1. This question is about forces.

An athlete trains by dragging a heavy load across a rough horizontal surface.

The athlete exerts a force of magnitude F on the load at an angle of 25° to the horizontal.

(a) Once the load is moving at a steady speed, the average horizontal frictional force acting on the load is 470 N.

Calculate the average value of F that will enable the load to move at constant speed.

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(2)

(b) The load is moved a horizontal distance of 2.5 km in 1.2 hours.

Calculate

(i) the work done on the load by the force F.

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(2)

(ii) the minimum average power required to move the load.

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(2)

(c) The athlete pulls the load uphill at the same speed as in part (a).

Explain, in terms of energy changes, why the minimum average power required is greater than in (b)(ii).

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(2)

(Total 8 marks)

2. A ball is thrown vertically upwards and comes down again. Air resistance is negligible. Which of the following graphs shows how the gravitational potential energy E_P varies with time t?

(Total 1 mark)

3. This question is about kicking a football.

A ball is suspended from a ceiling by a string of length 7.5 m. The ball is kicked horizontally and rises to a maximum height of 6.0 m.

(a) Assuming that the air resistance is negligible, show that the initial speed of the ball is 11 m s^{-1}.

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(2)

(b) The mass of the ball is 0.55 kg and the impact time of the kicker's foot with the ball is 150 ms. Estimate the average force exerted on the ball by the kick.

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(2)

(c) (i) Explain why the tension in the string increases immediately after the ball is kicked.

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(3)

(ii) Calculate the tension in the string immediately after the ball is kicked. Assume that the string is vertical.

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(3)

(Total 10 marks)

4. This question is about momentum, energy and power.

(a) In his *Principia Mathematica* Newton expressed his third law of motion as "to every action there is always opposed an equal reaction". State what Newton meant by this law.

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(1)

(b) A book is released from rest and falls towards the surface of Earth. Discuss how the conservation of momentum applies to the Earth-book system.

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(3)

(c) A large swinging ball is used to drive a horizontal iron spike into a vertical wall. The centre of the ball falls through a vertical height of 1.6 m before striking the spike in the position shown.

The mass of the ball is 3.5 kg and the mass of the spike is 0.80 kg. Immediately after striking the spike, the ball and spike move together. Show that the

(i) speed of the ball on striking the spike is 5.6 m s^{-1}.

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(1)

(ii) energy dissipated as a result of the collision is about 10 J.

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(4)

(d) As a result of the ball striking the spike, the spike is driven a distance 7.3×10^{-2} m into the wall. Calculate, assuming it to be constant, the friction force F between the spike and wall.

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(3)

(e) The machine that is used to raise the ball has a useful power output of 18 W. Calculate how long it takes for the machine to raise the ball through a height of 1.6 m.

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(3)

(Total 15 marks)

5. A ball falls vertically and bounces off the ground. Immediately before impact with the ground the speed of the ball is u. Immediately after leaving the ground the speed is v.

Which of the following expressions is the ratio of ?

A.

B.

C.

D.

(Total 1 mark)

6. This question is about collisions.

(a) State the principle of conservation of momentum.

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(2)

(b) In an experiment, an air-rifle pellet is fired into a block of modelling clay that rests on a table.

(not to scale)

The air-rifle pellet remains inside the clay block after the impact.

As a result of the collision, the clay block slides along the table in a straight line and comes to rest. Further data relating to the experiment are given below.

Mass of air-rifle pellet	= 2.0 g
Mass of clay block	= 56 g
Velocity of impact of air-rifle pellet	= 140 m s^{-1}
Stopping distance of clay block	= 2.8 m

(i) Show that the initial speed of the clay block after the air-rifle pellet strikes it is 4.8 m s^{-1}.

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(2)

(ii) Calculate the average frictional force that the surface of the table exerts on the clay block whilst the clay block is moving.

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(4)

(c) Discuss the energy transformations that occur in the clay block and the air-rifle pellet from the moment the air-rifle pellet strikes the block until the clay block comes to rest.

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(3)

(d) The clay block is dropped from rest from the edge of the table and falls vertically to the ground. The table is 0.85 m above the ground. Calculate the speed with which the clay block strikes the ground.

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(2)

(Total 13 marks)

7. This question is about dynamics and energy.

A bullet of mass 32 g is fired from a gun. The graph shows the variation of the force F on the bullet with time t as it travels along the barrel of the gun.

The bullet is fired at time $t = 0$ and the length of the barrel is 0.70 m.

(a) State and explain why it is inappropriate to use the equation $s = ut +$ to calculate the acceleration of the bullet.

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(2)

(b) Use the graph to

(i) determine the average acceleration of the bullet during the final 2.0 ms of the graph.

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(2)

(ii) show that the change in momentum of the bullet, as the bullet travels along the length of the barrel, is approximately 9 N s.

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(3)

(c) Use the answer in (b)(ii) to calculate the

(i) speed of the bullet as it leaves the barrel.

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(2)

(ii) average power delivered to the bullet.

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(3)

(d) Use Newton's third law to explain why a gun will recoil when a bullet is fired.

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(3)

(Total 15 marks)

8. This question is about forces.

A solid iron ball of mass 770 kg is used on a building site. The ball is suspended by a rope from a crane. The distance from the point of suspension to the centre of mass of the ball is 12 m.

(a) Calculate the tension in the rope when the ball hangs vertical and stationary.

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(1)

(b) The ball is pulled back from the vertical and then released. It falls through a vertical height of 1.6 m and strikes a wall.

(i) Calculate the speed of the ball just before impact.

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(2)

(ii) Calculate the tension in the rope just before impact.

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(3)

(c) The ball is brought to rest in 0.15 s. The sketch graph below shows how the force the ball exerts on the wall varies with time.

(i) State what quantity is represented by the area under the graph.

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(1)

(ii) Determine the maximum force F_{max} exerted by the ball on the wall.

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(3)

(Total 10 marks)