Physics 3AB

Motion and Forces
Test One
2013

Name: Solutions

Mark: / 57

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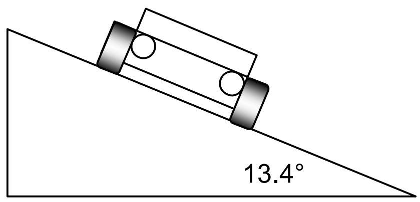
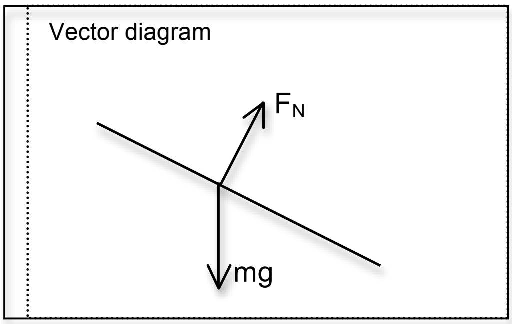
Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(13 marks)**

By banking the curves of racetracks it is possible for vehicles to turn in a horizontal circle without relying on friction. For a car of mass 1.70 x 10^3 kg the angle of banking is set at 13.4° above the horizontal. The curve has a radius of 171 m and the car drives at a speed to maintain its height.





(a) Draw a vector diagram showing (and labelling) the forces acting on the car in the space indicated above.

(2 marks)

(b) Calculate the magnitude of the centripetal force acting on the car.

(5 marks)

$$\sum F = ma \quad (0.5)$$
$$\sum F_V = F_N \cos\theta - mg = 0 \quad (1)$$
$$\sum F_H = F_N \sin\theta = ma_c \quad (1)$$

$$F_N \cos\theta = mg$$
$$F_N = \frac{mg}{\cos\theta}$$
$$\frac{mg}{\cos\theta}\sin\theta = ma_c \quad (1)$$
$$F_c = mg\tan\theta$$
$$= (1700)(9.8)(\tan 13.4) \quad (0.5)$$
$$= 3.97 \times 10^3\ N \quad (1)$$

(c) Determine the speed of the car in kmh^{-1}.

(3 marks)

$$F_c = \frac{mv^2}{r} \quad (1)$$
$$3.97 \times 10^3 = \frac{(1700)(v^2)}{171} \quad (1)$$
$$v = 20.0\ ms^{-1}$$
$$= 72.0\ kmh^{-1} \quad (1)$$

-1 mark incorrect or no conversion to kmh^{-1}

(d) Explain why a banked curve would be safer in wet conditions.

(3 marks)

- In wet conditions the friction between the tyres of a car and the road is reduced.
- On a banked curve a component of the normal force points towards the centre of the curve.
- This component of the normal force provides the centripetal force required for the car to maintain its circular path, reducing the reliance on friction.

Question 2 **(4 marks)**

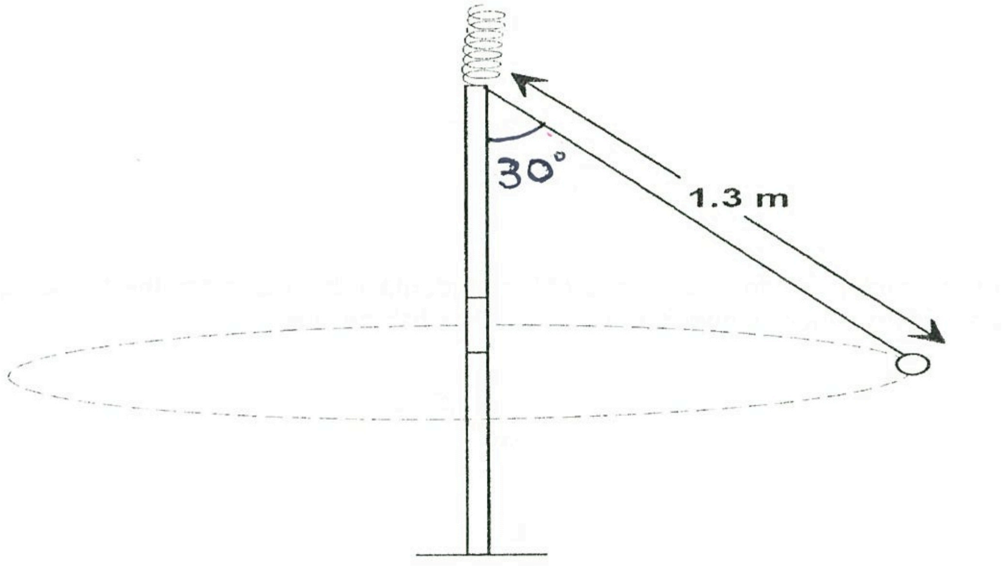
Calculate the deceleration of a snow boarder going up at 5.00° slope. Assume the coefficient of friction (μ_k) for waxed wood on wet snow is 0.1.

