THE UNIVERSITY OF SYDNEY

EDUH 1017 SPORTS MECHANICS

JUNE 2009

Time allowed: TWO Hours

MARKS FOR QUESTIONS ARE AS INDICATED
TOTAL: 70 MARKS

INSTRUCTIONS

- All questions are to be answered.
- Use a separate answer book for each section.
- All answers should include explanations in terms of physical principles.

DATA

Free fall acceleration at earth's surface \( g = 9.8 \text{ m.s}^{-2} \)
SECTION A
(Please use a separate book for this section.)

Question 1

You are given a force plate, like those used in the Sports Mechanics laboratory sessions, which produces small electrical signals (voltages) in response to applied vertical forces.

(a) You are asked to calibrate the force plate. What does this mean? Why is it necessary?

(b) Sketch a graph of force versus time as measured by the force plate when you walk across the plate. Point out and briefly explain the main features of your graph.

(c) A much heavier person now walks across the force plate much more quickly. Sketch a new graph of force versus time and point out the differences from your sketch in (b).

(5 marks)

Question 2

The picture shows an athlete doing a mini-hurdle lateral agility drill. This involves running sideways, back and forth over the mini-hurdles. When she lands on one foot outside the hurdle (as pictured here) she immediately changes direction.

(a) Sketch a diagram showing all the forces acting on her in the position show in the picture.

(b) Why does she push off on her foot like this to change direction?

(c) Do any of the forces change when she does the drill more quickly? Explain why or why not.

(5 marks)
Question 3

In an experiment, a motion detector is used to gather and display data for a person walking away from the detector. A student sketch of the distance versus time graph is shown below.

![Distance vs Time Graph](image)

(a) Based on this graph,
(i) sketch the corresponding velocity versus time graph.
(ii) sketch the corresponding acceleration versus time graph.

(b) The measured velocity versus time graph is shown below. In what ways is it a more realistic measurement of walking than your sketch in (a)(i)?

![Velocity vs Time Graph](image)

(5 marks)

Question 4

A 1050 kg car is travelling along a straight road at 20.0 m/s when it is rammed in the rear by a 1300 kg car that was travelling at 30.0 m/s just before the impact. The two cars stick together and continue moving forward together.

(a) Is momentum conserved in this collision? Why or why not?
(b) Is energy conserved in this collision? Why or why not?
(b) At what speed do the two cars move off together?

(5 marks)
Question 5

When a roller skater is spinning around as seen in the diagram, the friction between her and the ground is very small. As she spins, she moves her arms and one leg in and out to make herself spin faster or slower.

(a) Using the terminology of mechanics, explain how moving her arms and legs allows her to control her rate of rotation.

(b) Why is it important for this explanation that the friction between her and the ground is very small?

(5 marks)
SECTION B
(please use a separate book for this section.)

Question 6

In a school playground a young child gets hurt because he is moving too fast down a slide. Jill is asked to investigate the matter and suggest ways in which the slide can be made safer.

Jill does an experiment. She estimates that the smallest child has a mass of 8 kg so she places an 8 kg wooden box on the slide (with some clothing stuck to the bottom) and watches it slide down.

(a) Sketch the slide with the box in your answer book. Draw and label vectors to represent the forces acting on the box.

(b) Redraw the diagram in your answer book with the forces resolved into components parallel and perpendicular to the surface of the slide. Clearly label the force components.

(c) Jill measures the angle of the slide to be 35° from the horizontal. Calculate the force(s) on the box pulling it down the slide.

(d) Jill decides to include friction and finds that the coefficient of friction between the box and the slide is 0.15. Calculate the net force pulling the box down the slide.

(e) Name one thing that can be done to the slide to make it safer. Briefly explain why it will help.

(10 marks)
Question 7

You are putting together a team of pole vaulters for a national schools competition. You have realised that the speed with which the pole vaulters run up is critical to how high they can vault. To analyse the situation you ask Lara for help with some measurements.

Lara’s centre of mass is 1.00 m above the ground when standing upright. Her mass is 60.0 kg and she uses a light weight graphite-fibreglass pole with a mass that is small enough to ignore. When Lara just clears the bar set to a height of 5.00 m, her centre of mass actually passes 20 cm below the bar.

(a) If you take the ground as the zero level of gravitational potential energy, what is the gravitational potential energy of Lara’s centre of mass when she just clears the bar (D in the diagram)?

(b) In your measurements you have found that Lara’s speed as she clears the bar (D in the diagram) is around 2 m/s. What is Lara’s total mechanical energy as she clears the bar?

(c) Assuming no energy is lost in the jump, what is Lara’s speed just before inserting the pole into the ‘box’ (B in the diagram)?

(d) In your measurements you have also found that Lara is moving 40% slower just as she leaves the ground compared to when she inserted the pole into the hole (B in the diagram). Assuming no energy has been lost, where has the energy gone?

(e) How can Lara clear the bar yet have her centre of mass pass 20 cm below the bar?

(10 marks)
Question 8

A golfer chooses a 7-iron club to 'chip' the ball a short distance onto the green. His shot gives the ball a velocity of 15 m/s at an angle of 25 degrees to the horizontal. Ignore air resistance for the following calculations.

(a) What are the horizontal and vertical components of the ball’s velocity just after it is hit?

(b) How long will the ball take to reach its maximum height?

(c) Measured along the ground, how far will the ball have travelled when it hits the ground (i.e. what is its range?).

(d) How would this range change if this shot had been played on the Moon? Make sure to explain why it would change.

(10 marks)
Please note that Question 9 is worth 15 marks.

Question 9

In gymnastics, many of the actions require jumping off the floor and rotating the body in mid-air. Consider a simple jump executed by running forward, doing a single forward rotation in the air and landing on the feet.

Explain the mechanics behind the motion of the athlete in the jump by answering the following questions:

(a) Describe the motion of the gymnast’s centre of mass by using sketched graphs of:
   (i) horizontal position versus time,
   (ii) vertical position versus time,
   (i) horizontal velocity versus time,
   (ii) vertical velocity versus time.

   Clearly label your graphs with the phases of the jump.

(b) Draw a force diagram illustrating forces on the athlete:
   (i) at the point of take-off from the ground,
   (ii) in mid-air, in the middle of the rotation.

(c) How is it possible to perform complex moves in mid-air when there is nothing to “push against”?

(15 marks)

THIS IS THE END OF YOUR QUESTIONS