IB DIPLOMA Topical Past Papers

PHYSICS

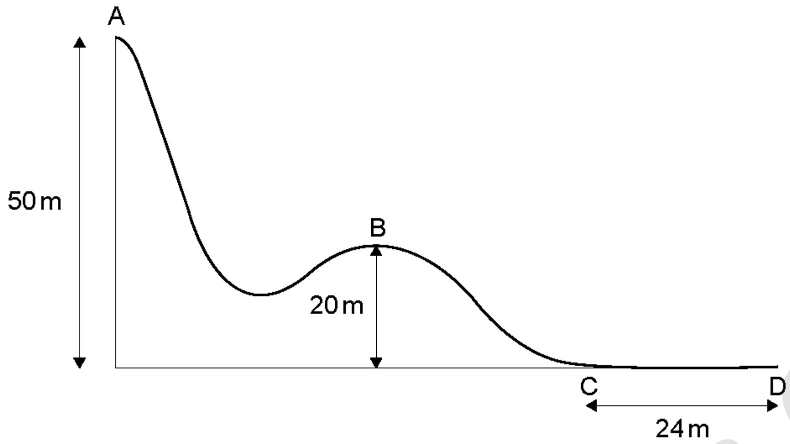
SL

PAPER 2

2017 — 2024

1 - (PHYSI/21_SL_Summer_2017_Q1) - *Mechanics, Thermal Physics*

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.



(a) A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

(i) From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m s^{-1}. [2]

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(ii) Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. [2]

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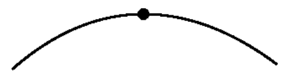
(b) (i) The dot on the following diagram represents the skier as she passes point B. Draw and label the vertical forces acting on the skier. [2]



(ii) The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. [3]

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(c) The skier reaches point C with a speed of $8.2\,m\,s^{-1}$. She stops after a distance of 24 m at point D.

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected. [3]

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(d) At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed $9.6\,m\,s^{-1}$.

(i) Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. [2]

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(ii) Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. [2]

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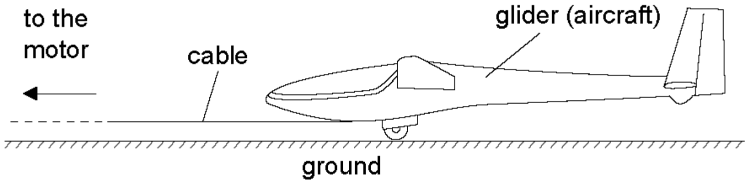
2 - (PHYSI/22_SL_Summer_2017_Q1) - *Mechanics*

A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.



(a) The glider reaches its launch speed of $27.0\,m\,s^{-1}$ after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. [2]

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(b) The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. [3]

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(c) The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. [3]

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(d) The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 $m s^{-1}$. Include an appropriate unit for your answer. [2]

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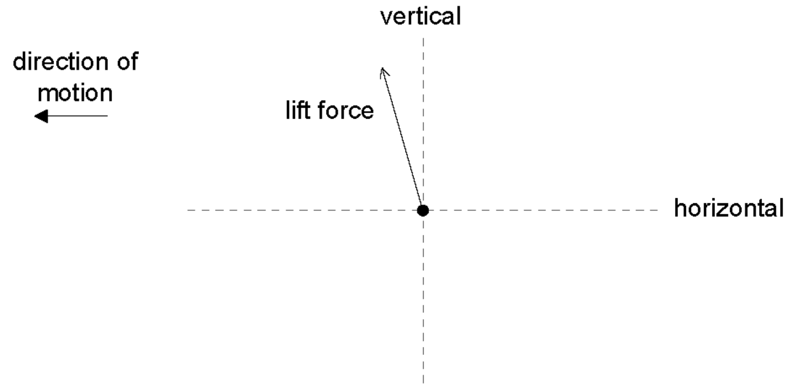
(e) After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider.



Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions. [2]

(f) Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. [2]

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(g) At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is $12.5\,m\,s^{-1}$. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. [3]

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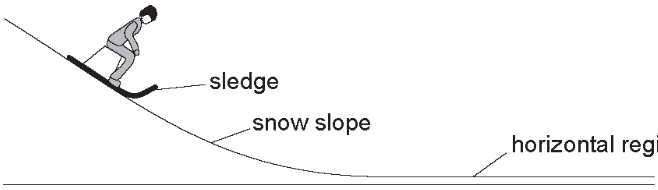
3 - (PHYSI/20_SL_Winter_2017_Q1) - *Mechanics*

A girl on a sledge is moving down a snow slope at a uniform speed.



