum of the ball after the collision,

....

....

(iii) the total change of momentum of the ball,

....

....

(iv) the average force acting on the ball during contact with the bat,

....

....

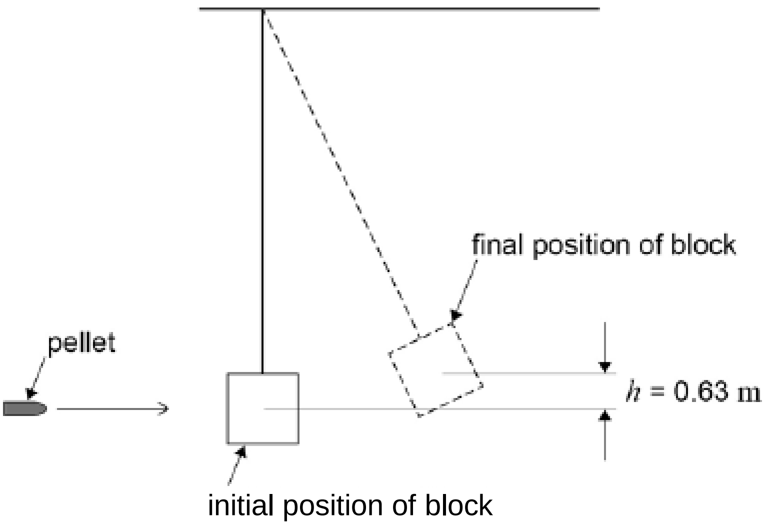
(v) the kinetic energy lost by the ball as a result of the collision,

....

....

(6)
(Total 7 marks)

Q8. The speed of an air rifle pellet is measured by firing it into a wooden block suspended from a rigid support.
The wooden block can swing freely at the end of a light inextensible string as shown in the figure below.



A pellet of mass 8.80 g strikes a stationary wooden block and is completely embedded in it. The centre of mass of the block rises by 0.63 m. The wooden block has a mass of 450 g.

(a) Determine the speed of the pellet when it strikes the wooden block.

speed = ... m s^{-1}

(4)

(b) The wooden block is replaced by a steel block of the same mass.
The experiment is repeated with the steel block and an identical pellet. The pellet rebounds after striking the block.

Discuss how the height the steel block reaches compares with the height of 0.63 m reached by the wooden block. In your answer compare the energy and momentum changes that occur in the two experiments.

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(4)

(c) Discuss which experiment is likely to give the more accurate value for the velocity of the pellet.

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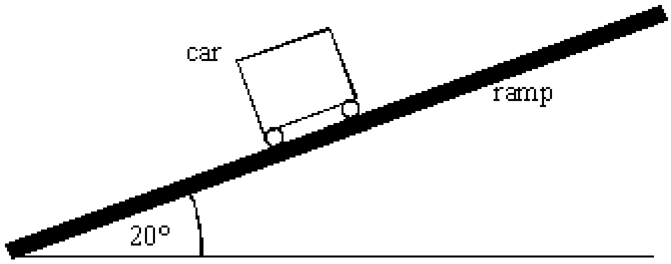
(2)
(Total 10 marks)

Q9. A fairground ride ends with the car moving up a ramp at a slope of 20° to the horizontal as shown in the diagram below.



(a) The car carrying its maximum load of passengers has a total weight of 6.8 kN. Show that the component of the weight acting parallel to the ramp is about 2.3 kN.

(2)

(b) The mass of the fully loaded car is 690 kg. Show that the force in part (a) will decelerate the car at about 3.3 m s^{-2}.

(2)

(c) The car enters the ramp at 22 m s^{-1}. Calculate the minimum length that the ramp must be in order for the car to stop before it reaches the end. Neglect the length of the car.

Minimum length ....

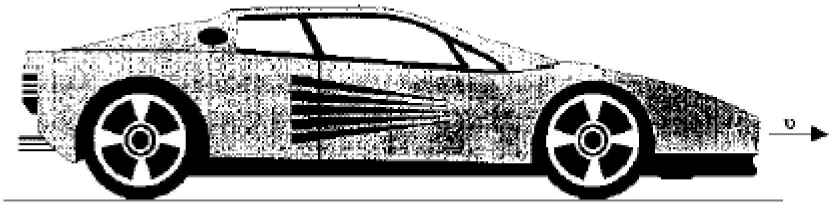
(2)

(d) The ride owner decides to use a shorter ramp and to install brakes on the car. The additional decelerating force provided by these brakes is 4600 N. Calculate the new stopping time.

Stopping time ....

(3)
(Total 9 marks)

Q10. The diagram shows a car travelling at a constant velocity along a horizontal road.



(a) (i) Draw and label arrows on the diagram representing the forces acting on the car.

(ii) Referring to Newton's Laws of motion, explain why the car is travelling at constant velocity.

....

....

....

....

(5)

(b) The car has an effective power output of 18 kW and is travelling at a constant velocity of 10 m s^{-1}. Show that the total resistive force acting is 1800 N.

....

....

....

