Question 10

Note: I'm a little easier on the units and significant figures (lose $^1/_2$ mark only) in this question because there are a lots of small calculations to do and it would be very easy to get 0.

Note: Don't "go negative" with the signs and units mistakes. For each individual questions, the minimum is zero.

(a) ***Two methods*: kinematics or energy method**

Energy:

Without air resistance, *mechanical energy is conserved*;

$PE_{initial} + KE_{initial} = PE_{final} + KE_{final}$

$mgh + 0 = 0 + {}^1/_2mv^2$

$gh = {}^1/_2v^2$

$v = \sqrt{(2gh)}$

$v = \sqrt{(2 \times 9.81 \times 2.00)} = 6.264 \approx \mathbf{6.26\ ms^{-1}}$

(2 marks altogether for derivation and calculation)

Note: Lose 1 mark for each algebraic or numerical mistake

Note: Lose $^1/_2$ mark for incorrect unit, lose $^1/_2$ mark if more than 4 sig figures quoted.

OR

Kinematics:

$v_0 = 0$ (let's say down is +ve)

$v_f^2 = v_0^2 + 2gs$

$v_f^2 = 2gs$

$v_f = \sqrt{(2 \times 9.81 \times 2.00)} = 6.264 \approx \mathbf{6.26\ ms^{-1}}$

(2 marks altogether for derivation and calculation)

Note: Lose 1 mark for each algebraic or numerical mistake

Note: Lose $^1/_2$ mark for incorrect unit, lose $^1/_2$ mark if more than 4 sig figures quoted.

(b) (i) Because the objects *moved together (or with the same velocity)* as though they were one object after the collision it was "perfectly inelastic" by definition. **(1 mark)**

Note: $^1/_2$ mark for mentioning "perfectly inelastic", $^1/_2$ mark for mentioning or implying italicised point

(ii) At the instant of collision, *momentum WAS conserved. Energy was NOT conserved* (because perfectly inelastic) **($^1/_2$ mark for each italicised point)**

Note: Strictly speaking, momentum was NOT conserved over the time of the collision because there is an external force, **gravity**, acting on the objects. However, if the time of the collision is short (**or in the wording of the question** "at the instant of collision", momentum is very nearly conserved. **Don't** expect this subtle caveat from the students.

(c) $P_{initial} = P_{final}$ (*or they can write* Momentum conserved)

$MV_i + 0 = MV_f + mV_f = V_f\,(M + m)$ (say, +ve is down)

$V_f = {}^{MV_i}/_{(M + m)}$

$V_f = {}^{(525 \times 6.26)}/_{(525 + 25)} = 5.975 \approx \mathbf{5.98\ ms^{-1}}$

(3 marks altogether for derivation and calculation)

Note: Here they must use a result from the previous question. Don't penalise them a second time for when using an incorrect velocity.

(d) Assuming constant friction force, pile-driver + pole had a constant deceleration.

Two methods: kinematics or energy method

kinematics method:

$v_f = 0$, $v_0 = 5.975$ ms^{-1} (let's say down is +ve)

$v_f^2 = v_0^2 + 2as$

$-2as = v_0^2$

$a = -v_0^2/2s = -(5.975)^2/(2 \times 0.750) = -23.8$ ms^{-2} (upwards)

But friction force F is; $F = ma = -(525 + 25.0)$ kg $\times$ 23.8 ms$^{-2} = -13090$ N $\approx -1.31 \times 10^4$ N

Magnitude of friction force $\approx$ ***1.31 × 10^4*** **N**

(3 marks altogether for derivation and calculation)

Note: Lose 1 mark for each algebraic or numerical mistake

Note: Lose $^1/_2$ mark for incorrect unit, lose $^1/_2$ mark if more than 4 sig figures quoted.

Note: Here they must use a result from the previous question. Don't penalise them a second time for using a previously incorrectly calculated quantity.

OR

energy method:

Friction does work on pile-driver + pole to convert KE into thermal E. Work done equals KE lost as thermal E (*i.e.* all of it).

$\therefore {}^1/_2mv^2 = W_{friction} = Fs\cos\theta = -Fs$ ($\cos\theta = 180°$ for friction)

$F = -({}^1/_2mv^2)/s$

$F = -({}^1/_2(525+25) \times 5.975^2)/0.750 = -13090$ N $\approx -1.31 \times 10^4$ N

Magnitude of friction force $\approx$ ***1.31 × 10^4*** **N**

(3 marks altogether for derivation and calculation)

Note: Lose 1 mark for each algebraic or numerical mistake

Note: Lose $^1/_2$ mark for incorrect unit, lose $^1/_2$ mark if more than 4 sig figures quoted.

Note: Here they must use a result from the previous question. Don't penalise them a second time for using a previously incorrectly calculated quantity.

Note: It is OK if they were not strict about their use of signs during the derivation in this "work" question, as long as they correctly quote the signs in the final answers. I have told them in lectures it is OK when doing work problems to calculate the absolute values and then to establish signs later.