Part 1: Work

1 Yes, a body can have energy without having momentum e.g. a stationary book on a table possesses gravitational potential energy.
No, a body having momentum will have kinetic energy.

2 Yes, the object is in uniform circular motion. Displacement is always perpendicular to centripetal force.

3 (a) (i) Car A. $\langle F \rangle = ma$ Since the same force is applied to both cars, acceleration experienced by car B is smaller (due to its larger mass). $s = \frac{1}{2}at^2$ To cover the same distance of 3.0 m, Δt is larger for car B due to the smaller acceleration. So car A finishes first.

(ii) Same work done on both cars and hence same gain in kinetic energy for both cars.

(iii) Car B. $KE = \frac{1}{2}mv^2 = \frac{1}{2}\frac{m^2v^2}{m} = \frac{p^2}{2m}$ Since the gain in KE is the same for both cars, momentum of car B is larger due to its larger mass.

(b) (i) Car A. Since the same force is applied to both cars, acceleration experienced by car B is smaller (due to its larger mass). $s = \frac{1}{2}at^2$ With a smaller acceleration, displacement of car B is lesser.

(ii) Impulse = $F\Delta t = \Delta p$ Hence both cars experienced the same Δp.

(iii) Car A. $KE = \frac{p^2}{2m}$ Since momentum is the same for both cars, car A has a larger KE due to its smaller mass.

4 (a) The tension in the string does no work because the motion of the pendulum is always perpendicular to the cord and therefore to the tension.

(b) The air resistance always does negative work because air resistance is always acting in a direction opposite to the motion.

(c) The weight always acts downwards, therefore the work done by the weight is positive on the downswing and negative on the upswing.

5 (a) Since the box is not undergoing acceleration, and the ground is frictionless, the force required to move the box by 5 m is 0 N, *Work done = F.s = 0*
(b) In order for box to move at constant velocity, the force exerted to keep the box moving must be the same as frictional force. *Work done = F.s = 230 (5) = 1150* J

(c) In order for box to move vertically upwards without an acceleration, the force required is of the same magnitude as the weight of the object. *Work done = F.s = 10 (9.81) (4) = 392* J

6 Work done by friction (net external force) on car = change in kinetic energy of car

$$-Fd = 0 - \frac{1}{2}mv^2 \quad .. \quad (1)$$

$$-Fd_{\text{new}} = 0 - \frac{1}{2}m(2v)^2 \quad .. \quad (2)$$

(2)/(1): $d_{\text{new}} = 4d$

7 The bullet loses kinetic energy as it gets stopped in the target.

Work done by resistive force on bullet = change in kinetic energy of bullet

$$-F(0.40) = 0 - \frac{1}{2}mv^2 = -\frac{1}{2}(0.300)(500)^2$$

$F = 9.4 \times 10^3$ N

Part 2: Conservation of Mechanical energy

8 From conservation of energy, since they have the same initial gravitational potential energy and kinetic energy, and they also have the same final gravitational potential energy, all three balls will have the same final kinetic energy and hence final speed before they hit the ground.

9 Elastic potential energy in spring is converted to potential energy of block. Hence,

$$\frac{1}{2}kx^2 = mgh$$

$$\frac{1}{2}(5.00 \times 10^3)(0.100)^2 = (0.250)(9.81)h$$

Solving h = 10.2 m

10 (a)

$$\text{Initial } (E_k + E_p)_A = \text{Final } (E_k + E_p)_B$$

$$\tfrac{1}{2}mv_o^2 + mgh = \tfrac{1}{2}mv_B^2 + mgh$$

$$v_o^2 = v_B^2$$

$$v_o = v_B$$

Therefore, the speed at B is v_o

$$\text{Initial } (E_k + E_p)_A = \text{Final } (E_k + E_p)_C$$

$$\tfrac{1}{2}mv_o^2 + mgh = \tfrac{1}{2}mv_C^2 + mg\tfrac{h}{2}$$

$$\tfrac{1}{2}v_o^2 + gh = \tfrac{1}{2}v_c^2 + g\tfrac{h}{2}$$

$$v_C^2 = v_o^2 + gh$$

$$v_C = \sqrt{v_o^2 + gh}$$

(b) let the speed at D be u ,

$$\frac{1}{2}mv_o^2 + mgh = \frac{1}{2}mu^2$$

$$v_o^2 + 2gh = u^2$$

$$u = \sqrt{v_o^2 + 2gh}$$

From D to E, $u = \sqrt{v_o^2 + 2gh}$, $v = 0$ ms^{-1}, $s = L$.

Using $v^2 = u^2 + 2as$

$$0^2 = v_o^2 + 2gh + 2aL$$

$$a = -\left(\frac{v_0^2 + 2gh}{2L}\right)$$

11 Using conservation of mechanical energy, consider man and cord as a system,

$$(E_K + E_{GPE} + E_{EPE})_i = (E_K + E_P + E_{EPE})_f$$

$$0 + 700\,(36) + 0 \quad = 0 + 700(4) + \frac{1}{2}k(32 - 25)^2$$

$k = 914$ N m^{-1}

12 As X moves up the plane by 2 m, Y moves down below the pulley by 2 m. At that instant, both X and Y would also have the same speed.