(1)

(c) The total resistive force consists of two components. One of these is a constant frictional force of 250 N and the other is the force of air resistance, which is proportional to the square of the car's speed.

Calculate

(i) the force of air resistance when the car is travelling at 10 m s^{-1},

....

....

(ii) the force of air resistance when the car is travelling at 20 m s^{-1},

....

....

(iii) the effective output power of the car required to maintain a constant speed of 20 m s^{-1} in a horizontal road.

....

....

....

(4)
(Total 10 marks)

M1. C

[1]

M2. B

[1]

M3. A

[1]

M4. A

[1]

M5. B

[1]

M6. (i) **ball** exerts **force on ground and** ground exerts force (on ball)/reaction ✓

and **these** forces are **equal** and **opposite** ✓

2

(ii) recognise that the downward force is the weight of the ball (accept gravity) ✓

recognition that the upward/reaction force (on the ball) is greater than the downward force on the ball ✓

2

[8]

M7.(a) kinetic energy is not conserved **(1)**

(1)

(b) (i) ($p = mv$ gives) $p = 0.12 \times 18 = 2.2$ N s **(1)** (2.16 N s)

(ii) $p = 0.12 \times (-15) = -1.8$ N s **(1)**

(iii) $\Delta p = 2.2 - (-1.8) = 4.0$ N s (3.96 N s) **(1)**
(allow e.c.f. from(i) and(ii))

(iv) $\left(F = \frac{\Delta(mv)}{\Delta t} \text{ gives}\right) F = \frac{3.96}{0.14}$ **(1)**

= 28 N **(1)** (28.3 N)
(allow e.c.f. from (iii))

(v) ($E_k = \frac{1}{2}mv^2$ gives) $E_k = 0.5 \times 0.12 \times (18^2 - 15^2) = 5.9$ J **(1)**

(6)

[7]

M8.(a) Max GPE of block = Mgh = 0.46 × 9.81 × 0.63 = 2.84 J ✓

The first mark is for working out the GPE of the block

1

Initial KE of block = ½ Mv^2 = 2.84 J

Initial speed of block $v^2 = (2 \times 2.84) / 0.46$

$v = 3.51\ ms^{-1}$ ✓

The second mark is for working out the speed of the block initially

1

momentum lost by pellet = momentum gained by block

$= Mv = 0.46 \times 3.51 = 1.61$ kg m s^{-1} ✓

The third mark is for working out the momentum of the block (and therefore pellet)

1

Speed of pellet = $1.58 / m = 1.58 / 8.8 \times 10^{-3} = 180\ ms^{-1}$ (183) ✓

The final mark is for the speed of the pellet

1

At each step the mark is for the method rather than the calculated answer

Allow one consequential error in the final answer

(b) As pellet rebounds, change in momentum of pellet greater and therefore the change in momentum of the block is greater ✓

Ignore any discussion of air resistance

1

Initial speed of block is greater ✓

1

(Mass stays the same)

Initial KE of block greater ✓

1

Therefore height reached by steel block is greater than with wooden block ✓

1

(c) Calculation of steel method will need to assume that collision is elastic so that change of momentum can be calculated ✓

1

This is unlikely due to deformation of bullet, production of sound etc. ✓

1

And therefore steel method unlikely to produce accurate results.

[10]

M9. (a) 6800 × sin 20

B1

= 2330 N

B1

2

(b) $a = F/m$

B1

= 2300/690 **or** 2300 = 690 × a

B1

2

(c) $v^2 = u^2 + 2as$

C1

s = [22 × 22/2/3.33] = 72.7 m [73.3 if using 3.3 m; 71.8 possible]

A1

2

(d) $F = 6900$

C1

$a = F/m$ = [9.99/10]

C1

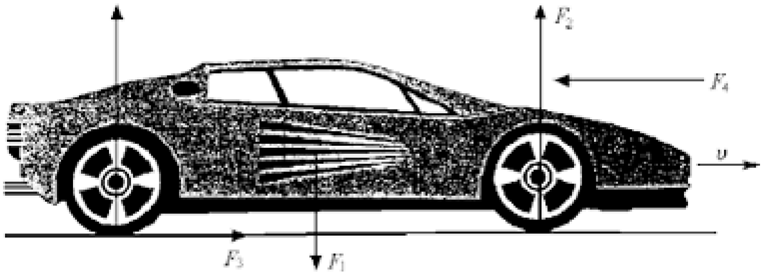
t = 22/99.9 or 22/10 s [= 2.2]

A1

3

[9]

M10.(a) (i)



F_1 weight / mg **(1)**
F_2 reaction or normal contact force **(1)**
F_3 driving force **(1)**
F_4 friction or air resistance **(1)**

(ii) zero acceleration **(1)**
zero resultant force **(1)**

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part.