$F_f = \mu_k F_N$.

$$F_f = (0.1)(mg\cos\theta)$$
$$= (0.1)(m)(9.8)(\cos 5)$$
$$\sum F = ma \quad (1)$$
$$= mg\sin\theta + F_f = ma \quad (1)$$
$$(9.8)(\sin 5) + (0.1)(9.8)(\cos 5) = a \quad (1)$$
$$a = 1.83\ ms^{-2}\ \textit{up the slope} \quad (1)$$

Question 3 **(5 marks)**

During a game of totem tennis a ball of mass 60.0 g swings freely in a horizontal circular path. The string is 1.30 m long and is at an angle of 30.0° to the vertical as shown in the diagram.



(a) Calculate the radius of the ball's circular path.

(2 marks)

$r = 1.30 \sin 30$ (1)

$= 0.650\ m$ (1)

(b) Calculate the tension in the string.

(3 marks)

$\sum F = ma$ (0.5)

$\sum F = T\cos - mg = 0$ (0.5)

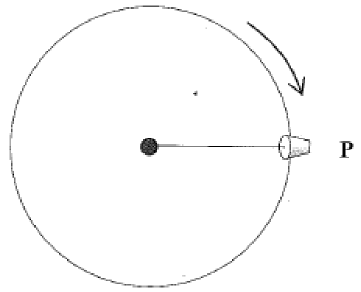
$T = \dfrac{mg}{\cos\theta}$

$= \dfrac{(0.06)(9.8)}{\cos 30}$ (1)

$= 6.79 \times 10^{-1}\ N$ (1)

Question 4 **(5 marks)**

To demonstrate circular motion to her students, a Physics teacher attached a 40.0 g rubber stopper to a length of fishing line and spun it clockwise in a horizontal circle when viewed from above.



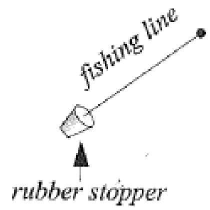
(a) If the rubber stopper completes a horizontal circle of radius 50.0 cm in 0.800 s, what is the magnitude of the tension in the fishing line?

(4 marks)

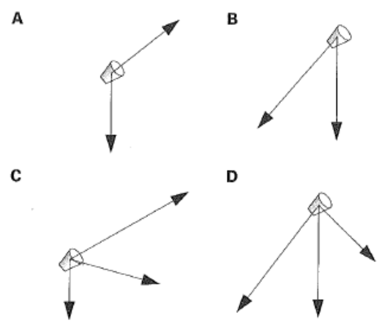
$$v = \frac{s}{t} \quad (0.5)$$
$$= \frac{2\pi(0.5)}{0.8} \quad (0.5)$$
$$= 3.93\ ms^{-1} \quad (1)$$

$$F_c = \frac{mv^2}{r} \quad (0.5)$$
$$T = \frac{(0.04)(3.93)^2}{0.50} \quad (0.5)$$
$$= 1.24\ N \quad (1)$$

At one instant in the motion, one of the students in the class has the following side-on view of the rubber stopper and length of the fishing line.



(b) At this instant, the forces (ignoring friction) acting on the stopper would be:

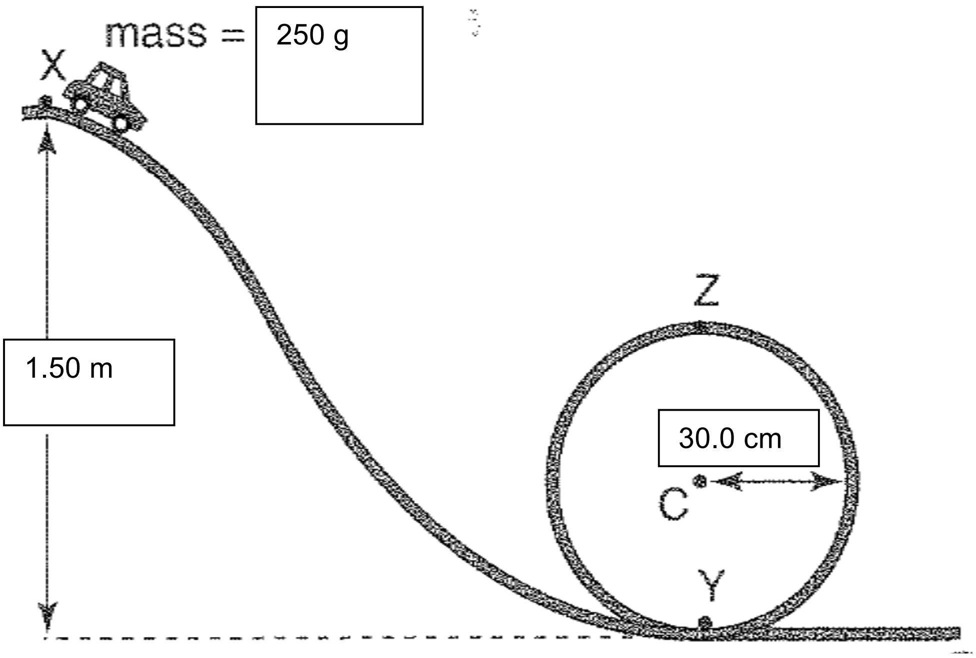


Answer: ____A_______

(1 mark)

Question 5 **(17 marks)**

A student arranges a toy car track with a vertical loop of radius 30.0 cm, as shown. A car of mass 250 g is pushed, with an initial speed of 2.00 ms^{-1}, from a height of 1.50 m at point X. The car moves down the track and travels around the loop. Ignoring friction answer the following questions.



(a) Calculate the speed of the car as it reaches the bottom of the loop at point Y. (3 marks)

$\Sigma E_i = \Sigma E_f$ (0.5)

$E_K = \frac{1}{2}mv^2$ (0.5) $E_P = mgh$

$\frac{1}{2}mu^2 + mgh_i = \frac{1}{2}mv^2 + mgh_f$

$\frac{1}{2}(2^2) + (9.8)(1.50) = \frac{1}{2}(v^2) + (9.8)(0)$ (1)

$v = 5.78\ ms^{-1}$ (1)

(b) Determine the centripetal acceleration of the car at point Y. (3 marks)

$a_c = \frac{v^2}{r}$ (1)

$= \frac{5.78^2}{0.30}$ (1)

$= 111\ ms^{-2}$ *upwards or towards the centre of the curve* (1)

(c) Determine the force of the track on the car at point Y.

(4 marks)

$\sum F = ma$ (1)

$\sum F_V = F_N - mg = \frac{mv^2}{r}$ (1)

$F_N = mg + \frac{mv^2}{r}$

$= (0.25)(9.8) + (0.25)(111)$ (1)

$= 30.2\ N$ *upwards or towards the centre of the curve* (1)

(d) Determine the minimum speed required by the car to maintain its circular path and not fall off the track.

(4 marks)

$\sum F = ma$ (0.5)

$\sum F = F_N - mg = \frac{mv^2}{r}$ (0.5)

will fall off track if $F_N = 0$ (1)

$mg = \frac{mv^2}{r}$

(0.5) $v = \sqrt{rg} = \sqrt{(0.30)(9.8)}$ (0.5)

$= 1.71\ ms^{-1}$ (1)

(e) Will the car make the loop? Justify your answer with appropriate calculation/s.

(4 marks)

$\Sigma E_i = \Sigma E_f$ (0.5)

$E_K = \frac{1}{2}mv^2$ (0.5) $E_P = mgh$

$\frac{1}{2}mu^2 + mgh_i = \frac{1}{2}mv^2 + mgh_f$

$\frac{1}{2}(2^2) + (9.8)(1.50) = \frac{1}{2}(v^2) + (9.8)(0.60)$ (1)

$v = 4.65\ ms^{-1}$ (1)

- Yes – the speed at the top of the loop is greater than the minimum speed required to maintain the circular path. (1)

(f) Where will the passengers 'feel' the heaviest? Explain your answer.

(3 marks)

- The passengers will feel heaviest at the bottom of the track.
- Here the normal force must be equal and opposite to the weight force and also provide the centripetal force for the cart to travel in a circular path.
- The normal force is what we perceive as our 'weight' – if it is greater than mg, we will feel heavier.

Question 6 **(4 marks)**

A rally driver approaches a corner at 90.0 kmh^{-1} North and turns out of it at 75.0 kmh^{-1} West. What is the change in velocity of the driver? Include a labelled diagram showing the change in velocity.

$\Delta v = \sqrt{90^2 + 75^2}$ (0.5)

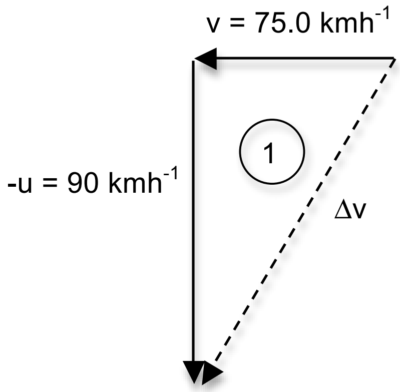
$= 117\ ms^{-1}$

$\tan\theta = \frac{opp}{adj} = \frac{90}{75}$ (0.5)