Using conservation of energy,

loss in GPE of Y = gain in GPE of X + gain in KE of X and Y

gain in KE of X and Y = $m_y g(2.0) - m_x g(2.0)\sin 30^\circ$ = $(5.0)(9.81)(2.0) - (4.0)(9.81)(2.0)\sin 30^\circ$

= 59 J

13 (a) Loss in gravitational potential energy of 5.00 kg object is converted into gain in kinetic energy for both 5.00 kg and 2.00 kg objects and gain in gravitational potential energy for the 2.00 kg object and work done against frictional force.

(b) $5.00\,(9.81)\,(4.00 \sin 50^\circ) = 2.00\,(9.81)\,(4.00) + \frac{1}{2}\,(5.00 + 2.00)\,v^2 + 10\,(4.00)$

$v = 3.02$ m s^{-1}

(c) The 2.00 kg mass will continue to travel upwards, converting its KE into GPE until the maximum height is reached.

$$\frac{1}{2}\,(2.00)\,(3.02)^2 = 2.00\,(9.81)\,(H - 4.00)$$

$$H = 4.46 \text{ m}$$

14 $(E_K + E_P)_i$ + work done by drag force = $(E_K + E_P)_f$

$$\left[\frac{1}{2}(60)(180)^2\right] - (200)(150) = \frac{1}{2}(60)v^2 + (60)(9.81)(150)$$

$$v = 169 \text{ m s}^{-1}$$

Part 3: Power

15 (a) $\langle P \rangle = F\langle v \rangle$

$200 = (50.0)(9.81)\langle v \rangle$

$\langle v \rangle = 0.408 \text{ m s}^{-1}$

(b) Work done = Fs = (50.0)(9.81)(5.00) = 2.45 kJ

16 Average power delivered by rain = loss in kinetic energy of rain per unit time

$= \frac{1}{2} mv^2/ t$

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

$= \frac{1}{2} [(300 \times 10^6)/(30 \times 60)] (12)^2$

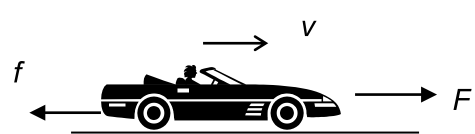
$= 1.2 \times 10^7$ W

17 At maximum constant speed, $f = F$

Power, $P = Fv$

$130 \times 10^3 = F(31)$

$F = f = 4.2 \times 10^3$ N



When going upslope at constant (maximum) speed,

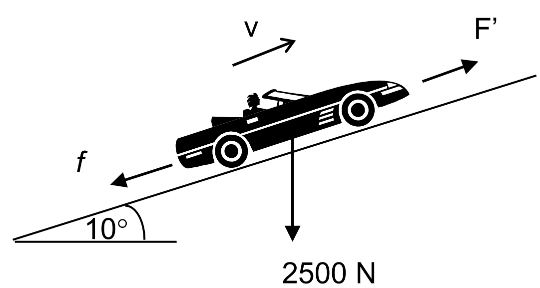
$F' = 4.2 \times 10^3 + 2500 \sin 10°$

$= 4.6 \times 10^3$ N

$Power = F'v$

$130 \times 10^3 = 4.6 \times 10^3 v$

$v = 28 \text{ m s}^{-1}$



18 "Using $F = kv^2$"

$800 = k(20)^2$ …… (1)

$F = k(40)^2$ …… (2)

gives $F = (2)^2(800) = 3200$ N

Power = Fv = 3200(40) = 128 kW

19 In one second,

the distance moved by the weights = 20 (0.5) = 10 m

output power = 50 (10) – (20) (10) = 300 W

20 (a) (i) Energy expenditure = 23 kWh = 23 x 1000 x 60 x 60 = 8.28×10^7 J

(ii) Average energy expenditure per km = $8.28 \times 10^7 / 122 = 680 \text{ kJ km}^{-1}$

(iii) For classic variant, average energy expenditure per km = (9.70 x 1000 x 60 x 60) / 29.1

$= 1200 \text{ kJ km}^{-1}$

(b) (i) The electrical energy produced is 30% of the chemical potential energy of the fossil fuel.
(ii) For electric model, average energy expenditure per km = (100/30) (680) = 2300 kJ km^{-1}

(c) (i) Amount of CO_2 emitted per km = (23/1000)(601)/122 = 0.113 kg
(ii) - Classic variant has lower CO_2 emission per km (105 g) than Electric variant (113 g)
- Classic variant uses less energy per km (1200 J) than the Electric variant (2300 J)
- Singapore relies more on natural gas for generation of electricity, so the CO_2 emission may be lower or the yield of power generation could be higher

(d) (i) area under the graph = 69 (±3) kWh
(ii) Note: same area under graph, thus taper later and end earlier.