(a) Draw the free-body diagram for the sledge at the position shown on the snow slope. [2]

(b) After leaving the snow slope, the girl on the sledge moves over a horizontal region of snow. Explain, with reference to the physical origin of the forces, why the vertical forces on the girl must be in equilibrium as she moves over the horizontal region. [3]

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(c) When the sledge is moving on the horizontal region of the snow, the girl jumps off the sledge. The girl has no horizontal velocity after the jump. The velocity of the sledge immediately after the girl jumps off is $4.2\ \text{m s}^{-1}$. The mass of the girl is 55 kg and the mass of the sledge is 5.5 kg. Calculate the speed of the sledge immediately before the girl jumps from it. [2]

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(d) The girl chooses to jump so that she lands on loosely-packed snow rather than frozen ice. Outline why she chooses to land on the snow. [3]

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(e) The sledge, without the girl on it, now travels up a snow slope that makes an angle of 6.5° to the horizontal. At the start of the slope, the speed of the sledge is $4.2\ m\,s^{-1}$. The coefficient of dynamic friction of the sledge on the snow is 0.11.

(i) Show that the acceleration of the sledge is about $-2\ m\,s^{-2}$. [3]

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(ii) Calculate the distance along the slope at which the sledge stops moving. Assume that the coefficient of dynamic friction is constant. [2]

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(f) The coefficient of static friction between the sledge and the snow is 0.14. Outline, with a calculation, the subsequent motion of the sledge. [2]

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ANSWERS

1 - (PHYSI/21_SL_Summer_2017_Q1) - *Mechanics, Thermal Physics*

a	**i**	$\frac{1}{2}v^2 = 0.24gh$ ✓ $v = 11.9$ «ms^{-1}» ✓
a	**ii**	internal energy is the total KE «and PE» of the molecules/particles/atoms in an object ✓ temperature is a measure of the average KE of the molecules/particles/atoms ✓
b	**i**	arrow vertically downwards from dot labelled weight/W/mg/gravitational force/F_g/$F_{gravitational}$ ***AND*** arrow vertically upwards from dot labelled reaction force/R/normal contact force/N/F_N ✓ W > R ✓

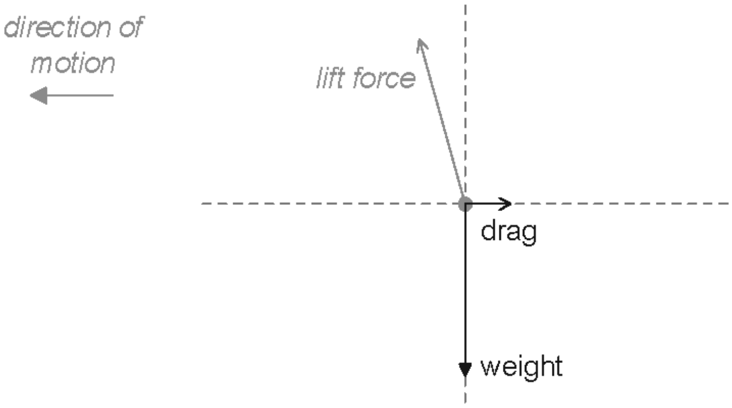
b	ii	***ALTERNATIVE 1*** recognition that centripetal force is required / $\frac{mv^2}{r}$ seen ✔ = 468 «N» ✔ W/640 N (weight) is larger than the centripetal force required, so the skier does not lose contact with the ground ✔ ***ALTERNATIVE 2*** recognition that centripetal acceleration is required / $\frac{v^2}{r}$ seen ✔ a = 7.2 «ms^{-2}» ✔ *g* is larger than the centripetal acceleration required, so the skier does not lose contact with the ground ✔ ***ALTERNATIVE 3*** recognition that to lose contact with the ground centripetal force ≥ weight ✔ calculation that v ≥ 14 «ms^{-1}» ✔ comment that 12 «ms^{-1}» is less than 14 «ms^{-1}» so the skier does not lose contact with the ground ✔ ***ALTERNATIVE 4*** recognition that centripetal force is required / $\frac{mv^2}{r}$ seen ✔ calculation that reaction force = 172 «N» ✔ reaction force > 0 so the skier does not lose contact with the ground ✔

c		***ALTERNATIVE 1*** $0 = 8.2^2 + 2 \times a \times 24$ therefore $a =$ «–»1.40 «ms^{-2}» ✔ friction force $= ma = 65 \times 1.4 = 91$ «N» ✔ coefficient of friction $= \dfrac{91}{65 \times 9.81} = 0.14$ ✔ ***ALTERNATIVE 2*** $KE = \dfrac{1}{2}mv^2$ = 0.5 x 65 x 8.2^2 = 2185 «J» ✔ friction force = KE/distance =2185/24 = 91«N» ✔ coefficient of friction $= \dfrac{91}{65 \times 9.81} = 0.14$ ✔
d	i	«76×9.6» = 730 ✔ Ns ***OR*** kg ms^{-1} ✔
d	ii	safety net extends stopping time ✔ $F = \dfrac{\Delta p}{\Delta t}$ therefore F is smaller «with safety net» ***OR*** force is proportional to rate of change of momentum therefore F is smaller «with safety net» ✔