$\theta = 50.2^\circ$

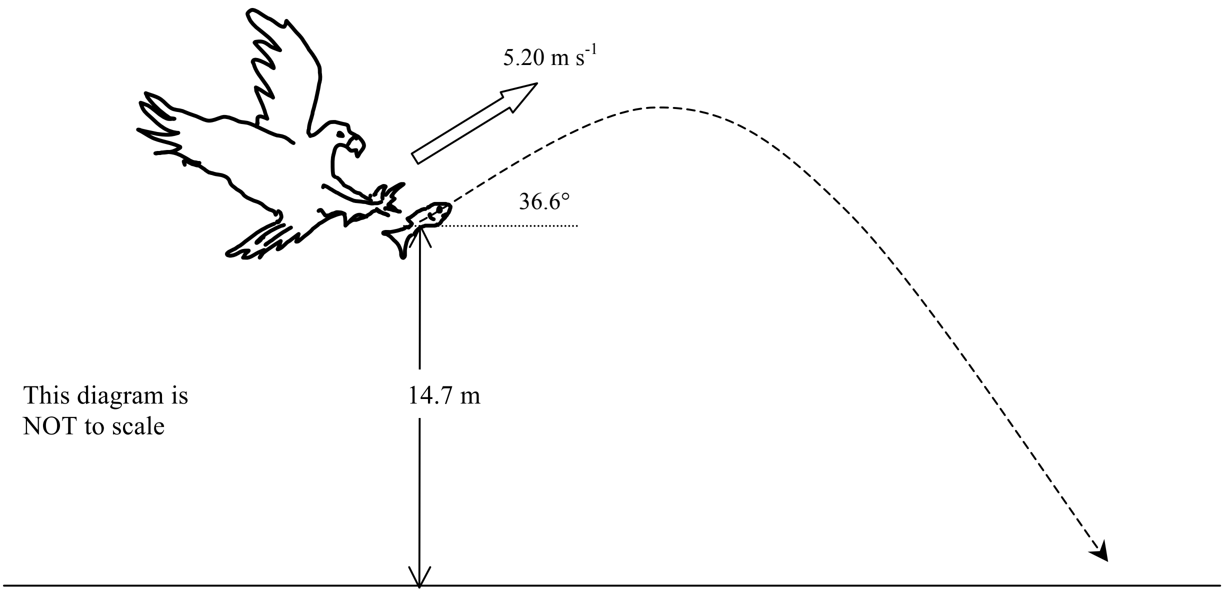
$\Delta v = 117\ kmh^{-1}\ W 50.2^\circ S$

(1) (1)



Question 7 **(15 marks)**

An eagle has captured a fish and is 14.7 m directly above the water when it releases the fish. The eagle is moving with a velocity of 5.20 ms^{-1} at an angle of 36.6° above the horizontal when the fish is released. Ignore air resistance for calculations.



(a) Calculate the time taken for the fish to reach the water.

(3 marks)

$s = ut + \frac{1}{2}at^2$ (1)

$-14.7 = (5.20\sin 36.6)(t) + \frac{1}{2}(-9.8)(t^2)$ (1)

$t = 2.08\,s$ (1)

(b) Calculate the horizontal distance that the fish travels during its flight back to the water.

(3 marks)

$s = tv$ (1)

$= (2.08)(5.2\cos 36.6)$ (1)

$= 8.68\,m$ (1)

(c) Calculate the maximum height above the water that the fish reaches during its flight.

(4 marks)

$v^2 = u^2 + 2as$ (1)

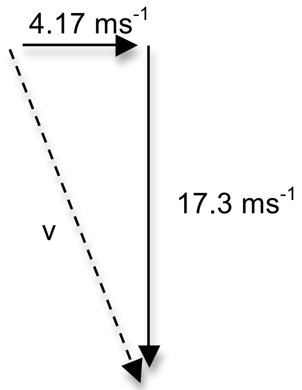
$0 = (5.2\sin 36.6)^2 + (2)(-9.8)(s)$ (1)

$s = 0.490\,m$ (1)

$0.490 + 14.7 = 15.2\ m$ (1)

(d) Determine the final speed of the fish before it hits the water.

(5 marks)



$v = u + at$ (0.5)

$v = (5.2\sin 36.6) + (-9.8)(2.08)$

$= -17.3\ ms^{-1}$ (0.5)

$v = \sqrt{(17.3^2) + (4.17^2)}$ (1)

$= 17.8\ ms^{-1}$

$\tan\theta = \dfrac{opp}{adj} = \dfrac{17.3}{4.17}$ (1)

$\theta = 76.4^\circ$

v = 17.8 ms^{-1} at 76.4° below the horizontal.

(1) (1)