THE UNIVERSITY OF SYDNEY

EDUH 1017 - SPORTS MECHANICS

JUNE 2010

Time allowed: TWO Hours

Total marks: 90 MARKS

INSTRUCTIONS
• All questions are to be answered.
• Use a separate answer book for each section.
• Hand in the answers to section A and B separately at the end of the examination.

DATA

Free fall acceleration at earth's surface \( g = 9.8 \, \text{m.s}^{-2} \)
Formula Sheet

\[ s_{av} = \frac{l}{t} \]
\[ v_{av} = \frac{d}{t} \]
\[ a_{av} = \frac{v_f - v_i}{t_f - t_i} \]
\[ v_f = v_i + at \]
\[ d = v_i t + \frac{1}{2}at^2 \]
\[ v_f^2 = v_i^2 + 2ad \]
\[ \cos \theta = \frac{\text{adjacent}}{\text{hypotenuse}} \]
\[ \sin \theta = \frac{\text{opposite}}{\text{hypotenuse}} \]
\[ p = mv \]
\[ F = ma \]
\[ F_{\text{gravity}} = mg \]
\[ F_{f (\text{max})} = \mu F_N \]
\[ W = Fd \cos \theta \]
\[ KE = \frac{1}{2}mv^2 \]
\[ PE_{\text{gravitational}} = mgh \]
\[ F = -kd \]
\[ PE_{\text{elastic}} = \frac{1}{2}kd^2 \]
\[ J = Ft \]
\[ \text{COR} = \frac{v_2}{v_1} \]
\[ \tau = Fd \]
\[ s = R\theta \]
\[ V = R\omega \]
\[ \alpha = \frac{\omega_f - \omega_i}{t_f - t_i} \]
\[ I = mr^2 \]
\[ \tau = I\alpha \]
\[ L = I\omega \]
SECTION A
(Please use a separate book for this section.)

Question 1

In one of the Sports Mechanics laboratory sessions you were asked to study a ball bouncing off the strings of a tennis racquet. This experiment involved measuring the height from which the ball is dropped onto the racquet and the height to which it rebounded. These heights are generally different.

(a) Using the principles of mechanics, briefly describe why these two heights are different.

(b) One way to express the results in the lab experiment used the coefficient of restitution (COR)

\[
\text{coefficient of restitution} = \frac{\text{speed after collision}}{\text{speed before collision}}
\]

How would you use the height measurements to estimate the speed of the ball before and after the ‘collision’ with the racquet strings, and thus calculate the COR?

(5 marks)

Question 2

A skier is standing at the top of a ski slope which is angled at 40 degrees to the horizontal. She begins to slide and slides straight down the slope, accelerating without needing to push with her poles.

(a) Draw a sketch of the skier as she slides down the slope. Show all the forces likely to be acting on her in this situation.

(b) Is there a net force acting on her? How can you be sure?

(c) Skiers often wax their skis to increase their speed. How would this affect any aspect of your answers?

(5 marks)
Question 3

During a shot-put throw the shot is initially swung around in a circle (from A to B in the figure), reaching a speed of about 3.5 m/s. It is then accelerated in more or less a straight line for about 1.7 m (from B to C in the figure), leaving the hand at roughly 14 m/s.

The mass of the shot = 7.26 kg

(a) How much kinetic energy does the shot initially gain in the turning phase (A to B)?

(b) How much kinetic energy does it gain during the straight line portion of the launch (B to C)?

(c) The value in (b) is the work done on the ball during the straight line portion of the launch. What is the average force exerted on the shot during this part of the launch?

(5 marks)

Question 4

A human being can survive a feet-first impact at speeds up to roughly 12 m/s onto concrete, 15 m/s onto soil and 34 m/s into water. Explain the spread in these values using the concepts of force and/or momentum.

(5 marks)

Question 5

The picture at right shows a female dancer spinning around in a pirouette. Experienced female dancers usually perform this manoeuvre *en pointe* – in a shoe with a hard, rounded block in the toe. This helps to minimise the friction between the foot and the floor. As she spins, she can move her arms and one leg in and out to make herself spin faster or slower.

Using the terminology of mechanics, explain:

(a) how moving her arms and legs allows her to control her rate of rotation

(b) how she could stop herself spinning.

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

Question 6

The velocity versus time graph below shows the motion of a motorcycle policeman on his motorbike during a brief pursuit of a speeding car.

(a) Briefly describe the policeman’s motion in words, using terms such as displacement, velocity and acceleration.

Sketch the following graphs that also illustrate the policeman’s motion. Make sure the axes of each graph are correctly labelled, with numerical values where possible.

(b) Acceleration versus time

(c) Displacement versus time

(d) Kinetic energy versus time

(10 marks)
Question 7

A goal keeper in soccer (football) places the ball on the ground and kicks it downfield. His kick gives the ball an initial velocity of 30 m/s at an angle of 22 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 kicked?

(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) Describe in words how this motion of the ball would change if you took air resistance into account.

(10 marks)

Question 8

The motion of swinging a tennis racquet is shown in the figure below. It starts from rest and accelerates to an angular speed of 80 radians/s after 0.1 s. The moment of inertia of the racquet is 0.05 kg.m$^2$.

(a) What is the angular acceleration of the racquet at the beginning of the swing?

(b) What is the angular momentum of the racquet at the end of the swing?

(c) Would it easier or harder to swing the racquet if it had its mass distributed differently – with more mass in the head and less in the handle?

(10 marks)
A pole vaulter uses a highly flexible pole to reach heights up to around 6 m. The diagram above shows the main phases of the jump – run-up (A on the diagram), take-off (B), release of the bar (C), passing over the bar (D) and landing (E).

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

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

   Clearly label your graphs with phases of the jump.

(b) Draw a force diagram illustrating forces on the athlete at the point of take-off from the ground (B).

(c) In terms of physical principles, explain why careful control of the athlete’s body position while passing over the bar (D) can increase the likelihood of a successful jump? (Hint: don’t simply say “to avoid bumping the bar”)

(d) Describe the energy transformations occurring at each marked phase of the jump, from the run-up to the landing.

**THIS IS THE END OF YOUR QUESTIONS**