(max 5)

(b) ($P = Fv$ gives) $18 \times 10^3 = F \times 10$ **(1)** (and $F = 1.8 \times 10^3$ N)

(1)

(c) (i) $1800 - 250 = 1.6 \times 10^3$ N **(1)** (1.55×10^3 N)

(ii) force = $4 \times 1.55 \times 10^3 = 6.2 \times 10^3$ N **(1)**
(allow e.c.f. from (i))

(iii) total force = 6200 + 250(N) **(1)** (= 6.45×10^3 (N))
($P = Fv$ gives) $P = 6.45 \times 10^3 \times 20 = 1.3 \times 10^5$ W **(1)** (1.29×10^5 W)
(allow e.c.f. for value of total force)

(4)

[10]

E3. Collisions between dynamics trolleys of similar mass, the basis of this question, are often studied when considering the conservation of momentum. This was an elastic collision, and so kinetic energy would be conserved as well as momentum. Four out of five students decided that the moving trolley would stop and pass all of its momentum on to the other trolley.

E4. This question tested the vector nature of momentum, the scalar nature of kinetic energy and the meaning of an elastic collision. Just over two thirds of the candidates realised that the exact reversal of momentum meant a change of 2*mv* and that an elastic collision meant no change in kinetic energy. Almost 20% of them chose distractor C, thinking there is no change in momentum.

E6. Part (a)(i) was rudimentary for an AS Physics candidate and most knew that the correct answer was 'the gradient'. The most common incorrect answers were 'area' or 'the line'.

In part (a)(ii), a significant number of candidates drew a **speed**-time graph with the 'speed' decreasing up to t1 and then a line sloping upwards to a maximum 'speed' at t_2. There were also many highly curved lines. However, candidates should have assumed that acceleration was constant here. Most types of ball would not experience significant air resistance in this situation, unless thrown to a very great height, and the height shown in **Figure 1** could not be greater than about 6 metres. Candidates, who perhaps had not practiced on similar questions, struggled to visualise the situation and think it through successfully. A surprising number had the velocity of the ball falling to zero as it approached the ground or accelerating upwards after it had been thrown.

A significant number of candidates did not attempt part (b)(i), suggesting they were not sufficiently familiar with Newton's laws. Many mentioned the weight of the ball acting downwards or the ball being equal. However, the force from the ball acting down on the ground is not equal to the weight because the ball is not in equilibrium. The speed would in fact be significantly greater and be determined by the speed, mass, shape and material properties of the ball.

Candidates' responses also indicated that they believed the ball would be in equilibrium because it was stationary at the instant shown in the diagram.

Candidates clearly thought they were giving appropriate responses to part (b)(ii). However, very few managed to pick up even one mark. Firstly, candidates did not recognise that the **forces** on the ball needed to be discussed. The correct response, 'the upward force on the ball is greater than the weight' was very rare. Many instead gave a description of the energy transfers involved.

Some stated that energy is the 'force' acting downwards. Many wrongly stated that the ground pushes up more than the ball pushes down; 'the upward force is bigger than the downward force exerted by the ball', being a typical statement. Some explained that this is because some of the downward force from the ball is 'absorbed'.

Many candidates clearly believed that the weight and the reaction force from the ground **have** to be equal and opposite. This was presumably due to a misunderstanding of Newton's 3rd law.

A significant number thought that as the ball is momentarily stationary, the forces are balanced. Some tried to explain by discussing the deformation of the ball and transfer of kinetic to potential energy.

Some thought that the upward force was a combination of the reaction force and a force 'from the ball reforming to its original shape'.

E7. A surprising number of candidates failed to answer part (a) correctly and did not seem to be aware that kinetic energy was central to any discussion on inelastic collisions.

In part (b) the calculations were generally well done although it was rare for a candidate to take into account the change of direction in part (ii). Also the unit of momentum caused problems for a significant proportion of candidates. In part (v) the calculation of the loss of kinetic energy produced more difficulties than expected. The most common error was for candidates to first subtract the velocities and then use the result to calculate the loss of energy.

E9. There was a general lack of confidence in this part, some candidates permutated likely numbers until they found a combination that fitted the answer.

This part was mostly answered very successfully.

Most could handle the equations of motion here but weaker candidates became confused

and could not carry through the necessary manipulations.
Many were able to work towards a complete and accurate solution. A common error was to forget that there were two forces acting on the car and that it was therefore appropriate to use the resultant of these forces.

E10. The majority of candidates were able to identify in part (a) the reaction forces, the weight and the resistive forces, but very few were able to identify the driving force correctly. Other errors which occurred were not drawing the arrows carefully enough and leaving their direction and point of origin vague. Labelling the arrows was also frequently ambiguous. Part (ii) was often not answered well. Candidates had great difficulty expressing themselves in a way that demonstrated understanding and often equated forces to velocity and incorrectly applied Newton's third law of motion to the situation.

Part (b) was well answered with the majority of candidates selecting and correctly rearranging the appropriate formula. Candidates found part (c)(i) more difficult and many did not realise that a simple subtraction of the forces was required. Part (ii) also caused problems for weaker candidates although a significant proportion did realise that the force was a factor of four greater than the force quoted in the question. Candidates fared better with the calculation in part (iii) and correct solutions were often seen.