2 - (PHYSI/22_SL_Summer_2017_Q1) - *Mechanics*

a		correct use of kinematic equation/equations ✔ 148.5 ***or*** 149 ***or*** 150 «m» ✔
b		$a = \dfrac{27}{11}$ ***or*** 2.45 «m s^{-2}» ✔ $F - 160 = 492 \times 2.45$ ✔ 1370 «N» ✔

c		***ALTERNATIVE 1*** «work done to launch glider» $= 1370 \times 149$ «$= 204$ kJ» ✔ «work done by motor» $= \frac{204 \times 100}{23}$ ✔ «power input to motor» $= \frac{204 \times 100}{23} \times \frac{1}{11} = 80$ ***or*** 80.4 ***or*** 81 k«W» ✔ ***ALTERNATIVE 2*** use of average speed $13.5\ \text{m s}^{-1}$ ✔ «useful power output» $=$ force $\times$ average speed «$= 1370 \times 13.5$» ✔ power input $=$ «$1370 \times 13.5 \times \frac{100}{23} =$» 80 ***or*** 80.4 ***or*** 81 k«W» ✔ ***ALTERNATIVE 3*** work required from motor $=$ KE $+$ work done against friction «$= 0.5 \times 492 \times 27^2 + (160 \times 148.5)$» $= 204$ «kJ» ✔ «energy input» $= \frac{\text{work required from motor} \times 100}{23}$ ✔ power input $= \frac{883000}{11} = 80.3$ k«W» ✔

d		$\omega = «\frac{v}{r} =» \frac{27}{0.6} = 45$ ✔ rad s^{-1} ✔
e		 drag correctly labelled and in correct direction ✔ weight correctly labelled and in correct direction ***AND*** no other incorrect force shown ✔
f		name Newton's first law ✔ vertical/all forces are in equilibrium/balanced/add to zero ***OR*** vertical component of lift mentioned ✔ as equal to weight ✔
g		any speed and any direction quoted together as the answer✔ quotes their answer(s) to 3 significant figures ✔ speed = 12.7 m s^{-1} ***or*** direction = 9.46° ***or*** 0.165 rad «below the horizontal» ***or*** gradient of $-\frac{1}{6}$ ✔

3 - (PHYSI/20_SL_Winter_2017_Q1) - *Mechanics*

a		arrow vertically downwards labelled weight «of sledge and/or girl»/W/mg/gravitational force/F_g/$F_{gravitational}$ ***AND*** arrow perpendicular to the snow slope labelled reaction force/R/normal contact force/N/F_N ✔ friction force/F/f acting up slope «perpendicular to reaction force» ✔	*Do not allow G/g/"gravity".* *Do not award MP1 if a "driving force" is included. Allow components of weight if correctly labelled. Ignore point of application or shape of object.* *Ignore "air resistance".* *Ignore any reference to "push of feet on sledge".* *Do not award MP2 for forces on sledge on horizontal ground* *The arrows should contact the object*
b		gravitational force/weight from the Earth «downwards» ✔ reaction force from the sledge/snow/ground «upwards» ✔ no vertical acceleration/remains in contact with the ground/does not move vertically as there is no resultant vertical force ✔	*Allow naming of forces as in (a)* *Allow vertical forces are balanced/equal in magnitude/cancel out*
c		mention of conservation of momentum ***OR*** $5.5 \times 4.2 = (55 + 5.5)$ «v» ✔ 0.38 «m s^{-1}» ✔	*Allow $p = p'$ or other algebraically equivalent statement* *Award **[0]** for answers based on energy*

d		same change in momentum/impulse ✔ the time taken «to stop» would be greater «with the snow» ✔ $F = \frac{\Delta p}{\Delta t}$ therefore F is smaller «with the snow» ***OR*** force is proportional to rate of change of momentum therefore F is smaller «with the snow» ✔	*Allow reverse argument for ice*
e	**i**	«friction force down slope» $= \mu mg\cos(6.5) =$ «5.9 N» ✔ «component of weight down slope» $= mg\sin(6.5)$ «$=$ 6.1 N» ✔ «so $a = \frac{F}{m}$ » acceleration $= \frac{12}{5.5} = 2.2$ «m s^{-2}» ✔	*Ignore negative signs* *Allow use of $g = 10\,\text{m s}^{-2}$*
e	**ii**	correct use of kinematics equation ✔ distance $=$ 4.4 ***or*** 4.0 «m» ✔ ***Alternative 2*** KE lost $=$ work done against friction $+$ GPE ✔ distance $=$ 4.4 ***or*** 4.0 «m» ✔	*Allow ECF from (e)(i)* *Allow **[1 max]** for GPE missing leading to 8.2 «m»*

f		calculates a maximum value for the frictional force $=$ «$\mu R =$» 7.5 «N» ✔ sledge will not move as the maximum static friction force is greater than the component of weight down the slope ✔	*Allow correct conclusion from incorrect MP1* *Allow 7.5 > 6.1 so will not move*